Knowledge Management in Civil Protection at the Example of Fire Brigades

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Abstract: Knowledge management is essential for successful disaster management. This paper conducts a Systematic Literature Review at the intersection of the knowledge management field and disaster management and examines the available body of literature. Fire departments are chosen as the focus group as they are the most prevalent emergency services. There are many publications that deal with knowledge management during the response phase of an emergency. Often, the literature focuses on the application of knowledge management in large-scale disasters to link the various organizations on-scene. What is missing in most approaches is a prior step of implementing and training the knowledge management system. Therefore, this literature review seeks to provide an overview of approaches for daily routines and small-to-medium incidents that serve as a training ground. However, literature on non-incident phases and smaller incidents is scarce. As information technologies are developing rapidly, there is no modern and recent description of the current use of knowledge management solutions in this area.

1 INTRODUCTION

Growing administrative regulations, new high-tech equipment and changing environmental circumstances constantly increase the necessary information and knowledge that civil protection personnel need to know (Schultz et al., 2024b), (Weidinger et al., 2021). This knowledge about processes, techniques and equipment has to be stored adaptively so that it is easy to learn new things, refresh familiar ones and be aware of changes (Oktari et al., 2020). Existing knowledge is rarely stored in a structured way, so new or promoted civil protection members have to retrieve information from their experienced colleagues or documents (Schultz et al., 2024b). It is rarely possible to inform oneself or look up information from one central source. These circumstances were the trigger for the examination of the existing literature body concerning knowledge management (KM) solutions within civil protection (CP) by performing a Systematic Literature Review (SLR), according to (Xiao and Watson, 2017). This paper focuses on fire departments as one of the most widespread emergency services (Brushlinsky et al., 2019). The remaining paper is structured as follows: Chapter 2 contains a brief introduction to the fields of CP and KM, followed by a discussion on the application of KM within CP and its characteristics and particularities. Chapter 3 describes the application of the SLR. The organizational aspects are outlined and then categories are derived into which the resulting publications can be classified. Chapter 4 discusses the findings from the SLR in detail and identifies the research gaps. Chapter 5 concludes the work, gives a summarizing statement and outlines subsequent steps.

2 FOUNDATION

The preface gives a brief overview of the theoretical principles of information and knowledge management in section 2.1. The heterogeneity of CP systems is presented in section 2.2 in order to illustrate differences between countries or regional authorities. Section 2.3 links the two topics KM and fire brigades and outlines the characteristics of KM applied in the structures of fire brigades.

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2.1 Knowledge Management

KM is a key success factor and a necessity of many businesses due to the increasing knowledge bases, the need for a competitive advantage or internationalization and managing of e.g. staff turnover (International Organization for Standardization, 2018), (Omerzel and Gulev, 2011). The ISO norm 30401 describes KM as follows: "Knowledge management is a holistic approach to improve learning and effectiveness through optimization of the use of knowledge, in order to create value for the organization. Knowledge management supports existing process and development strategies" (International Organization for Standardization, 2018). Most literature related to KM uses the building blocks of knowledge management by (Probst et al., 2012) as a basis for describing KM processes (e.g. (North, 2021), (Oliveira and Pinheiro, 2021)). The building blocks by North consist of six key components: Knowledge identification, acquisition, development, distribution, utilization, and preservation.

The Association of German Engineers (Verein Deutscher Ingenieure (VDI)) has issued a guideline for KM in the engineering sector that describes the basic concepts in VDI-5610:2009 (VDI Verein Deutscher Ingenieure e.V., 2009). The guideline aims at advising businesses on introducing a knowledge management system (KMS) and distinguishes the terms data, information and knowledge as concepts that build on each other. Two different types of knowledge are differentiated: implicit and explicit knowledge. Implicit knowledge is "bound to persons, difficult to communicate and hardly to formalize", whereas explicit knowledge "can be formalized on different levels (e.g. speech, writing); it is therefore communicable and storable in various media" (International Organization for Standardization, 2018). The process of KM in (VDI Verein Deutscher Ingenieure e.V., 2009) (depicted in Figure 1) corresponds with the building blocks described by (Probst et al., 2012).

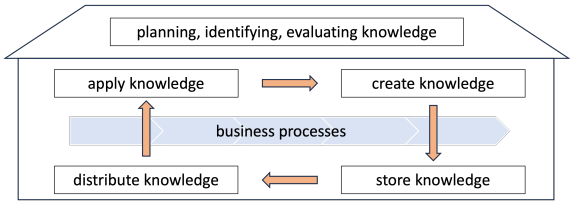

Figure 1: Knowledge management process according to (VDI Verein Deutscher Ingenieure e.V., 2009).

In summary, it can be stated that the presented scientific foundations (North, 2021), and (Probst et al., 2012) have their origin in organizational and especially business-oriented research domains. They still form the scientific basis for KM in recent literature. Also the presented norms (International Organization for Standardization, 2018) and (VDI Verein Deutscher Ingenieure e.V., 2009) focus on fostering KM in businesses. Nevertheless, these concepts are versatile and are being used in other areas as business-oriented KM as well.

2.2 Civil Protection

CP is used as a summary for all activities that aim at protecting people in a certain area from natural (e.g., earthquake, drought flood or hurricane) or man-made (e.g., technical failure, terror) hazards (Waugh and Tierney, 2007). Among others the following organizations comprise the CP: emergency services (fire brigades, emergency medical response/ ambulance, and police), public administration (municipal, region/county/provincial/national etc.) and also technical/scientific services (Waugh and Tierney, 2007). It is organized differently from country to country (cf. (Alexander, 2010) and (Zambrini et al., 2020)) and thus structures and prerequisites differ. Setting the focus on fire brigades, many countries maintain a system with mostly professional (paid) firefighters, such as Italy or Great Britain (Alexander, 2010). On the contrary, Germany, Austria or Switzerland and other Western European countries like Poland or the Netherlands, among others, maintain a firefighting system that heavily relies on volunteer firefighters (whereas professional firefighters are also present, mostly in bigger cities) (Brushlinsky et al., 2019), (Zambrini et al., 2020). The procedure of CP organizations can be categorized into different phases related to the central disaster. The disaster management circle (Inan et al., 2018) (Haddow et al., 2021) is used in multiple variations whereas the core steps are always similar: Prevention, Preparedness, (Disaster/Impact), Response and Rehabilitation. The transition between two phases is not necessarily a certain point but rather a gradual change.

The tasks of the various CP organizations are diverse. As mentioned at the beginning of this section, they can be categorized into emergency services, public administration and technical/scientific services. Each of them has its own field of responsibility, which may vary across borders. But all of them need to evolve and have to adapt to new technologies and procedures.

In recent years, various IT-solutions have been developed to support emergency operations. The examined technologies range from technical solutions such as drones and exoskeletons (Gottschalk, 2019), emergency response information systems (Weidinger

et al., 2021) to the digital interconnection of units with the help of IT (Spaling et al., 2018). The introduction of new technologies is also linked to the need to adapt existing procedures to new circumstances. This may lead to challenges, that emergency responders face while using IT in incidents and are presented by Elmasllari who identifies twelve problems that arise when using IT for disaster management (Elmasllari, 2018) which are excerpted below:

- Reliability: Digital systems have to function when they are used in an emergency.
- Interoperability: IT-based tools must be able to exchange data and information with other systems and thus provide interfaces for import and export. The usage of IT restricts the user to the means of communication provided by the system.
- The price of structured data: Data, information and knowledge that should be stored in a system need to be expressible and explicit to be able to store it in a digital system. The graphical user interface limits the possibilities to those intended by the programmers.

2.3 Knowledge Management in Civil Protection

This section combines the two aforementioned topics KM and CP and outlines the particularities of KM in CP. As already mentioned in Section 2.1, all of the KM concepts and the norms ISO 30401 and VDI 5610 focus on the operational context of enterprises. The special character of (volunteer) CP is not reflected directly in the KM concepts (Lee et al., 2011). In addition, the mostly volunteer staff often does not have the time and money (as companies do) to deal with KM and implement it as a business strategy (Oliveira and Pinheiro, 2019), (Alexander, 2010). This leads to an underrepresented usage of KM in CP while the tools and techniques do exist for enterprises. Furthermore, the amount of knowledge required for successful disaster management is already enormous and vast, yet much of it is tacit and drawn as expertise from previous experience (Oliveira and Pinheiro, 2019), (Oktari et al., 2020) (Klein, 2017). CP organizations are moreover mostly run or organized by the state or public bodies, which are not run as businesses with a profit intention but are funded by the taxes allocated to them (Waugh and Tierney, 2007). This is not necessarily a downside, as there is hardly any competitive situation among two units (Omerzel and Gulev, 2011); the willingness to collaborate across unit borders is way higher than it is among companies (Schultz et al., 2024b). The particularities of KM in CP compared to the enterprise context is, among others, the following: The knowledge has to be available more or less immediately in crisis situation since the disaster and its effects do not allow any delay (Elmasllari, 2018). Furthermore, the need to share knowledge between units is greater than between companies. Therefore, specific requisites must be elaborated for KM systems which shall be used for emergency services that respond to an event.

There are already several digital solutions to support one or another dimension of knowledge. Information Management Systems (IMS) are used as administrative support systems for keeping track of incident reports, personal member data and equipment history (Schultz et al., 2024b). KMS are defined as a part of management systems related to knowledge (International Organization for Standardization, 2018) and are rarely used in CP (Schultz et al., 2024b). There are only few documentations about the implementation and usage. Two German examples are the Einsatzleiterwiki[1] (incident commander wiki) or the web-based portal BKS-Portal[2] for CP personnel in the state of Rhineland-Palatinate. The first one provides basic information sorted by keywords or alarm patterns, whereas the latter serves in the state of Rhineland-Palatinate as a central platform for exchanging information and knowledge. Another approach describes the implementation of a KM infrastructure in New South Wales, Australia (Pickles, 2004). It is implemented by a content management system for managing web-content and e.g. a document management system. The application of KM in CP has been a research topic for many years as the existing literature reviews show (Fauzi et al., 2024), (Anand et al., 2022), (Oktari et al., 2020), and (Dorasamy et al., 2013). Nevertheless, the implementation of successful KMS is still a topic of ongoing research and development. The fire brigades have an important role in the CP ecosystem as they are involved in large scale disasters as well as small and daily occurring incidents (Weidinger, 2022), (Kapalo et al., 2019) and are usually among the first organizations on-scene. Which leads to the intention of this paper to examine the literature available with a special focus on fire brigades and identify research needs and gaps in the literature body.

[1] https://einsatzleiterwiki.de/
[2] https://bks-portal.rlp.de/

3 SYSTEMATIC LITERATURE REVIEW

The process of the SLR, as proposed by (Xiao and Watson, 2017), aims to capture and evaluate the current status of a certain research field. It consists of eight stages, which are grouped into the following three phases: Planning, conducting and reporting. The literature review process can be partially performed iteratively in order to deal with unforeseen issues and to amend the search with extended keywords. The remainder of this chapter is structured following the SLR process proposal and depicted in Figure 2.

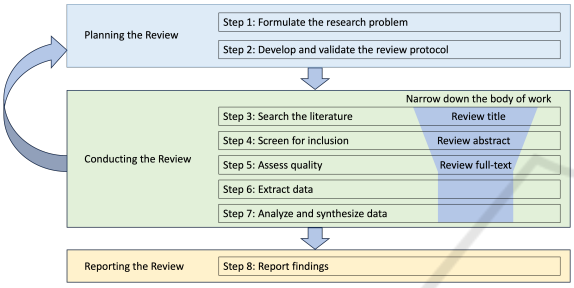

Figure 2: Systematic Literature Review process based on (Xiao and Watson, 2017).

3.1 Formulate the Research Problem

As mentioned before, the literature body concerning KM in CP, and in particular in the fire brigades, is not very mature and scattered. There are many publications on KM in business environments. A decent amount of publications focus on KM in CP but the focus is mostly on large-scale disasters like earthquakes, floods, etc. These few existing publications (e.g., (Inan et al., 2018), (Pickles, 2004) and other literature reviews (Fauzi et al., 2024), (Anand et al., 2022), (Oktari et al., 2020), and (Dorasamy et al., 2013)) mostly deal with one or several phases of the disaster management circle, examining the application of KM, e.g., in the response phase. The application and examination of KM in this article not only focuses on the typical disaster management circle phases but is extended to include supporting tasks that members of disaster management organizations perform like training, administrative work and other processes that can be supported by a KMS (Schultz et al., 2024b). This is intended to improve the attitude and capability of users of KMS to be able to handle a KMS during an incident in a timely and serious environment and not be overwhelmed by the additional IT system (Weidinger et al., 2021), (Elmasllari, 2018).

3.2 Develop and Validate the Review Protocol

Therefore, this literature review focuses on applications of KM in fire brigades. The literature should be analyzed with regards to the different disaster phases and solutions that might be applicable in daily routines as well. Differing prerequisites and requirements by professional and voluntary firefighters (c.f., (Alexander, 2010)) should be considered. For example, voluntary firefighters have a primary job and training, exercises, and administration take place in their free time. The research is driven by the following research questions (RQ):

- Which literature is available concerning knowledge management within civil protection (focusing on fire brigades) and to which phases of the disaster management circle does it refer to? (RQ1)
- How is the implementation and training of knowledge management systems performed, are there differences between professional and voluntary personnel, and is knowledge management applied in daily routines (non-incident times)? (RQ2)
- What digital knowledge management systems exist that are being used in civil protection? (RQ3)

The SLR is conducted as a desk study with the four-eyes principle by two researchers to minimize personal bias. Only online sources in English or German are included in the literature list. The search was performed during February and April 2023, with an update search shortly before submission in May 2024.

3.3 Search the Literature

Google Scholar[3] and Scopus[4] were used as the initial sources for publications by applying different combinations of search strings. The search was also performed as a backward search by examining the references of the initially found publications for other relevant literature. To find papers that already cited the relevant publications, the forward search by Google Scholar and Scopus was used. Various keywords were derived from the research questions and formulated as a boolean expression to search the databases. Following the initial review of the initial publications, an expansion of the search term was conducted to include additional relevant keywords. In order to cover a period of 20 years, publications from 2003 onward were considered further. Older literature was

[3]https://scholar.google.com/
[4]https://www.scopus.com/

excluded since the focus is on KM and its digital supporting tools. A wider scope does not make sense given the exponential evolution of technology. The second search iteration, which included both backward and forward searches, yielded 390 publications that met the search criteria. The search was terminated in April 2023 after the search pattern was fully exhausted. Repeating the search immediately before submission yielded two further results. Finally there were 392 publications given to the SLR process.

3.4 Screen for Inclusion

Subsequently, a two-step process was carried out to review the papers for inclusion in this review. The first step was to examine the title to determine whether the publication fits into the desired set. If the title was not sufficiently informative, the abstract of the work was taken into account. Each of the two researchers independently rated all of the 392 publications with the labels “include”, “discuss” and “discard”. Afterwards, both ratings were merged: papers marked by one or both with “include” were included (62), the “discuss” papers (if one or both marked a paper as “discuss”) were examined in a joint meeting to determine whether the paper was relevant or not (76), and all papers marked by both researchers with “discard” were discarded from the literature body (254). A subsequent backward and forward search yielded further publications (9), which were assessed for inclusion in the literature inventory and then added. Combined with the outcome of the ”discuss”-marked papers, this resulted in a total of 138 publications, which were used as the basis for the in-depth analysis.

3.5 Assess Quality

The second step of the quality assessment process is the review of the entire publication. There was no access to the full text of 11 publications through the provided library and other sources. In addition, 47 papers were excluded as not covering both key topics, two papers were found to be duplicate and another 36 papers were considered inappropriate for the research questions and were hence discarded. A total of 42 papers were considered for further analysis.

3.6 Extracting Data

By applying the inductive coding concept, publications were evaluated for inclusion in this paper. The publications were assigned to different categories. The results’ overview of the literature review can be found in the Open Research Knowledge Graph (Schultz et al., 2024a), where the categories for each publication are aligned to the ones of the literature review.

3.7 Analyze and Synthesize Data

Four overviews and reviews throughout the past 20 years were identified that are relevant for the research goal. Starting with the analysis by (Dorasamy et al., 2013), they already pointed out the need for unified terminologies. The stated need for a better understanding of determinants for KMS success factors is already partially addressed by other publications (e.g., (Seneviratne et al., 2010)). The research gap of what is missing in KM research towards a theoretical background is addressed by (Oktari et al., 2020). The investigation by (Anand et al., 2022) on KM in crisis gives a suitable overview of the literature according to the disaster management circle. The most recent review paper by (Fauzi et al., 2024) takes a bibliographic perspective and categorizes the literature body into different clusters, which should point out current and upcoming trends. No distinction is made between professional and voluntary personnel. Although the search queries are rather broad, the number of publications linking KM and CP is rather small and still partially related to management literature and strategies.

The response phase is covered by most publications that are related to the disaster management circle and there are only a few publications related to the other phases. The publication by (McNaughton and Rao, 2018) focuses on the application in the Caribbean region. Their approach is to implement a knowledge broker to share disaster information between Caribbean states. Mayor challenges are standardization and a coordinated production of knowledge and knowing what knowledge is where. The work is continued in (Rao and McNaughton, 2019). The proposed lessons-learned approach by (Rostis, 2007) gives input on how to integrate this source of knowledge into a KMS (Rostis, 2007). (Otim, 2006) chose the approach of case-based KM which relies on already captured knowledge from previous incidents, similar to Rostis approach. As a sole source of knowledge, case-based systems always face the problem of requiring a previous case that is comparable and stored in the system. Yet, it can provide guidance if cases occur more often, but then emergency personnel might already know the solution. The two following publications refer to mostly large-scale disasters like floods (Lee et al., 2011) or earthquakes (Cinque et al., 2015). They investigate the exchange of information during an event between different disaster

management agencies and point out the need for information systems focusing on the public sector (Lee et al., 2011). Similarly, (Saoutal et al., 2015) cover the inter-organizational exchange of knowledge as well, augmented by elaboration on awareness issues and a proposed system architecture. The publication by (Seneviratne et al., 2010) covers disaster knowledge success factors which deal with a lessons-learned approach again, here in the recovery phase. The identification of technological, social, legal, environmental, economic, functional, institutional and political factors provide a good basis for developing and maintaining knowledge and information management systems.

The publications on models and meta-models seek to elaborate models that are able to represent the characteristics of this domain and provide means to describe activities or entities. This includes formal language models that are used as a foundation for human- and machine-readable descriptions. (Othman and Beydoun, 2010) apply a case-based reasoning approach, which accepts input queries and outputs a model fragment that should be suitable for the decision makers independently of the type of disaster. The results of the publication are four Unified Modeling Language (UML)-diagrams for each of the four disaster management circle phases. The UML-diagrams are validated with existing meta-models and augmented with missing items. This work is preparatory and continued in (Othman and Beydoun, 2016). (Franke et al., 2010) create a new description language, based on interviews and the Business Process Model and Notation (BPMN) to enable the depiction of temporal dependencies. It is supposed to be used within and between organizations and activities can be combined flexibly. A simplified process modeling language for disaster management is proposed by (Ziebermayr et al., 2011). It should help sharing the knowledge of experienced people. Unfortunately, no implementation is described in the publication. (Benaben et al., 2016) examine the information extraction from data flows for emergency management and the credibility of data sources. They propose a meta-model that helps transforming incoming data into information and knowledge subsequently. The core meta-model is surrounded by four packages for the domains context, partners, objectives and behavior (Benaben et al., 2016).

Only one relevant paper by (Oliveira et al., 2022) was found that deals with the sharing of tacit knowledge (the knowledge that is not explicitly written down but rather in the practitioners' heads (as experiences)). There are other publications in the business-related body of literature that deal with tacit knowledge, but in the field of emergency management, this is the only one that is relevant to the research questions. (Oliveira et al., 2022) elaborated on indicators for tacit knowledge sharing and measures to be implemented. Six excerpted indicators are: individual time management: whether practitioners have the time for sharing their knowledge; mutual confidence: firefighters need to trust each other; relationship network: who has which knowledge and is willing to share it with others; hierarchy: people with hierarchically higher positions need to allow access to their knowledge; knowledge storage: differentiation between storing explicit knowledge (in databases) and implicit knowledge in peoples' heads; power: having knowledge is perceived as a kind of dominance over others who lack knowledge.

Descriptions of practical implementations of KMS within the CP domain are rare. Only three scientific publications were found that cover KM solutions. (Pickles, 2004) describes a solution for the Australian New South Wales fire brigade to share information within and with other organizations. Unfortunately, no further publications could be retrieved for this solution. (Othman and Beydoun, 2016) is the continuation of (Othman and Beydoun, 2010) and describes a knowledge-based approach to structuring, storing and reusing disaster management knowledge. They describe a system architecture for a knowledge sharing system. Lastly, (Timm et al., 2013) cover a state-wide knowledge and collaboration platform which should be implemented by using open-source solutions to replace a commercial and costly solution. Except for the last one, the first two deal with KMS during or mainly related to an incident. Yet, the application and usage of KM systems in non-incident phases can provide users with an increased level of confidence.

4 DISCUSSION

The SLR revealed papers that are related to KM in the disaster management field. The scarce amount of recent publication shows that there is a need to research KM within disaster management to foster the usage of digital KM systems in that field. Studies on sharing knowledge in non-profit organizations are rare but do exist, although limited only to tacit knowledge (Oliveira and Pinheiro, 2021) or are focused on emergency response information system (Weidinger et al., 2021), (Alexander, 2010). One interesting approach is the development of a knowledge broker for Small Islands Developing States (SIDS) by McNaughton and Rao in (McNaughton and Rao, 2018) and (Rao

and McNaughton, 2019). It deals with important aspects like avoiding knowledge silos, distributing information about who has which information and aligning organizations' vocabularies to gain a common understanding. Their use-case is on SIDS, but their assumptions are transferable to the fire brigades as well.

Concerning RQ1, this SLR revealed a decent amount of scientific literature dealing with KM in CP. The focus, although, is more on generic disaster management than especially on fire brigades (e.g. (Saoutal et al., 2015), (Oktari et al., 2020)). The response phase is covered by the majority of publications; the other phases are only covered by a few. The usage of a KM system in non-incident phases can help the users get familiar with the system; however, only a few publications could be found. None of them were suitable for the research goal (e.g., too specific on a location or circumstance). The conclusion that using a KMS in non-incident phases will improve user capabilities during a stressful and timely limited incident scenario cannot be drawn from the identified scarce literature. Also, KMS are mostly used in large-scale disasters with multiple agencies involved and many people affected. It is not described that practitioners use these systems already in small-to-medium incidents with manageable challenges.

The implementation in existing organizations and procedures as well as the training with KMS was addressed in RQ2. Unfortunately, the identified publications only refer to theoretical concepts (e.g. (Otim, 2006), (Rostis, 2007), (Franke et al., 2010)). Literature, describing a practical implementation with a validation, is scarce. One solution is presented by Cinque et al. in (Cinque et al., 2015). Their supporting platform aims at connecting various stakeholder organizations by introducing a common ontology and vocabulary. The actual implementation in existing procedures or the training is not part of their publication. Differences between voluntary and professional fire fighters are only addressed in a few publications that focus on the sharing of knowledge in volunteer or non-profit organizations (e.g. (Oliveira et al., 2022), or (Oliveira et al., 2022)). The integration of KM into daily routines to familiarize with these systems is not described by any of the identified publications. Partially, results from business sciences might be applicable for fire departments as well, up to the point where the organization switches from non-incident to an incident. There is an immense change of requirements and conditions taking place, which also affect the usage of a KMS (weather conditions, stress, limited time) (Weidinger et al., 2021), (Elmasllari, 2018).

Concerning RQ3, there are few publications describing concrete KM solutions and their applications, but these systems are either private and not accessible by the authors or in an old state and describe software that is or was used years ago. As information technologies are evolving quickly, a modern and recent description is lacking that describes the current usage of KM solutions in the field.

5 CONCLUSION

This literature review was carried out in order to analyze the intersection of KM and CP. KM in fire brigades is considered particularly relevant, as these organizations have to deal with different types of incident scenarios. Following a SLR based on (Xiao and Watson, 2017), the current state of the literature body on KM in CP was elaborated. It identified that the predominant focus is on KM during an incident to help practitioners in the response phase. There is not much literature covering non-incident phases. However, it can be argued that systems for everyday operations would be useful. This could help users to get acquainted with the system and eventually increase their confidence during stressful and time-sensitive incidents. It is not only necessary to have a KMS, but also the knowledge culture (cf. (International Organization for Standardization, 2018)) has to be embodied in an organization. As stated by Rao and McNaughton, the practitioners need to be aware of which information and knowledge exists and where it is stored. The maintenance of knowledge silos hampers the development of a shared understanding of knowledge that could be helpful for coping with incidents and disasters (Rao and McNaughton, 2019). The findings will be used in further research dealing with the development of KMS for fire brigades.

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