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Review Article

Design and Framework for Developing Disaster Health Information System (DHIS): A Systematic Review

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Abstract

Background: Health information systems are critically important in disaster management. It supports disaster management activities and the information needed for decision-making support. We aimed to evaluate comprehensively published literature on disaster health information systems designed to identify and extract the required framework and components.

Methods: A systematic review approach was used to systematically seek, screen, and synthesize data extracted from papers on using health information systems in disasters from the electronic databases (Scopus, PubMed, ProQuest, and SAGE) with no limit up to Jan 2022 following the PRISMA declaration for reporting. The inclusion criteria consisted of full-text journal articles, publications in English, and studies focusing on disaster health information systems, critically evaluated articles using the Joanna Brigg Institute (JBI). Content analysis was used to analyze extracted data.

Results: Of 998 identified references, 18 articles were finally included and analyzed in this study and they are good quality according to appraisal results using JBI. Most reports described research of development or working prototypes and working framework; only two referred to early research or proposed design or framework. Of 18 articles; identified into 3 themes; 4 DHISs in pre-disaster, thirteen DHISs used during the disaster, and one DHIS in post-disaster were identified.

Conclusion: All the systems have a design or framework starting from strategies and plans, information flow, disaster management, and operation engagement, and involve all stakeholders, including the community. Its systems are supported by the latest technology and methods and the principles of integration and interoperability to obtain a DHIS that can assist decision-making processes.

Keywords: Design; Component; Health information system; Disaster

Introduction

The occurrence of disaster events is highly uncertain and cannot be averted. They can transpire unexpectedly and without any warning. Various calamities, such as earthquakes, tsunamis, floods, volcanic eruptions, fires, and other natural disasters, pose significant challenges to humanity. Therefore, we must always remain prepared to confront them if they occur (1). Natural disasters have occurred more frequently over the past ten years. Numerous nations were impacted, the WHO report states, more than 700,000 people perished, over 1.4 million suffered injuries, and about 700,000 people lost their homes. A disaster will result in material and human losses, especially in underdeveloped nations where fatalities and economic loss are more likely to be higher (2).

Dealing with natural disasters, which are unforeseeable events, necessitates management as the primary tool to prepare for them. As a result, the health information system plays a critical role in implementing disaster preparedness measures. However, no universal template can be used in every disaster zone globally. This is due to the unique features and attributes of each area. Therefore, it is necessary to undertake innovative and sustainable initiatives to establish a system that aligns with disaster management requirements in a particular area (3).

The most recent advancements in the development of information technology for disaster management must be carried out sustainably. Four processes are included in disaster management: mitigation, preparedness, response, and recovery. Information and Communication Technology (ICT) plays a crucial role in enhancing disaster preparedness, mitigation, prevention, and management. By leveraging these technologies, nations around the globe can enhance the efficiency and sustainability of their disaster management strategies and policies (4).

Information systems are very supportive of disaster management activities, from smooth and quick communication, virtual team collaboration, and communication with experts with all stakeholders and the information shared with the public (1). Before the advent of Geographic Information Systems (GIS), real-time data was unavailable for disaster decision-making, leading to mostly pre-established plans. However, with the integration of GIS, data from diverse sources can now be combined, providing a significant advantage for stakeholder collaboration. Rapid information delivery facilitated by GIS greatly benefits communities affected by disasters. GIS spatial interpolation allows for the acquiring of geographical, disaster history, and injury-related data in disaster-stricken areas (5).

ICT in the mitigation phase is relatively less explored than other areas, primarily because it necessitates the integration of additional technologies, such as predictive machine learning algorithms, to suggest effective mitigating measures (6).

The objective of this study was to conduct a comprehensive evaluation of published literature on disaster health information systems design to identify and extract the required framework and components. To provide a proposed design for disaster health information systems.

Methods

We used the systematic review approach to seek, screen, and synthesize data extracted from papers on using health information systems in disasters. We followed the PRISMA declaration to report this systematic review. There was no prior protocol or publication for this systematic review. The PRISMA checklist was employed (7).

Search strategies

The electronic databases (Scopus, PubMed, ProQuest, and Sage) were scrutinized by two independent researchers. Table 1 illustrates the search phrases employed in the databases. We used the software Endnote for document management (8).

Table 1: Keyword combinations and terms

Database	*Keywords*
PubMed	"Information system"[tiab] AND (disaster [tiab])
SAGE	"Information system" AND ("disaster management "OR "disaster planning")
Scopus	"Information system" AND "disaster management" AND "health"
ProQuest	("information system" AND "disaster management" AND "health") AND (at.exact("Article" OR "Literature Review") AND stype.exact("Scholarly Journals") AND subt.exact("disasters" OR "emergency preparedness" OR "information systems" OR "emergency response" OR "internet of things") AND la. exact("ENG"))

Inclusion and exclusion criteria

The selection process for papers was based on specific inclusion and exclusion criteria, and only those meeting all the following were considered:

- Full-text journal papers (excluding conference and meeting abstracts)
- English-language publications
- About disaster health information systems
- "Community level, or organizations and institutions involved in health relief of all kinds of disasters."

Excluded

- Review or serial (book series).
- The system of the model without the design mentioned it.

Quality control

Two reviewers (ATI & LN) independently evaluated the quality of each publication for the systematic review and meta-synthesis using the JBI critical appraisal instrument created for Qualitative Studies.

Data Synthesis

The present study will examine the existing models, framework, and components of the disaster health Information system. The existing models will be compared in terms of their design, elements, components, and then categorized according to its function, characteristic and feature from content of extraction data.

Protocol and Registration

The Study protocol has been registered with PROSPERO (registration number: CRD42022322499, available at https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022322499

Results

Search result

We reviewed articles on the design and components of DHIS from Jan 1, 1990, to Jan 11, 2022. Overall, 998 references were returned through searching the databases, of which 951 were retained after removing the duplicate results using Endnote. Next, the inclusion and exclusion criteria identified 65 articles with potentially qualified records by reading the titles and abstracts. Through further full-text assessment, 53 articles were eligible. Moreover, another screening with the Population, Exposure, Outcome, dan Study Design (PEOS) scheme was included by reading full articles. Therefore, 18 articles were finally included in the systematic review (Fig. 1).

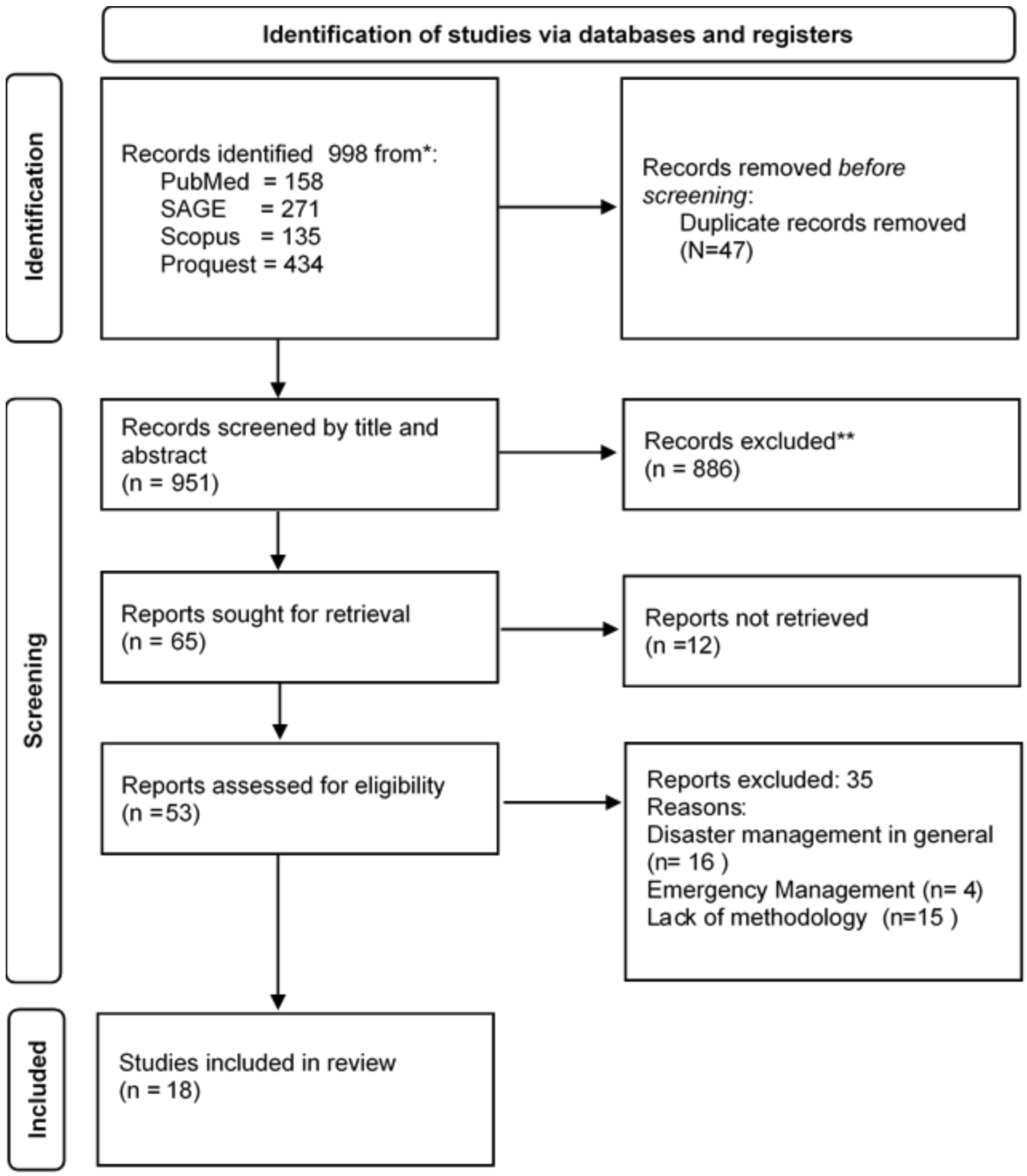

Fig. 1: Process of screening and selection reviewed studies with PRISMA flow diagram

Quality Appraisal result

Overall, 16 of 18 articles are categorized as high-quality articles with a "yes" response rate of over 75%, ranging from 6/8 questions to 9/9 questions. However, there were two articles with lowest scores, each scoring 5/8 questions. The two reviewers discussed this matter and decided to include these articles, considering that their scores are still above 50%.

Results

Of 18 Studies, 7 of 18 are in the America (USA), 5 in Asia (2 in Indonesia), 5 in Europe, and only one in Africa, published from 2005 until 2021. Most reports described research of development or working prototypes and working framework; only two referred to early research or proposed design or framework as a recommendation for developing the system. Most of evaluation used for the studies were simulation/exercise (11 papers), laboratory trial (2 papers), and data volunteer used (1 paper), the rest were without evaluated method (4 papers) (Table 2).

Table 2: Characteristic and quality assessment report (JBI)

Author	*Country*	*Study Type*	*Evaluation method*	*JBI Score*
Abd-Alrahman and Ekenberg (8)	Sudan	Framework propose model	-	8/9
Seyedin and Jamali (9)	Iran	Propose model	-	9/10
Troy et al., (10)	USA	Implementation project	laboratory trial	6/8
Hadi et al. (11)	Indonesia	Prototype Development	Scenarios Field Simulation	7/9
Tavakoli et al. (12)	Iran	Prototype Development	Destructive earthquake scenarios of the exercise simulated	9/10
Sutiono et al. (13)	Indonesia	Prototype Development	System assessment, simulated	8/9
Lenert et al. (14)	USA	Evaluation of Implementation information system	simulation exercise with 100 simulated victims	8/9
Walderhaug et al.(15)	Norway	Prototype design and evaluation	A near real-life evaluation during a full-scale military exercise.	5/8
Chronaki et al. (16)	Greece	Evaluation of Implementation information system	The operational earthquake readiness exercise	7/8
Calik et al. (17)	Turkey	Implementation project	Laboratory testing	7/8
Schmidt F. (18)	Germany	Prototype development	Tested in Germany using data from volunteers	9/9
Chan et al. (19)	USA	Evaluation of Implementation information system	Simulated disaster victim volunteers in the exercise	9/9
J. Jokela et al. (20)	Sweden and Finland	Prototype design and evaluation	Two simulated mass-casualty situations	8/9
Fry and Lenert (21)	USA	Prototype development	-	7/8
Mears et al. (22)	USA	Prototype development	-	5/8
Demers et al. (23)	USA	Prototype design and evaluation	Field tested in several exercises	6/8
James P. Killeen (24)	USA	design, development, and deployment	32 patient scenarios	7/8
Zhao et al. (25)	China	framework development	Simulation from real data Wenchuan earthquake	7/8

The design and components of DHIS features from data extraction identified and they divided into three themes: pre-disaster (4 articles), during-disaster (13 articles), and post-disaster (1 articles). The system's functions were categorized and summarized for each, the key characteristics of various implementations were contrasted, and the evaluation techniques employed were explained and comparing key elements of several implementations. (Fig. 2)

Based on the researchers' findings, the designs or frameworks for each theme are as follows: In the pre-disaster stage, the system includes the proposed design of disaster information management, communication, and decision-making framework, the Community Disaster Information System (CDIS), and the Disaster Alert Information System. The system used during the disaster stage comprises patient tracking, an Emergency Medical Care Information System, and a Web GIS for collecting and analyzing Covid-19 cases. Meanwhile, in the system used in the post-disaster stage, there is one framework specifically designed for A Rapid Public Health Needs Assessment after the disaster. The arrangement of the reviewed systems above is based on the extracted results from Table 3.

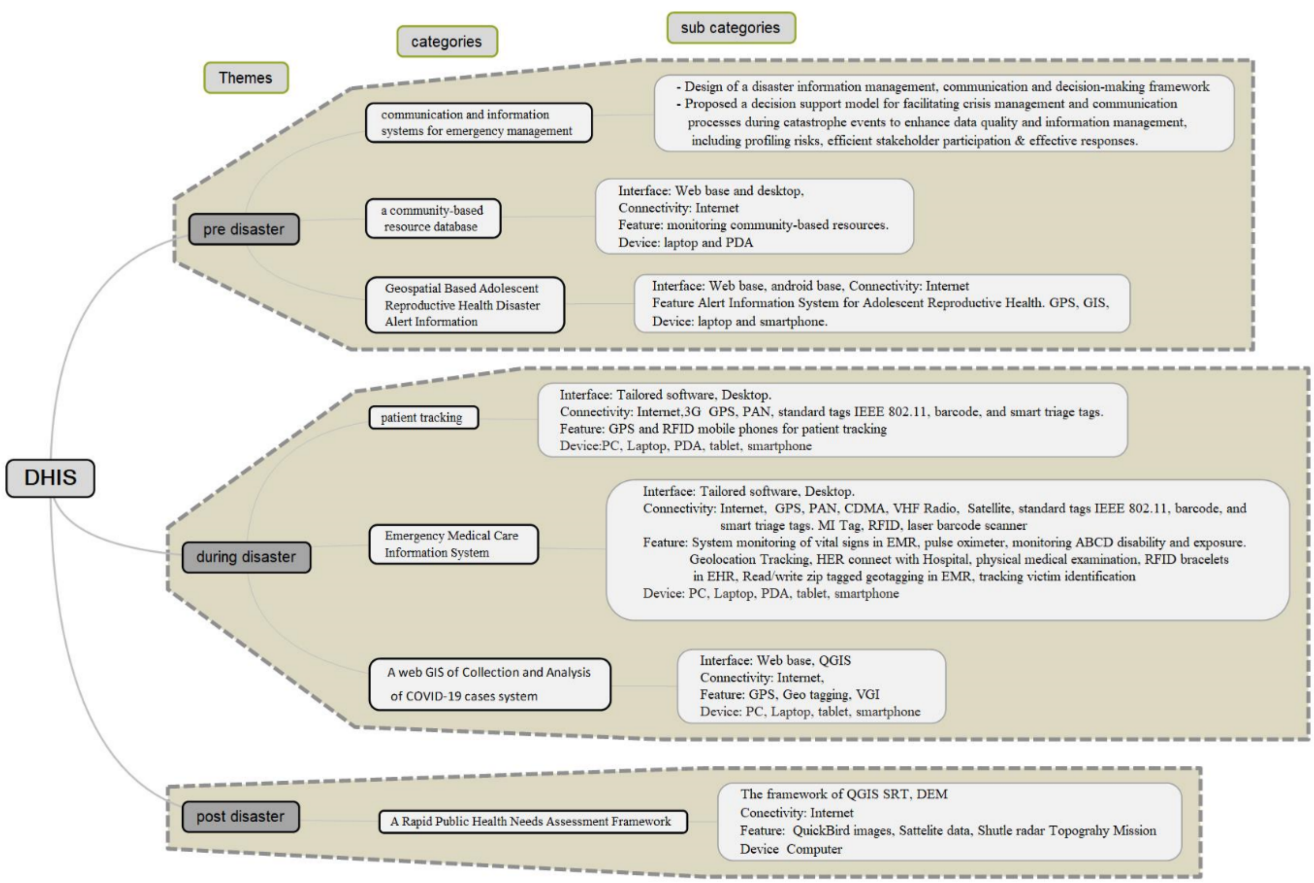

Fig. 2: Overview of Identified Key Results Regarding DHIS

Table 3: Content analysis of disaster health information system

No	*Categories*	*Content: Characteristics and features*	*Specific: Component system*
	Theme: Pre-Disaster		
1	Communication and information systems for emergency management	- Design of a disaster information management, communication, and decision-making framework - Proposed a decision support model for facilitating crisis management and communication processes during catastrophe events to enhance data quality and information management, including profiling risks, efficient stakeholder participation & effective responses.	- 1. Strategies and Plans, 2. Information Flow, 3. Disaster Management, 4. Operation Management (8) - Five different information databases for E.M. (Demographics, disaster, managers, hospitals, and laboratories) (9)
2	A community-based resource database	Interface: Web base and desktop, Connectivity: Internet Feature: monitoring community-based resources. Device: laptop and PDA	Community Disaster Information System (CDIS) 1. Database records: information on community-based resources. 2. Employs the standard classification system basic needs 3. searching and viewing information in disaster situations (10)
3	Geospatial Based Adolescent Reproductive Health Disaster Alert Information	Interface: Web base, android base, Connectivity: Internet Feature Alert Information System for Adolescent Reproductive Health. GPS, GIS, Device: laptop and smartphone.	Design of Geospatial Based Disaster Alert Information System for Adolescent Reproductive Health. Database**:** - Location, logistics, health workers, target, healthcare facilities, safe points. -Reports: location point, logistics on target, service on time (11)
	Theme: During Disaster		
1	Patient tracking	Interface: Tailored software, Desktop. Connectivity: Internet, 3G, GPS, PAN, standard tags IEEE 802.11, barcode, and smart triage tags. Feature: GPS and RFID mobile phones for patient tracking Device: PC, Laptop, PDA, tablet, smartphone	Model of natural disaster patient tracking system: Minimum data set : location, demographic, physical description requirements, medical and its additional information (12) Components of secure patient tracking and coordination system: - Central WIISARD server - tracking of victims and updates every time - EMR, Communication Capabilities - Future Security with Radio link encryption (23)
2	Emergency Medical Care Information System	Interface: Tailored software, Desktop. Connectivity: Internet, GPS, PAN, CDMA, VHF Radio, Satellite, standard tags IEEE 802.11, barcode, and smart triage tags. MI Tag, RFID, laser barcode scanner Feature: System monitoring of vital signs in EMR, pulse oximeter, monitoring ABCD disability and exposure. Geolocation Tracking, EHR connect with Hospital, physical medical examination, RFID bracelets in EHR, Read/write zip tagged geotagging in EMR, tracking victim identification. Device: PC, Laptop, PDA, tablet, smartphone	- Design of emergency medical care in the early stages of disasters: Database relational Tables: (Demography, Medical Record, Message Table) (13) - Design of a wireless, quickly deployable, scalable medical device: Networking system, Database and objects, a communications device, an EMR, and an RFID tag, 4.iMOX sensor platform, and Command-center software system (24) - Design of the evacuation assistance system's information-gathering and exchange components (EvacSys): Focuses on capturing information about airways (A), breathing (B), circulation (C), disability/dysfunction (D), and examination/exposure (15) - Prehospital health emergency information system (PHEIS): -Specific emergency and health assessment interoperable workflows -EHR system and SAFE to track suspicious cases and communicate information (16)
	Theme: During Disaster		
			- Design of Incident information system medical module (IISMM): - Relational database , - Physical medical examination data (17) - The framework of EMR and communications technologies: Patient lists, status, and tracking of victims, Command Center (19) - A centralized disaster information system (Triage-service), and Web-based information pages to access (20). - Design of MASCAL: Database, application server, Turn-Over & Registration Applications, Main personnel database, dashboards that integrate relevant data, location of supervisors, patient information, additional staff responders (21)

Table 3: Continued…..

			- The EMS Performance Improvement Toolkits: EMS system response time, The Credentialing Information System (CIS), Vehicles, The State Medical Asset Resource Tracking Tool (SMARTT), The Prehospital Performance Improvement System (PREMIS) (22) - WIISARD First Responder (WFR) handheld wireless devices to electronically record and document patient status, medical care, and disposition on the scene. -Electronic, intelligent patient monitoring devices tracking victim identification -Management systems accessing data and displaying victim, provider, and scene information. -CalMesh nodes, communications infrastructure for the site. -Integrated of EMR software, Barcodes, and scanning. (24)
3	A web GIS of Collection and Analysis of COVID-19 cases system	Interface: Web base, QGIS Connectivity: Internet, Feature: GPS, Geo-tagging, VGI Device: PC, Laptop, tablet, smartphone	Web-based with Internet accessed by mobile devices, tablets, and laptops, with Volunteered (Covid-19 person) VGI.(18)
Theme: Post-Disaster			
1	A Rapid Public Health Needs Assessment Framework	The framework of QGIS SRT, DEM Connectivity: Internet Feature: QuickBird images, Satellite data, Shuttle radar Topography Mission Device: PC	-GIS technology and high-resolution remote sensing images Data -Satellite Data: collect pairs of pre- and post-earthquake QuickBird images to detect the damaged area using a high-resolution commercial satellite -Infectious Disease Incidence Data derived from the national web-based infectious disease surveillance, -Population Data: census data based -Geographic Information Data from Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) estimating earthquake casualties and injures. -Rapid Medical Resource Damage Assessment -Public Health Needs Assessment After an Earthquake -Water Supply Assessment-Risk Assessment of Infectious Disease (25)

Discussion

"Disaster management" refers to all aspects of preparing for and responding to disasters, including pre-and post-disaster operations. It could be used to manage the risks and effects of a disaster, underlining the fact that there are three stages to a disaster: before, during, and after. Therefore, pre-, during-, and post-disaster stages were used to categorize disasters. The stages of a disaster are not distinct entities; they interact and overlap. They do not conflict with one another. Table 3 shows the tables of all the identified designs or frameworks based on the systematic literature review. They are classified into three themes and call stages by the WHO including before, during, and after disaster stages.

DHIS in a pre-Disaster stage.

Proposed design of disaster information management, communication, and decision-making framework

This category contains recommendations and suggestions for developing a disaster management information system (8). Starting from strategy, planning, and flow of information as well as management of information and communication as follows: Strategies and plans starting at the national level down to the regions. Information Flow: from setting data, input data processing to analysis. Disaster Management: from case management, information exchange and communication, decision-making, and preparedness response. This follows the statement of a thorough plan for disaster preparedness that considers the entire society and incorporates all aspects of the health sector. A clear governance structure that can coordinate action across numerous institutions, such as hospitals, emergency services, PHC, public health agencies, pharmacies, nonprofit and community organizations, and supply chain logistics, is necessary to establish such a comprehensive preparedness plan (9). Moreover, a memorandum of agreement between various disaster response stakeholders and staff and community education are some initiatives that could help health organizations respond to disasters better (26). As another operation management recommends, the integration above is used to prepare an information system database. In addition, it also recommends five different information databases for emergency management: demographics, disaster, line managers, hospitals and health facilities, Laboratories, and emergency posts (9).

Community Disaster Information System

This system was developed to support the searching and viewing of information, even in disaster situations, using a web-based information system, 'standalone' software applications for laptops and handheld PDAs, and complete printable directory reports (10). The design includes database entries (names, addresses, online Google maps, phone numbers, website addresses, operating hours, a basic description of services, connections with the Red Cross specifically, languages spoken, and other details about neighborhood-based resources). The standard classification system's basic needs are emergency food (food pantries, specialty food providers), occasional emergency food, drinking water, and formula/baby food.

Information System for supporting disaster management based on a community is important. The three phases in which volunteer communities play a part in disseminating catastrophe information are pre-disaster, emergency response, and post-disaster. Socialization, role-playing, disaster counseling, eradicating false information about catastrophes, etc., are some activities. The volunteer communities work with local opinion leaders and community leaders to effectively interact with the public (27).

Disaster Alert Information System

The development and implementation of Geospatial Based Disaster Alert Information System specifically designed for Adolescent Reproductive Health. This system has a narrower focus on the components related to adolescent reproductive health (11). The design of the information system encompasses several key elements, including the database (Administrator, location, target population, logistic distribution, distribution of health workers, aggregate target, healthcare facilities, logistic packages, and safe points for health workers), health workers (target information, mother health services, child health services, teenager health services, mental health services, HIV/AIDS services, served target, and target location), and stakeholders (reports, public reports, location points, logistics for target areas, and timely service provision).

The system can run by web-based application interface designs and an Android base with the dashboard showing several crucial indications and maps that dynamically track field development. It can be operated on computers and smartphones equipped with a GPS and GIS system using an internet network and all function correctly based on the outcomes of this laboratory trial for a disaster preparedness information system. This will have many benefits for disaster management, especially in terms of integration with the ordinate points provided by the Regional Agency for Disaster Management (BPBD) and community involvement in using applications to improve disaster preparedness and mitigation.

The key to improving catastrophe readiness for an efficient response at all levels in a system like this is reliable, fast, and accurate early warning. Early notification triggers quick action. It helps local governments to carry out prepared evacuations if necessary, protect real estate and sources of income, and give first responders time to be ready and be ready for search and rescue emergency operations (28).

Disaster Health Information system during the disaster stage

Patient tracking

The system is specifically designed for patient tracking and coordination of the technical components of the system for victims of natural disaster (12, 23). System components include the minimum data set (Demographic factors, appearance requirements, medical data, and geographical data). Additional information (medical data, patient demographics, and secondary location data). At the same time, the supporting technologies and features encompass Informatics Technology Tagging, GPS, PAN, a web portal, 3G wireless transmission capabilities for communication, and RFID readers. These elements ensure reliable communication during disaster response, and for future security opportunities. The system utilizes various devices such as laptops, PDAs, and smartphones. Identifying and monitoring victims in natural disasters play a crucial role in collecting valuable data, enabling timely communication, and addressing the medical needs of patients while minimizing duplication of efforts. This critical aspect facilitates the development of disaster response strategies and helps reduce casualties in the affected area (12). The tracking system is crucial in catastrophe scenarios, including identifying and tracking victims of natural disasters, for gathering crucial data and permitting timely communication, it is crucial for the country that this information be categorized and distributed to institutions and health officials (29).

Emergency Medical Care Information System

This information system functions primarily when providing victims assistance or health services during a disaster. These systems are designed to document the condition of victims in an updated manner and document the provision of services or actions in digital or electronic form using various platforms such as web base, tailored software, or desktop applications which operated on devices such as laptops and mobile devices. This documentation is stored in electronic medical records that are easily searchable; data can be accessed, including tracking victim identification. They can be integrated with systems in healthcare facilities such as hospitals (24). The main components of these systems are a database of victim demographics and EMR (13), Airway, Breathing, Circulation, Disability, and Exposure (ABCDE) status (15), and medical modules in assisting victims (17). Stored data and information must be accessible and integrated with other health systems (healthcare facilities, hospitals, or prehospital treatment) (14, 21, 22).

Telecommunications systems used for all systems were internet either through WIFI or cellular networks; besides that, some use other systems as alternatives, namely VHF Radio (13) and Terrestrial Trunked Radios (TETRA) (20), which will be useful if the area is not reached by the internet. Other technologies used include positioning technology to provide information on the victims or helper's position using GPS technology and RF 802.11 Geolocation as an alternative when GPS is not as optimal as indoors. At the same time, other technologies are tagging to store and communicate data using a laser barcode scanner, RFID Zip, labels and bracelets, and intelligent triage tags (ITTs).

A Web GIS of Collection and Analysis of Covid-19 cases system

This system is an open-source web-based GIS information system that focuses on the developing and evaluating VGI during the Covid-19 epidemic. Its purpose is to assess the feasibility of VGI in terms of technological implementation and data protection. (18). It is aligned with utilization of a GIS-based Multi-Criteria Decision Analysis (MCDA) technique the initiative to set up vaccination centers outside of hospitals during the post-Covid-19 pandemic to developed incorporates a scientific and strategic spatial decision support method (30).

Devices that can be used for this system are mobile devices, tablets, and laptops. It uses a web-based platform with an internet connection. System evaluation has been done on VGI (patient with Covid-19). VGI terms reference spatial data produced and shared online by private individuals or unofficial organizations, i.e., regular people using the right means to collect and share their opinions and geographic knowledge (31).

Disaster Health Information system in the post-Disaster stage

Its framework designed for rapid assessments of the public health needs, including 1) estimating casualties and injuries; 2) identifying damaged medical facilities; 3) estimating drinking water needs; 4) identifying areas at risk of disease; and 5) identifying temporary settlement sites with high-resolution remote sensing pictures and GIS technologies (25). Indeed, utilizing GIS has been successfully implemented to support evacuation planning by providing vulnerability analysis and assessing healthcare accessibility (32).

The system's primary component for detecting damage is the data gathering and processing of satellite data sets of pre- and post-earthquake Quick Bird photos. The nationwide web-based infectious disease surveillance was used to gather data on infectious disease incidence. Census information was turned into gridded population data with spatial resolution. Additionally, geographic information is derived from the DEM of SRTM.

Evaluation of this system using Wenchuan earthquake data in China, which had a 77% accuracy estimate and resulted in approximately 288,000 injuries and 96,000 deaths. 82.3% of the current medical facilities suffered severe damage. Every day, 40,000 tons of safe drinking water were required to meet the necessities of life.

Lessons Learned

The trials and evaluation highlighted several issues. Integration with the EHR was unstable due to network fluctuation and latency problems, and the WIFI network's data entry process was delayed by security measures (16). The primary takeaway for software developers developing systems for catastrophic conditions is to design with robustness and resilience, and simplicity is the key to user adoption. When using VGI, data protection, ethical considerations, and legal considerations must be made (18).

Conclusion

A systematic review of the design and components for the disaster health information system achieved consensus including three stages of a disaster, namely pre-disaster, during the disaster, and post-disaster. All the systems have a design or framework starting from strategies and plans, information flow, disaster management, and operation engagement, and involve all stakeholders, including the community.

The components of all systems in disaster management include setting up a disaster early warning system, maintaining a database of all stakeholders, integrating information, and establishing community-based disaster preparedness. Additionally, the systems involve the analyzing, monitoring, and tracking of victims, integration with health facilities, and utilizing various technologies in disaster risk reduction.

It is important for future study in developing DHIS to use the latest technologies that encompass functionality, working principles, and its applications with more accessible devices.

Journalism Ethical consideration

The authors have diligently adhered to all ethical considerations, including plagiarism, misconduct, data fabrication and falsification, double publication and submission, redundancy, and more.

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Conflict of interest

There is no conflict of interest.

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