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Knowledge-Based Decision Support System for Emergency Management: The Pandemic Framework

[1]Bahaa Ahmad Masmas & [2]Azlinah Mohamed
[1]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Malaysia
[2]Institute for Big Data Analytics and Artificial Intelligence, Universiti Teknologi MARA, Malaysia

bahaa.ahmad.m@hotmail.com
azlinah@uitm.edu.my

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ABSTRACT

Emergency management systems (EMS) assist emergency managers to resolve emergencies on hand, through analyzing the emergency characteristics and consolidating data from different departments that are involved in resolving the emergency. Many countries have adopted various forms of EMS that are specialized in resolving one type of emergency, and studies demonstrate their effectiveness in producing better decisions. However, the COVID-19 pandemic uncovered the lack of a comprehensive framework that could deal with different emergencies. It also revealed the inability of the current systems to communicate with each other to retrieve the needed data. The aim of this study is to show the current state of EMS in emergency departments by constructing a framework for a knowledge-based decision support system for emergency management focusing on resolving pandemics. Qualitative approach was adopted in this research, where the authors reviewed emergency management in general and pandemics in specific. Existing EMS systems were investigated, and knowledge-based decision support systems were explored. Approaches for integration, communication, and collaboration were also studied. As a result of this study, a comprehensive framework, i.e., a knowledge-based decision support system for emergency departments, focusing on resolving pandemics was introduced. The framework was validated by a domain expert who provided insights and suggestions for future research. While the primary research focus is to assist emergency managers in resolving the COVID-19 pandemic, the proposed framework is unique by adopting different approaches and techniques that enable the system to deal with various emergencies not limited to the current pandemic.

Keywords: Decision support system, emergency management, knowledge-based system, pandemic.

INTRODUCTION

Pandemic is an emergency situation, where a disease spreads across a wide region in a short time (Alwidyan et al., 2020). Pandemics, floods, and earthquakes are among the emergencies that need urgent and speedy response to be contained. Different synergic teams collaborate to control a pandemic. For example, in the case of COVID-19, the health department understands the situation and tries to raise awareness to decrease the spread of the disease; emergency call centers receive suspected cases; emergency response teams send ambulance vehicles; the police department and civil defense are involved in imposing the lockdown in high-risk areas (Shanker et al., 2020).

The power of information systems and artificial intelligence in consolidating and analyzing the data has led some countries to adopt and develop emergency management systems (EMS) (Neville et al., 2016). These systems help emergency managers to make vigilant decisions for resolving the situation in hand, by retrieving the needed data, analyzing the emergency characteristics, and proposing optimized solutions and procedures (Li & Xiao, 2010). These systems have been implemented in different functions of emergency management preparedness, mitigation, response, and recovery. Many systems have been implemented recently, like the flood response management system for locating the victims of floods. Another example is the MySejahtera mobile application for informing Malaysian citizens on the recent updates regarding the COVID-19 pandemic. Besides, it is used for crowd control and citizen tracing for better information on possible infection areas that have been visited by COVID-19 patients.

A system framework is defined as the abstraction in which the system provides generic functionalities that could be selected or changed by user needs. It provides a application-specific system. In general, a system framework includes programs, codes, toolsets, and application programming interfaces that bring together all the different components to enable the development of a system (Riehle & Gross, 1998).

An emergency like the COVID-19 pandemic requires careful planning to facilitate an urgent restructuring of many aspects of emergency management (EM) (Schreyer et al., 2020). This research intends to design a framework of a decision support system for emergency management (the pandemic framework) by identifying the main components.

Recently, many countries have adopted various forms of emergency management systems (EMS) that are specialized in resolving a specific type of emergency. Past studies show the effectiveness of EMS in producing better and vigilant decisions. However, the recent COVID-19 pandemic has demonstrated the lack of a comprehensive framework that could deal with different types of emergencies because of the unprecedented situation. Meanwhile, developing a system for each type of emergency is very costly and not all emergencies could be determined beforehand (Sahoh & Choksuriwong, 2017). Currently, there are many systems that have been deployed in emergency departments for dealing with a specific emergency. However, when a new emergency with different characteristics encounters the system, it fails to adapt, resolve, and produce appropriate solutions. The recent pandemics (SARS, Ebola, flu, and others) show the lack of having a flexible system that has the ability to deal with different emergency scenarios, which requires a plethora of data from different interdependent systems. Besides, it reveals the inability of the current systems to communicate with each other to retrieve the needed data due to the systems' isolation with no data standardization (Nunes-Vaz et al., 2019).

This study aims to construct a knowledge-based decision support system framework for the pandemic. This aim is subdivided into three objectives: a) To identify the components of a knowledge-based decision support system for an emergency management framework; b) To design a knowledge-based decision support system emergency framework; and c) To construct and validate the framework of the knowledge-based decision support system for emergency management. To achieve these objectives, different inter-related topics will be reviewed throughout the research in the Related Studies section. The remainder of the paper will be structured as follows: the Methodology section discusses the methods and materials that will support this study. The other parts of the study consist of framework design, development, and validation.

This research concentrates on identifying the components needed to design a comprehensive framework for assisting emergency managers in disaster management departments (emergency departments) in making better and vigilant decisions related to the COVID-19 pandemic. This framework will try to comply with the needs of emergency managers in Malaysia. Adopting the framework will assist in better availability and consolidation of information from different sources for the emergency managers to review and make timely decisions to save lives and reduce losses.

RELATED STUDIES

This section comprises a review of the types of emergencies and their management, definition of pandemic, investigation of existing emergency management systems (EMS) including their categorization based on the nature of the emergency, knowledge-based emergency system and emergency decision support systems, and approaches for integration, communication, and collaboration.

Emergency is defined as a situation that is catastrophic in nature; this situation could be of human or nature causes. The consequences of this incident would lead to the obstruction or reduction of the capabilities of the public and business infrastructure, and danger to human lives. This will then negatively affect the availability of goods and services, and further impact the economy and social conditions in a region (De Nicola et al., 2019). One of the emergency cases that require a rapidly applied procedure is pandemic such as COVID-19 (Alwidyan et al., 2020). The uniqueness of COVID-19 is the easy spreading of the disease between people and the exponential growth of infected cases. COVID-19 has exhibited a crucial issue of how to manage limited resources, such as medical staff, police, and other medical and rescue materials, in containing the situation (Jacobsen, 2020). Dealing with emergencies through the appropriate response preparation, communicating and managing with the bodies that are involved in resolving the situation (police force, hospitals, rescue teams, isolation areas, etc.), and planning for recovery require proper emergency management (EM) (Neville et al., 2016). Therefore, the main aim of EM departments is to save lives and reduce losses with respect to the resources available in resolving the emergency. This could be achieved though the main functions of emergency management, namely preparedness, mitigation, response, and recovery.

Existing EMS

The recent developments in information systems, artificial intelligence, and information technologies have devised new ways to manage data and information to be analyzed and produce optimized solutions and recommendations. These technologies are suitable for EM, which facilitate in consolidating and analyzing data from different departments to extract better knowledge to be used in decision-making by emergency directors. Table 1 summarizes the recent existing EMS systems, including a brief description of the systems, the systems' purpose, and the technologies used.

Table 1

State-of-the-Art Existing Emergency Management Systems

System	Purpose	Technologies	Year	Reference
Virtual Operations Support Teams (VOST)	Voluntary digital participation for collaborative emergency management	Geolocation – mapping – spatial analysis – data mining	2020	Fathi et al. (2020)
Hybrid sensing for emergency management System	Analyze social media posts to collect emergency data	AI – NLP – geoparsing – witness detection	2020	Avvenuti et al. (2020)
Multi-label learning vector quantization neural network	Prediction model to forecast the type of events	Artificial neural network	2019	Chen et al. (2019)
Mobile for emergencies	Inform citizens and emergency operators	Positioning systems – NLP – Modeling	2018	Astarita et al. (2018)
Multimedia systems for managing emergencies	Environmental situation recognition	What-if scenarios analysis – multimedia technology	2016	Tang et al. (2016)
Knowledge-based model for emergency management	Scenario modeling system	Model network – knowledge element networks	2016	Chen and Wang (2016)
Emergency response system in cities	Crowdsensing and heterogeneous data analytics	Data integration – modeling – geo-fence	2016	Abu-Elkheir et al. (2016)

(continued)

System	Purpose	Technologies	Year	Reference
Wireless networks in emergency management	Locating hazards and people – optimizing human evacuation	Sensor networks – distributed decision-making – simulation	2013	Gelenbe and Wu (2013)
Epidemic management information system	Emergency response	Information systems – Database	2012	Zhang et al. (2012)
Application of situation assessment in emergency management	Evaluation of emergency, various situation elements and their impact	Fuzzy Algorithm – Data fusion	2010	Li and Xiao (2010)
Emergency management for information systems in public health	Public health surveillance system	Data mining (clustering)	2010	Murota et al. (2010)
Context-aware emergency management system	Pressing of request calls during an emergency	Context-aware algorithms	2009	Bhavanishankar et al. (2009)

Son et al. (2020) identified five types of technology used to support EM resilience. These technologies are mapping tools, event history log, mobile communication application, integrated information management system, and decision support tools.

Previous Knowledge-Based Implementation in Emergency Management Decision Support Systems

Decision support systems (DSS) are systems that can assist decision-makers with helpful information and reports in making vigilant decisions (Neville et al., 2016). These systems use statistics, optimization, modeling, and other techniques in producing the supporting information (Hernández & Serrano, 2001). One of the methods used in decision support is the knowledge-based system (KBS), which is a system that uses artificial intelligence techniques to handle tasks in a specific domain usually handled by skilled experts (Arain, 2015). Table 2 summarizes previous applications of KBS in emergency management. These systems benefit in assisting the decision-makers by providing them with faster processing of information, and in some levels, automating the decisions. Besides, the most important feature of KBS is the ability to explain its decisions.

Table 2

Approaches in Utilizing Knowledge-Based System in DSS for Emergency Management

System	Purpose	Technologies	Year	Reference
OpenWHO.org	Transfer of Ebola outbreak knowledge	N/A	2018	Utunen et al. (2018)
Smart emergency management based on social big data analytics	Emergency event understanding	Big data analytics – real-time computation – cloud computing	2017	Sahoh and Choksuriwong (2017)
Unconventional emergencies management based on domain knowledge	Decision-making	Ontology – rule-based system	2016	Feng et al. (2016)
DSS for emergency management	Event detection – emergency support	Ontology – modeling	2015	Han and Xu (2015)

(continued)

System	Purpose	Technologies	Year	Reference
Pandemic flu emergency management system	Decision support – planning, coordinating, and controlling actions	Knowledge-based system – modeling – elicitation	2013	Fogli and Guida (2013)
Emergency management knowledge acquisition	Semi-automated knowledge acquisition	Web 2.0 – Modeling	2011	Chen et al. (2011)
Knowledge-based models for emergency management systems	Incident identification in flood domain	Expert system	2001	Hernández and Serrano (2001)

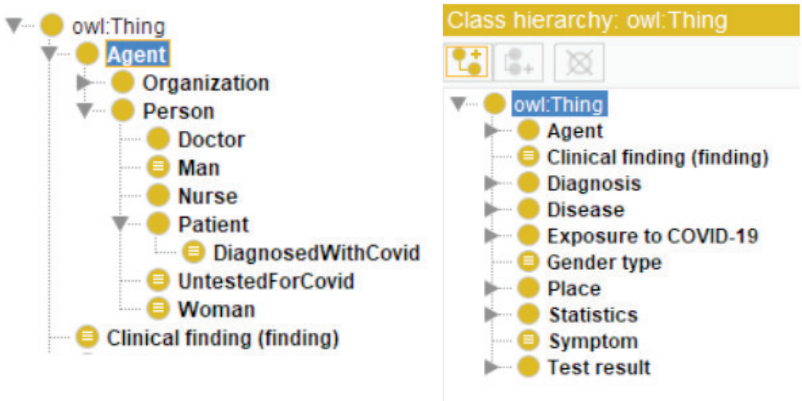
Studies showed that during the COVID-19 pandemic emergency, the current DSS systems are not effective in supporting the emergency directors in making decisions. Foddai et al. (2020) related these systems' weakness to the stress applied to the systems during emergencies due to a vast amount of resources allocated (food, medical equipment, electricity, fuel, etc.). Moreover, these systems are not accountable to be used during sensitive situations that involved human lives (Nunes-Vaz et al., 2019).

Another important aspect to explore is the knowledge-based system that involves knowledge representation, which will arrange the domain knowledge in a way the computer can understand. There are plenty of techniques of knowledge representation, namely: 1) logical representation, which consists of predicate and propositional logics; 2) semantic network, which represents the entity and its relations (kind and inheritance relations); 3) production rules, which represent the domain knowledge and are saved in the working memory; and 4) ontology, which tries to identify and categorize the concepts (Laurini, 2017).

Recently, great efforts have been made in developing COVID-19-related ontologies, including Lusignan et al. (2020), who developed an ontology for identifying COVID-19. He et al. (2020) created an ontology for the COVID-19 infectious disease, which identified the virus's implications and could be used to detect the virus based on the patients' symptoms. Chansanam and Ahmad (2020) developed and evaluated an ontology model to identify entities related to the pandemic, including the persons, information, organizations, and diagnosis. As depicted in Figure 1, the tool used to develop the ontology model is protégé.

Figure 1

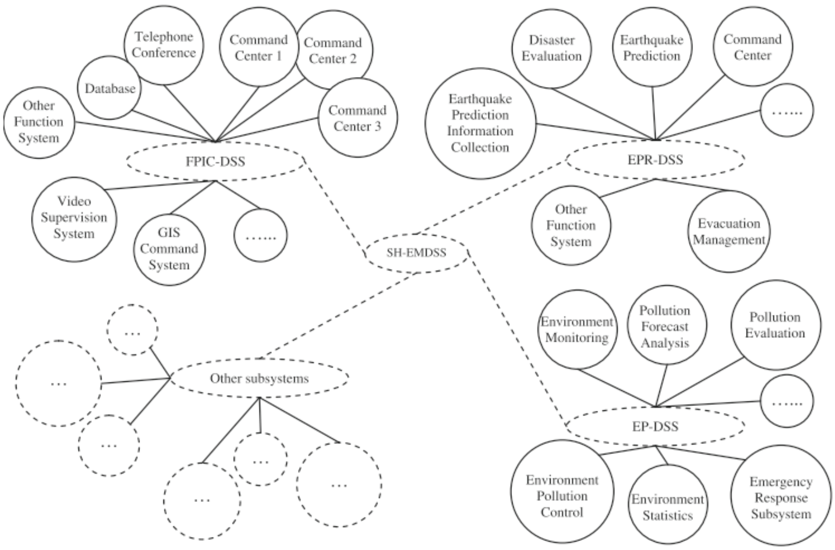
Ontology Model using Protégé (Chansanam & Ahmad, 2020)



Another use of the ontology model is the classification of documents that would lead to efficient retrieval of documents according to the situation. Dhakal et al. (2020) introduced an ontology-based semantic modeling to support knowledge-based document classification on disaster-resilient construction practices. It could facilitate the retrieval of information in times of disasters and emergencies. Another application of ontology is the emergency response decision support system framework for e-government application (Shan et al., 2012). This system utilized an ontology to filter and identify information coming from various systems in emergency rooms, which would create automatic integration and consolidation of the current systems. Figure 2 depicts the ontology adopted by Shanghai emergency management decision support system (SH-EMDSS).

Figure 2

Shanghai Emergency Management Decision Support System (SH-EMDSS)'s Semantic Network (Shan et al., 2012).



Approaches for Integration, Collaboration, and Communication

Pandemics create extensive damages and losses within the society and environment (Rautela 2006), precisely during the premiere stage of the outbreak. The lack of an early warning is the main cause for a large number of infections for any new diseases (Lauras et al., 2013). Having the appropriate communication means will control the spread and help the government to operate more efficiently, according to Hartama et al. (2017) and Lauras et al. (2013). To assert a better quality of decisions, all relevant information from different departments must be available for analysis and processing. There are two main approaches for integration either by data integration or by adopting a specific system architecture. The next two paragraphs will explore these two approaches.

There are many data integration approaches that have been implanted in the EM field, which assist decision-makers in making a timely decision. In contrast, data integration is beneficial yet it is not easy to implement due to the heterogeneous data sources (Kou et al., 2010). The system could collect a huge amount of data but in the specific emergency only. The data integration technique must have the ability to filter and present just the relevant data to be processed (Khovrichev et al., 2019). Neville et al. (2016) introduced EMS with spatial database management system. The relevant data are retrieved from different systems using an application programming interface (API). Another approach is by adopting the data warehouse system, which includes integrating data from multiple, large, and distributed databases and storing these data in a centralized data warehouse via the extraction, transformation, and loading (ETL) tools (Penkova et al., 2012).

The second approach is through adopting a system architecture that would assure data availability in real-time, as well as data standardization. There are many forms of architecture that have been introduced thirty years ago for integrating large-scale systems. One of these approaches is the Enterprise Architecture (EA), which is defined as a collection of components, such as tools and methods, necessary to re-architect the whole enterprise. This system architecture is able to integrate hundreds to thousands of systems and applications (Vernadat, 2006; Gampfer et al., 2018). System of systems (SoS) is another architecture integration framework in which any system integrates large, heterogenous, pre-existing, physically distributed behavior systems (Jiang & Wang, 2013). SoS is usually composed of interdependent constituent systems that work indirectly toward a unified goal (Benali et al., 2012; Repta et al., 2014; Vargas et al., 2016; Axelsson et al., 2019). The third framework for system architecture that affirms integration is the Cyber-Physical System (CPS), which aims to develop a unified framework for implementing complicated systems. An example of the CPS approach is the cloud-based emergency management network system that provides dynamic network services (Repta et al., 2014; Sriramulu et al., 2017). The previously mentioned techniques facilitate the communication and collaboration between different departments (Liu et al., 2018; Smith et al., 2020).

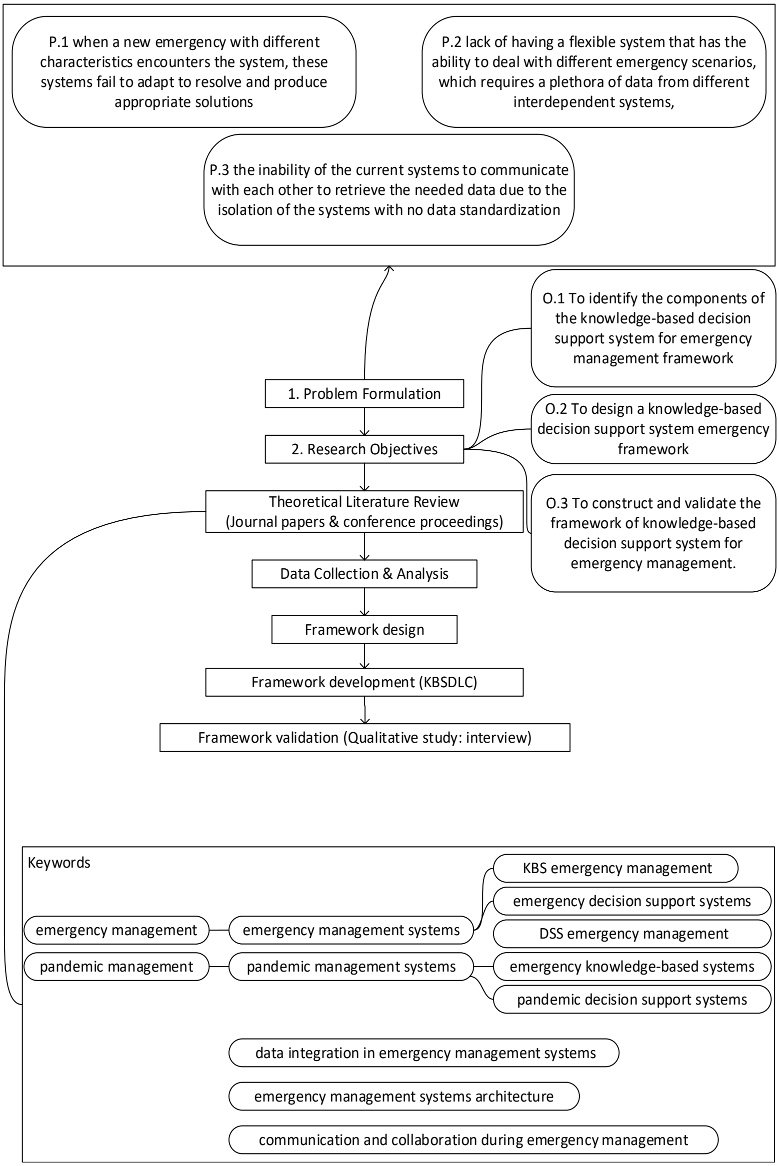
In conclusion to the Related Studies section, a gap surfaces such as the lack of a framework that is able to handle different kinds of emergencies. This research will try to overcome these limitations by introducing an integrated framework for knowledge-based decision support system (KB-DSS) for emergency departments.

METHODOLOGY

The study began with a deduction where the literature was narrowed down to the particular research aim. Later, the induction was performed by discussing the application of knowledge-based decision support systems specifically within emergency departments. The structure of this research depended on various elements that were incorporated with the research purposes and systematically illustrated for data collection and data analysis processes. Research design can be defined as a preparation of research strategy with detailed information about the research in order to avoid uncertainties at a later stage and to bridge the research gap. The detailed research methodology workflow is derived and delivered in Figure 3. Figure 3 depicts the research framework with the stated problem statement, objectives, and keywords used in the review.

Figure 3

Research Framework



The following Table 3 represents the research design, which relates to each objective, its purpose in this research, and how it will be achieved using the method.

Table 3

Research Design

Objective	Purpose	Instrument	Deliverables
a) To identify the components of a knowledge-based decision support system for an emergency management framework	Understand related topics related to the problem and identify main framework components	Journal papers and conference proceedings	Theoretical literature review
b) To design a knowledge-based decision support system emergency framework	Design the framework according to UML	Based on Literature Review	Pandemic KB-DSS framework for emergency departments
c) To construct and validate the framework of the knowledge-based decision support system for emergency management	Development of a prototype adapting the system development life cycle (SDLC) approach and validation of the proposed framework with domain experts	Interview	Qualitative study

Preliminary Study

According to the Danish Evaluation Institute's (EVA) (2004) preliminary study, there is an initial exploration of issues related to a proposed quality review or evaluation. The purpose of the research is to introduce a framework for a knowledge-based decision support system for emergency management for the COVID-19 pandemic in Malaysia. To achieve that, an exploratory study was conducted to explore and better understand the emergency management discipline and to explore the previous application of information systems in this area. Nevertheless, the COVID-19 pandemic is a relatively recent event. The identification of the main variables to be included in the framework was based on related areas. Snowball sampling method was adopted to conduct this preliminary study. This technique is defined as a technique for gathering research subjects through the identification of an initial subject that is used to provide the names of other actors (Levine, 2014). Limitations of the study that had been confronted were that the present study was focused on Malaysia, and the lack of an official action plan to deal with a pandemic. Therefore, the preliminary study was based on a secondary data source, i.e., the COVID-19 pandemic plan for the Victorian health sector, which was the action plan to deal with the recent pandemic in Australia and had been published in March 2020 (Mp, 2020). The generalization and application of the plan in Malaysia will be discussed in the next section.

The main findings of the action plan as mentioned above are as follows:

1. Main objectives: to reduce the mortality rate associated with COVID-19, to decelerate the spread of the virus, to ensure the right response, and to mitigate and minimize the impact of the pandemic on the community.
2. The pandemic is divided into three stages and related actions:
   Stage 1. Initial containment: Investigation of the outbreak as it occurs, communication with at-risk individuals, preparation of hospitals, and engaging with the healthcare sector for better knowledge on best practices.
   Stage 2. Targeted action: Imposing social distancing plans with other government agencies (police, ambulance, fire services, transportation, and education agencies), implementation of hospital resources strategies.
   Stage 3. Peak action: Applying appropriate resources management (diverting from less urgent care), focusing on testing on critical areas.

The primary variables that could be concluded from this analysis are: 1) V.1 - the pandemic and citizens statistics; 2) V.2 - hospital readiness and its available resources; and 3) V.3 - other government agencies that are involved in resolving the issue at hand.

Data Collection and Analysis

To construct the intended framework, the research was divided into two main parts. The first part is adoption of the theoretical literature review method, whereby the literature review would discuss and explore the main theories, techniques, and applications related to the design of the framework of a knowledge-based decision support system for emergency management of the COVID-19 pandemic. This phase started by collecting data from ACM, Elsevier, and IEEE, which included journal papers and conference proceedings.

Most of the papers that were compiled were published within five years. The keywords used for extracting the data were as follows: 1) For exploring emergencies and pandemic management (“emergency management”, “pandemic management”), the number of references was 14. 2) For exploring previous EMS (“emergency management systems”, “pandemic management systems”), the number of references was 13. 3) For exploring knowledge-based decision support systems in emergency departments (“emergency decision support systems”, “pandemic decision support systems”, “emergency knowledge-based systems”, “KBS emergency management”, “DSS emergency management”), the number of references was 18. 4) For exploring approaches for integration (“data integration in emergency management systems”, “emergency management systems architecture”, “communication and collaboration during emergency management”), the number of references was 15.

It is worth mentioning that this research excluded search results that were related to the management of emergency departments in hospitals, as well as medical studies related to emergency rooms/ departments (ER/ED).

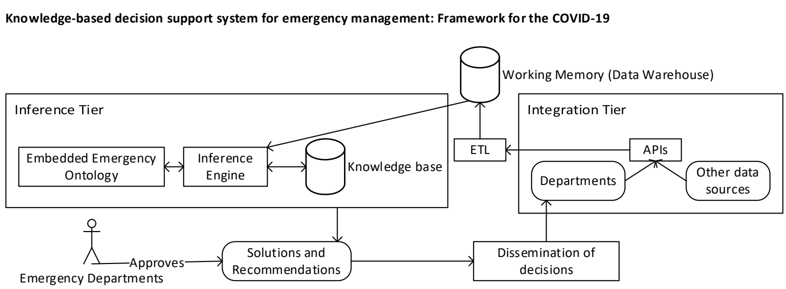
The analysis of the previous papers concluded that most of the previous EMS focused on one function of emergency management. Besides, these systems were specialized in resolving one kind of emergency, such as flood, flu, and pandemic. The proposed framework was deemed as unique as it adopted different approaches and techniques that would enable the system to deal with different emergency situations. This could be achieved through detecting the emergency characteristics (embedded ontology), retrieving relevant data from different departments (integration approach), and providing solutions and recommendations (knowledge-based approach). The next section illustrates the proposed framework.

Framework Design

The recent pandemic has illustrated a gap in the previous EMS, in which these systems are unable adapt to new kinds of emergencies. This research's objectives are to explore the emergency management discipline, identify the main components of the emergency management system, and introduce a framework for DSS that utilizes the knowledge base (KB) technology by using the emergency ontology approach in dealing with different kinds of emergencies. This framework's components were derived from analyzing the previous studies and research related to the topic. Therefore, the proposed framework consisted of two primary tiers, mainly the inference tier and the integration tier, as illustrated in Figure 4.

Figure 4

Research Framework



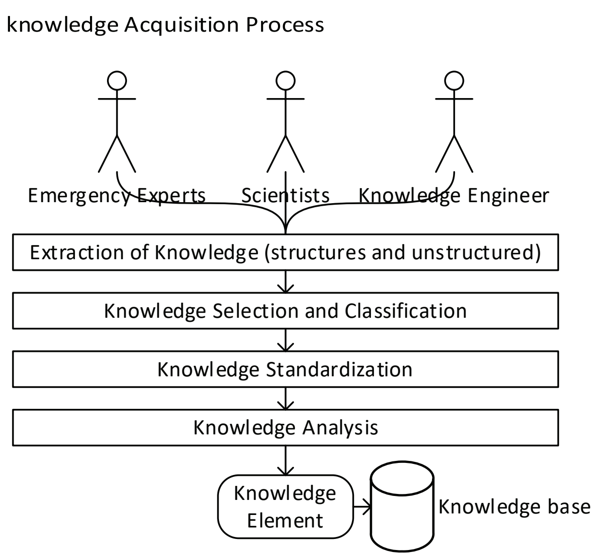
Inference Tier

The decisions were supported through implementing a knowledge-based system that consisted of the following: 1) Knowledge base (KB) that contains the domain experts' knowledge and experiences (Fogli & Guida, 2013); 2) An embedded emergency ontology for emergency detection (Feng et al., 2016); 3) Data warehouse as a working memory that will store relevant data for making vigilant decisions; and 4) Inference engine that will have the logic develop diagnosis and solutions, and will match the facts held in the working memory with the knowledge stored in KB.

The process of knowledge extraction is shown in Figure 5. This process was conducted in collaboration between scientists, domain experts, and knowledge engineers. This approach started with the knowledge engineer conducting interviews with the experts to gain their knowledge. This knowledge could be structured or unstructured. Later, the knowledge was selected and classified, and then standardized and analyzed. Finally, the product of this process, i.e., the knowledge element, would be stored in KB. This knowledge could be previous experiences, best practices in resolving an emergency, resource allocation methods, and ways of analyzing data that will indicate or predict an emergency.

Figure 5

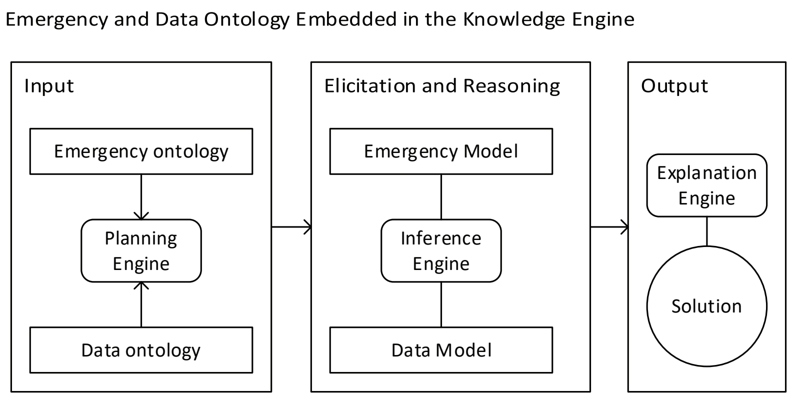
Knowledge Acquisition



Meanwhile, the emergency and data ontology, which would ensure the system's flexibility, was utilized in detecting the characteristics of the emergency and detecting the relevant data needed to resolve the situation. In case of an emergency, this ontology element was adopted from Han and Xu (2015), which would work as follows: from the available data and information, an emergency model and a data model would be developed to be used in producing the solution. The process is as illustrated in Figure 6.

Figure 6

Embedded Emergency Ontology



Integration Tier

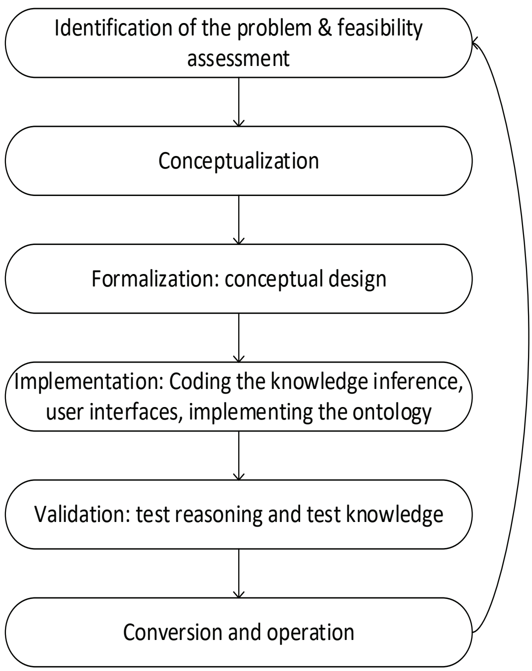
The proposed framework adopted a data integration approach as mentioned in Penkova et al. (2012), which consisted of utilizing APIs and extracting the data from different departments and other sources of data that would be stored in the data warehouse for further analysis. The data would also be used as working memory for the knowledge-based system. These data were extracted from different sources and systems, which had no standard format. This problem could be solved by utilizing the extraction, transformation, and loading (ETL) tools. After the ETL process, the data stored in the data warehouse would be standardized and cleaned and ready to be analyzed through online analytical processing (OLAP) tools. The integration tier would open a new medium that would enable more comfortable communication and collaboration between departments involved to resolve the emergency at hand.

Framework Development

The development of the prototype followed the system development life cycle (SDLC) approach. Weitzel and Kerschberg (1989) introduced a methodology for developing knowledge-based system (KBS) based on the traditional SDLC but with adaption to the KBS requirements. Figure 7 depicts the phases and tasks in KB-SDLC.

Figure 7

Knowledge-Based System Development Life Cycle (KB-SDLC)



Framework Validation

The validation of the proposed framework was done with an expert in the area of emergency management, i.e., Resilient Cities Researcher on Disaster Management (Collaborative Multi Agency for Resilient Communities). The respondent gave a good review on the proposed framework, stating that the components followed the standard knowledge-based systems and had a good potential. However, he recommended to consider amending the framework design after taking the real-world emergency managers' needs into account. Furthermore, the respondent suggested researching more on the openness of sharing the data between different states or agencies, which was considered a very complicated issue that needed more effort. The future research could focus on validating and improving the proposed framework through qualitative and quantitative research approaches via simulation and interviews with more domain experts. Considering the pandemic situation, the authors could not hold interviews with more domain experts. As the study scope is Malaysia, future interviews and surveys will target top management employees in the emergency management departments. As for the validation of the framework, interviews will be conducted with chief information officers in the National Disaster Management Agency (NADMA) of the Prime Minister's Department. According to NADMA's official website, the agency was formed in October 2015 in response to previous disastrous flood events in 2014. NADMA's main functionality is "to ensure safety and national well-being by developing multi-agencies to improve capacity and preparedness in disaster management".

CONCLUSION

This study explored previous EMS systems, main components for developing EMS, KB-DSS applications in EM, and lastly, the approaches for integration that will ensure data availability and ease of communication. Previous systems showed limitations in identifying low adaptability with new kinds of emergencies that they might face. Apart from that, these systems lacked an integration method. The present study proposed a knowledge-based emergency management system known as the pandemic framework, which overcomes the previously developed systems' pitfalls, through adopting knowledge-based system, ontology for detecting emergencies, and integration approach through APIs and ETL tools. The future plan for research is to validate the proposed framework through qualitative and quantitative research methods via simulation and interviews with more domain experts.

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