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Decision Support System Application in Disaster Management

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ABSTRACT

Disasters such as earthquake, flood, fire, and tsunami result in catastrophic human suffering, loss of property and other negative consequences. The continues threats of future disasters enforce human to find best possible ways to detect and take premeasured actions based on calculated risks to reduce these negative impacts of disasters. With the rapid technologies advancement, it will not be able to eradicate disasters in totality, however with the application of decision support system (DSS), it will bring many beneficials to the Disaster Management especially when the disaster response team must make quick decision during the stressful time and/or within the complex situation with more reliable information. This study conducted to understand the roles of DSS in Disaster Management and its impact.

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1. Introduction

Disaster refers to a severe disruption to the functioning of a community or society, resulting in extensive human, material, economic, or environmental consequences that surpass the affected entity's capacity to address using its own resources[26][27]. The classification of disasters can be broadly categorized into four main types:

a. Natural Disasters (e.g., Floods, Earthquakes, Extreme Temperatures, Landslides, Tsunamis, Avalanches, and Volcanic Activity)
b. Man-Made Disasters (e.g., Environmental Degradation, Pollution, Accidents)
c. Complex Emergencies (e.g., Food Insecurity, Epidemics, Armed Conflicts, Displaced Populations)
d. Pandemic Emergencies (e.g., Coronavirus Disease (COVID-19), Ebola, Zika, Avian Flu, Cholera, Dengue Fever, Malaria, Yellow Fever)

Following a disaster, comprehensive emergency operations become imperative, necessitating swift decision-making, resource mobilization, and immediate action by both governmental and non-governmental entities. Any delays in response can result in immeasurable losses. The advent of information technology over the past few decades has significantly facilitated prompt and scientific decision-making in disaster management[29].

A Decision Support System (DSS) is an information technology application designed to analyze data and present information effectively, aiding users in making informed decisions. It plays a crucial role in facilitating communication and information flow within a team during pre-disaster, disaster events, and post-disaster events. Generally, a DSS incorporates four essential elements to fulfill its decision-support purpose: a data bank, data analysis capabilities, normative models, and technology for information presentation. With the rise in the frequency of disasters globally, including the ongoing COVID-19 pandemic, governments and organizations are increasingly relying on DSS to enhance their disaster management capabilities.

This paper conducts a comprehensive analysis of research articles to assess the utilization of Decision Support Systems in disaster management. The systematic review addresses the following research questions:

a. What role does a DSS play in assisting the decision-making process in disaster management?
b. What are the impacts (benefits and limitations) of DSS in disaster management?
c. What are the steps/configurations involved in the current development of DSS?

The remainder of this paper is organized as follows: Section two provides a Literature Review, Section three details the Research Methodology, Section four presents Result Findings and Discussion, and finally, Section five concludes the review.

2. Literature Review

Disasters are a common challenge faced by human sustainable development. Disaster prevention and mitigation aimed at reducing social vulnerability and reducing the impact of disasters is the starting point for a country and society with the characteristics of resilience. The academic community generally divides disaster management into four stages: disaster prevention, disaster preparedness, disaster response and disaster recovery based on the theory of disaster life cycle.

a. Disaster prevention – this phase focus for future mitigation plan, to reduce or eliminate risks.
b. Disaster preparedness – this phase usually is the primary focus by disaster/emergency team as well as many of the available of DSS systems. The main goal is to save lives as many it can and minimize the disaster damage.
c. Disaster response – this is the phase where emergency team take necessary actions when disaster is triggered. All the effort and resources are mobilized as part of response activities.
d. Disaster recovery – is the phase which focus to return lives back to normal condition. It can be further categorized to short-term recovery which return to basic normal life necessity and long-term recovery activity which may take several years post-disaster event, including rebuild damaged assets and maintain economic growth.

There is no one-size-fits-all blueprint for disaster recovery, whether for individuals, communities, or nations. Each country affected by natural disasters has its own unique process of economic reconstruction. However, most countries face common challenges and difficulties in post-disaster reconstruction. Post-disaster reconstruction means a whole new process of economic development for affected people, communities and countries [31].

The use of decision support systems can help to ease operational restrictions like workload and resource availability as well as communication. Due to these limitations, it is more challenging to recognize duties in a timely way and to react to situations rapidly. This is especially true for victims in developing nations like Malaysia, where economies frequently largely rely on aid from abroad to help them recover from such tragedies [32]. The efficacy of government-provided relief and emergency operations has a significant impact on catastrophe impact in these nations[33].

To manage disasters more effectively, many countries have setup their own emergency team which cooperate with multiple group that provide response to the disaster. For example, Malaysia established the Disaster Management and Relief Committee, which consists of representatives from the federal, state, and local government levels. Since the MKN is responsible for coordinating, establishing, and ensuring that the policies and the disaster management mechanism are followed and put into practice at all levels, the MKN will serve as the lead agency for disaster management in the nation[33]. Thus, the application of DSS will bring beneficial in Disaster Management which involved multi-level communications and teams that are distributed in different geographical locations.

3. Research Methods

3.1 Sistematic Literatire Review (SLR)

Literature review has been applied in numerous academic fields such as medicine, robotics, and software engineering[1][2][3]. This is a research method that systematically reviews the existing literature on a certain problem, understands the research progress of the problem to be studied, and makes clear which problems have mature research results[4]. It is helpful to help us find frontier problems and expand the research ideas and methods of researchers[1][4]. As shown in Figure 3-1, Xiao and Watson (2019) proposed a set of flow charts, which we learned and modified it with our understanding[7].The flow chart summarizes the specific research process of current literature review methods.

Systematic literature review is also widely used in decision support systems. Teniwut and Hasyim (2020) conducted a systematic literature review of the supply chain related decision support system from 2009 to 2019. They used VOSviewer and other bibliometric tools to process a large amount of data collected.[5]In a systematic review of 136 articles from 2017 using the PRISMA model, researchers found that the main trends of concern in DSS are machine learning and neural networks[6].

Numerous other significant DSS studies have also used systematic literature review[8][9][10]. It can be seen that the literature review method plays an important role in the development of the DSS field, and the application of this method in the DSS field is of value and application significance. Therefore, SLR (Systematic Literature Review) is chosen as the research method, and PRISMA model is used to analyze and deal with research objectives.

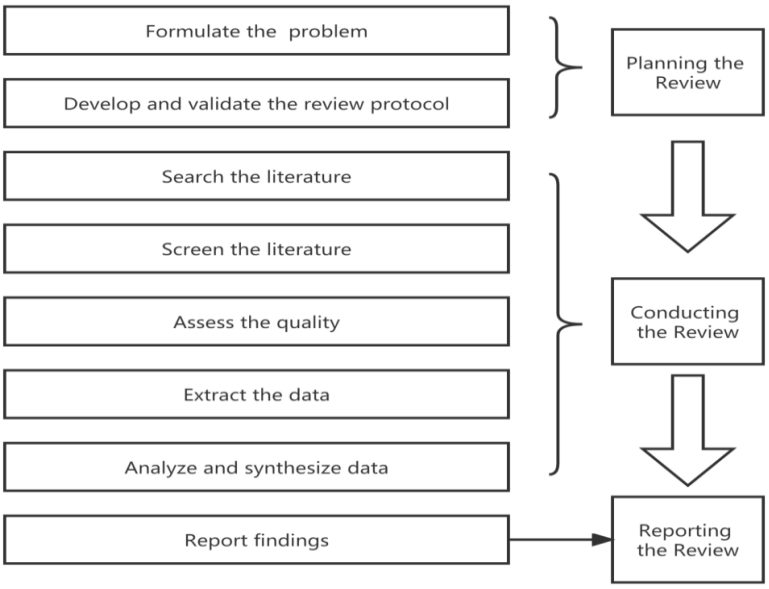

Figure 1. Process of Systematic Literature Review (Adapted from Xiao and Watson,2019)

3.2 PRISMA

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) is a set of standard specifications for the research quality of Systematic Reviews. It is suitable for the review of published literature containing original data, aiming to improve the scientific and comparability of systematic reviews.

The core part of the PRISMA model is literature retrieval. This study established the retrieval strategy as shown in Table 1 for the purpose of the study and related requirements.

Table 1. The Strategy of Literature Retrieval

Strategy		
Screening	Key keywords	1. “Decision Support System” 2. “Disaster Management”
	Alternate keywords	1. “DSS” 2. “Disaster Management”
	Database	ScienceDirect
	Time Line	2010-2020
	Language	English
	Type	Journal(research articles)
Eligibility	Criteria	1.It has at least one concrete example case
		2.It has an introduction to DSS development
		3.It helps answer the research questions

This study only conducted a literature search on the ScienceDirect database of Elsevier Corporation. As shown in FIG. 3-2, the main keywords and alternative keywords were searched at the same time, and repeated references were screened out, and then further screening was carried out according to the screening strategy above.

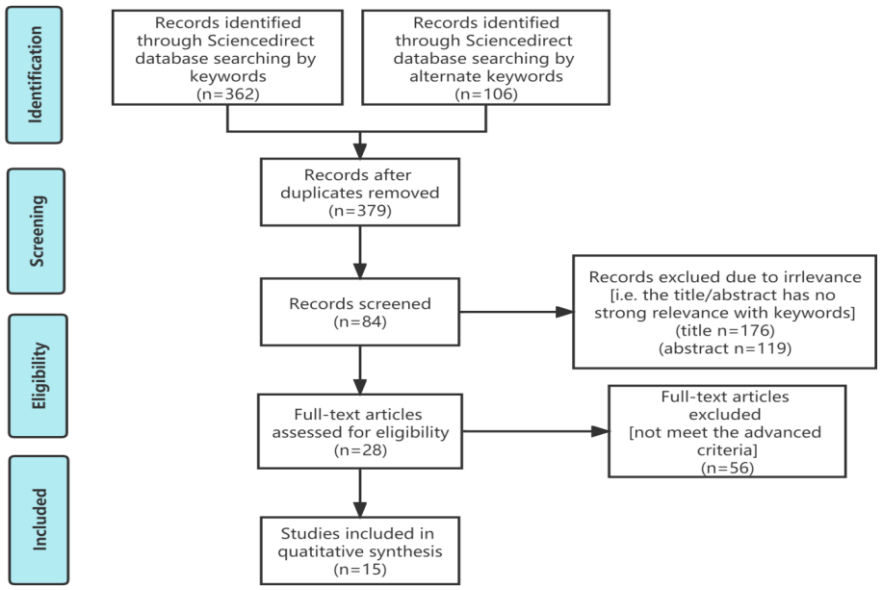

Figure 2. Research Process Based on PRISMA Model

3.3 Qualitative Syntheses

Based on the PRISMA model, we finally selected 15 articles for qualitative synthesis. The brief information of specific literature is summarized in Table 3-2. The results of qualitative synthesis are elaborated in the following sections.

Table 2. Studies Included in Qualitative Synthesis

Study No.	Year	Title	index
study1.	2018	Developing a decision support system for Disaster Management: Case study of an Indonesia volcano eruption.	**Error! Reference source not found.**
study2.	2010	A natural-disaster management DSS for Humanitarian Non-Governmental Organisations.	**Error! Reference source not found.**
study3.	2020	A decision support system for scheduling the shifts of physicians during COVID-19 pandemic.	**Error! Reference source not found.**
study4.	2020	A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19).	**Error! Reference source not found.**
study5.	2017	Smart levee monitoring and flood decision support system: reference architecture and urgent computing management.	**Error! Reference source not found.**
study6.	2013	Distributed simulation of city inundation by coupled surface and subsurface porous flow for urban flood decision support system.	**Error! Reference source**

			not found.
study7.	2012	Development of Decision support system for flooD Disaster risk management.	**Error! Reference source not found.**
study8.	2017	A hybrid decision support system for managing humanitarian relief chains.	**Error! Reference source not found.**
study9.	2017	An integrated evacuation decision support system framework with social perception analysis and dynamic population estimation.	**Error! Reference source not found.**
study10.	2014	THESEUS decision support system for coastal risk management.	**Error! Reference source not found.**
study11.	2017	Bridging the gap between decision-making and emerging big data sources: An application of a model-based framework to disaster management in Brazil.	**Error! Reference source not found.**
study12.	2020	Decision support for medical disasters: Evaluation of the IMPRESS system in the live Palermo demo.	**Error! Reference source not found.**
study13.	2018	One page project management application on flood preparedness: Case study of Thailand.	**Error! Reference source not found.**
study14.	2017	RF-CLASS: A remote-sensing-based flood crop loss assessment cyber-service system for supporting crop statistics and insurance decision-making.	**Error! Reference source not found.**
study15.	2014	An integrated expert system for fast disaster assessment.	**Error! Reference source not found.**

4. Results and Discussion

4.1 The Role of DSS

In this research, we found that in a large number of literatures, the role of DSS is reflected in the early warning and simulation of disasters before the occurrence of disasters, mainly in floods[15][16][17][20][23][24] and medical disasters [13][14][22]. The preparedness and mitigation have more emphasis as it is believed that it could highlight the risks and raise necessary awareness. In addition, DSS can also provide decision support for emergency response and disaster reduction for different specific institutions and organizations, such as NGOs,

provide decision support of human resource management and work planning for all kinds of personnel in major disasters[12][14]. Some DSS do not focus on specific disasters, but strive to play a role in various complex disasters. They are often able to timely plan evacuation and evacuation plans after the occurrence of multiple disasters and provide decision support for decision makers in rescue plans[18][19]. There are also DSS systems that are not directly related to the disaster itself, but focus on addressing the disruption of the supply chain caused by the disaster. They provide decision support for improving the supply chain to support disaster relief supplies[14].

The usage of DSS tools is highly anticipated to help stakeholders, government officials, volunteers and others by facilitating the decision-making process. For example, during pre-disaster, DSS can plays critical roles to investigate if there is potential flood by distinguishing between flooded and non-flooded images. This makes the process of screening or investigating the flooded areas from a large crowd of informants faster. As DSS also stored past historical data, it can estimate the potential impacts and provide alerts to high-risk flood areas or early warning system and subsequently create awareness for community preparation. Another example for preparedness is an earthquake simulation DSS that can predict damage to buildings and disruption of utilities. These estimates can serve as the basis for developing emergency response plans and for organizing tests and exercises of response capability. At this early stage of preparedness, DSS already started plays vital role to save lives and minimize damage that could cause by the disaster.

During the disaster, DSS can provide reliable and up-to-date information for searching and rescue of victims in large-scale disasters. The biggest challenges we are facing today in disaster management include: (1) How to allocate effectively and reasonably the disaster relief resources? (2) How to make full use of the limited disaster relief resources to optimize their effectiveness? (3) How to prevent or minimize the loss of life and property to the maximum degree? [25]. With the integrated expert system to DSS, it can assess the disaster data quickly and effectively then mobilize the required resources in certain rescue operations. A study in Philippines (a disaster prone country) includes the usage of Twitter as input source of data and the DSS can categorize the outputs into 5: evacuation, roads and bridges, electricity, food and water, medical which can further reduce the loss of life and expedite relief to the victims.

4.2 The Impact of DSS

During disaster, collaborating with multiple teams, agencies or disasters responders can be a challenging task, especially there is often a need for quick decision making under a stressful time or within a complex situation. A high-level of information accuracy is required to make the right decision. It is well known that ICT and the application of DSS system in disaster management has brought many benefits to local people and government. The most obvious impact is that DSS significantly improves the efficiency of disaster management when a disaster occurs. It can become the central of information communication and assist the command center officers to organize tasks with real-time and more reliable information. The information collected also can be used for long term relief planning as well as for future preventive/mitigation plan. The data can be collected and stored then used by DSS systems for early detection or develop prediction mechanism to protect the health and safety of people. This efficiency improvement is also reflected in many other aspects, such as human resource management[12][13][18], supply chain management[14], organization coordination[22], relief evacuation[17][18] [19]and so on.

DSS also provides security for people and property during disasters. Among them, the most obvious is the protection of disaster victims. Secondly, DSS also makes contributions to preventing disaster relief personnel from receiving injuries and secondary injuries[13].The protection of local residents' property before and after disasters is also one aspect of the huge impact of the DSS system, which is mainly reflected in the disaster control of crops and houses under floods in this paper[23][24].

4.3 The Steps and Configuration of DSS

Mostly DSS are developed based on DSS needs, such as evacuation planning in response phase of disaster management, damage assessment and identification of effective response measures, searching and rescue of victims in large-scale disasters, flood risk management, forecasting forest fire, monitoring for potential earthquake or tsunamis, and others. In order to meet different needs, diverse decision makers and complex external environment, the existing DSS systems in practical application often have different configurations. "Bottom up and Top Down Approaches" were used to construct DSS from conceptual framework to actual case assessment in a DSS for volcanic eruption response[11].

Many DSS are linked to a variety of external databases to provide data support for DSS, such as open source Internet databases and open government or institutional databases[12][17][23][24]. Some DSS integrated a variety of development technologies and designed multi-method composite DSS, such as big data[21], Delphi method[25], geographic information system[19][24], etc. Despite the integration of different modules, most DSS development follows a few general steps, which require obtaining requirements (identifying problems), developing a data management/processing system, and a user interface[15].

5. Conclusion

This paper presented a systematic review on decision support system in disaster management, which allowed providing a comprehensive framework. In relation to the research question identified, this review aims to identify the role of DSS in disaster management, the impacts(benefits and limitations) of DSS on disaster management, and steps/configuration involved in the current development of DSS. The literature search and screening process followed the guidelines of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).

Through the analysis of the 15 articles investigated, this review answers all the research questions: (1)What is the role of DSS and how it assists the decision-making process in disaster management? (2) What are the impacts (benefits and limitations) of DSS in disaster management? (3)What are the steps/configuration involved in the current development of DSS? The findings showed that decision support system plays an important role both before and after a disaster. Before disasters, it can simulate, monitor and give early warnings. After a disaster, it provides critical support for rapid rescue, accurate assessment and reconstruction. The research results also show that DSS has a positive impact on disaster management in many aspects, including disaster management efficiency, rational allocation of human resources, scientific supply chain management, and reduction of casualties, resident property losses, and damage from secondary disasters, etc.

Although DSS has played a great role in disaster management, it still has limitations and shortcomings. Some existing DSS are too complex, the training cost for relevant personnel is high, and the learning cost for decision makers also needs to be optimized[12]. Due to the complexity of disasters in reality, limited by the current hardware and technology, many DSS will have low accuracy due to fewer input system parameters, which may even make the system output wrong decision recommendations[14][16][18][22][24]. In addition, because DSS needs to meet different requirements in different domains, this leads to one of the characteristics of DSS, which is that there is no universal DSS. Therefore, there are many kinds of DSS to deal with a single disaster[15], and DSS to deal with multiple disasters need diverse disaster events to verify[19][25].

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