Geospatial Intelligent Decision Support System Conceptual Framework for Disaster Management in Developing Countries

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Abstract

Today GIS technology is using in different fields for intelligent decisions in disaster management. Many conceptual frameworks for disaster management the first aimed at helping the decision makers. Particularly Intelligent Decision Support System (IDSS) conclude the integration between the real time data expert system and model computations for taking the right decision in the right time. In this paper, the researcher presents a geospatial intelligent decision support system conceptual framework for Disaster Management in developing countries. This conceptual framework can help decision makers to decrease the damage and trapped or injured people in disaster areas. Also, this conceptual framework will support the medical services and save lives in the right time.

Keywords — *Disaster Management, Spatial Decision Support System (SDSS), Spatial Database Management System, geospatial information, mobile decision-making, Geographic Information Systems (GIS)*

I. INTRODUCTION

The components of a typical SDSS include database, a model base, and a user interface. Spatial decision support systems (SDSS) evolved from the decision support systems (DSS) by including the geospatial context. These systems provide the users with a decision-making environment enabling the analysis of geographical information [1]. A SDSS is designed to solve a specific decision problem, or class of similar problems [2]. Geographic information systems (GIS) have been described as generators for SDSS [3]. Also, the development of new communication and information technology means is crucial to increasing competition, improving services and communication between institutions [4].

GIS methods and geo-spatial technologies are being used in all phases of disaster management life cycle. SDSS provide assistance to decision-makers seeking to solve semi-structured decision problems with a geo-spatial component. In recent years, intelligent agent concepts have been applied in decision support systems (DSS) for disaster management. Many limitations presented to the difficulty of manipulating the spatial information with the traditional expert system. So, the purpose of spatial decision support system includes expert system (ES) and geographic information system (GIS) to select the best decision in disaster emergency.

Furthermore, multi-criteria evaluation MCE has been implemented in a mobile decision-making context by many researches for Location Based Services [5, 6, 7].

II. SPATIAL DECISION SUPPORT SYSTEMS (SDSS)

The SDSSs emerged from the combination of the functionality of Geographic Information System (GIS) with the processes and methods of Decision Support Systems (DSS) [8].There are several technologies that can support spatial decisions, such as geographic information system (GIS), expert system (ES) remote sensing (RS) and the DSS [9].

This integration happened, from the limitations that faced by many researchers in using spatial data in decision making. On the other hand, the efficiency of GIS to store and manage geographic data, however, without help in decision making [10].

So, spatial decision support systems (SDSSs) are typically composed of (1) an enabled database system for managing spatial data, (2) a mathematical model or the expertise to assist in predicting the outcomes of decisions and (3) a graphical user interface to display tabular reports to assist in decision making [1,11].

III. DISASTER MANAGEMENT LIFE CYCLE

The UN International Strategy for Disaster Reduction (UNISDR) defines disaster as: "A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources [12]". There are many disaster management life cycles started by the traditional model which contained two phases Pre-Disaster risk- phase and Post-disaster recovery phase. Then Tuscaloosa model that divided disaster management activities into four functional classes: mitigation, preparedness, response, and recovery.

The traditional model contains only two phases: Pre-Disaster risk-reduction model phase and Post-disaster recovery phase. The first stage contains preparation, mitigation, and prevention. The second stage contains response, recovery, and development. It is a trivial model that doesn't consider the moment of which the crisis occurs. Moreover, data integration and decision making is not easily achieved [13].

Tuscaloosa model that divided disaster management activities into four phases as following mitigation, preparedness, response, and recovery as seen in figure1. Using SDSS in the last phases are more importance because these two phases response and recovery helping in saving people and properties also dealing with the disaster in the right time. Using geospatial approach in DSS can be considered for fast deal with the disaster and recover this.

Fig 1: Tuscaloosa model [14]

But Tuscaloosa model needs experienced managers to deal with the disaster and take the right decision. Also needs huge budget to response and recover the disaster in the right time. All the aspects to deal with the disaster must be predefined in advance so when the disaster happened we can take the right decision in the right time.

Moreover, Kelly divided the disaster management cycle into eight phases. He proposed a circular model that reduces the complexity of disasters and also handles the nonlinear nature of disaster events. The ability to learn from actual disasters is the main advantage of this model [15]. As Tuscaloosa model this model needs experienced managers and trained people to deal with the disasters, development and construction then mitigation and warning in the right time. In Kelly's circular model a database for the previous disaster, action, inputs, functions and outputs were available but the managers who will response, deal and recover with the disaster.

Once the event occurs as Figure 2, the initial response involves rescue (hours to days) and relief operations (days to weeks). GIS-based incident command systems and consequence analysis tools help emergency managers in the immediate response phase [16].

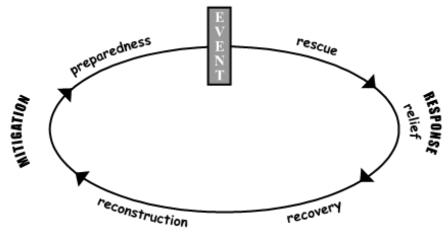

Fig 2: Schematic representation of the emergency response cycle [16].

The disaster management cycle is a conceptual model in which the various stages and activities of disaster management are defined.. In the following model disaster management activities are clustered in pre-disaster (risk assessment, mitigation and prevention, preparedness), emergency activities (warning, rescue and relief operations, damage and needs assessment) and post-disaster (rehabilitation and reconstruction) phases as seen in figure 3 [17].

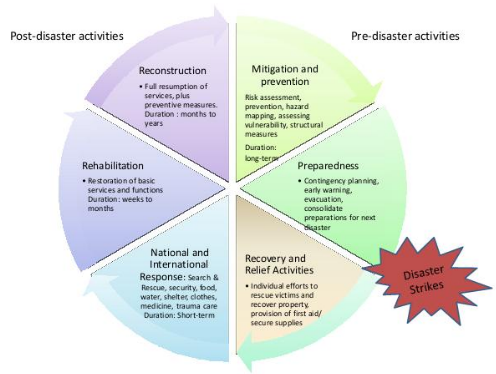

Figure3. Disaster management cycle [17]
Source: prepared for the WG AADA by the SAI of Indonesia

There are many other models for the disaster management life cycle but all these models based on database, trained people and big budget.

IV. USING GEOSPATIAL IDSS IN DISASTERS

Using geospatial and intelligent systems in DSS can assist for take the right action and decisions in the right time also save a lot of lives. Geospatial technology supports in response and recover the disaster. Furthermore, IDSS can help in critical government operations and vital and medical services.

Geospatial information can be benefited in all the stages of disaster management life cycle preparedness, warning, response, recover, mitigation and rescue the disaster areas. The ability to capture events, integrate into enterprise computing platform, apply fast processing, and share live real - world data is a key challenge that distinguish new worlds of intelligence and smartness[18].

Also, According to Aggarwal, the evolution of the DSS may be divided into four generations: the first DSS generation focused on data; the second DSS generation focused on improving the user interface; the third DSS generation focused on models and the fourth, the present-day generation, was obtained by introducing new analytical web-based applications [19]. Moreover, internet/intranets and spatial analysis systems during the mitigation and preparation phases, satellite communications were mainly used during the emergency phase, remote sensing, cellular and radio communications [20].

The aim of a disaster response is to restore normality as quickly as possible, with the initial stage of emergency response being both critical and immensely stressful. The extent of prior warning, and the ways in which this may allow avoidance or controlling actions to be taken are seen to be vital [21]. The initial setting up of a critical control centre, the facilitating of mutual aid between the emergency services, the establishment of a management system, and the formulation of communication structures more widely are all initial elements of such an emergency response[22].

Furthermore, from disaster management perspective, maps enable the location-specific assessment of hazard, risk, vulnerability, and damage. They are required with different levels of geographic detail in terms of disaster management life cycle, from the moment an incident occurs through long -term recovery and into mitigation [23]. Also, The use of GPS (for coordinates), coupled with GIS and remote sensing data have been employed to assist in compiling quick damage estimates [24].

And, Chen et al. present a GIS-based framework that integrates all the elements to do it effectively: a web portal to store information and distribute geographically the available resources, a mobile application that allows the requisition of resources, and a system for automated resource management [25].

The need for up-to-date geo-spatial information determines using some mobile applications to detect the raped people by location based application. These applications can help in disaster management phases such as response and recover. During disaster, the decision makers could benefit from these alerts form the location based application.

In the most recently disasters like tsunamis, many data obtained by volunteers who collected digital spatial data related to some areas which couldn't reach to it due to the popularization of GPS facilitates citizen participation. This data was more updated and live videos in these areas. This Volunteer Geographic Information (VGI) helped in many disasters in the last years. Also the GPS as a tool can help to reach to the isolated areas.

William E. Roper presented examples of the use of remotely sensed data to support disaster management includes [26]:

1) Develop accurate digital terrain models and 3-D surface features as a means for modeling landforms along rights-of-way.
2) Visualize terrain from different perspectives, with the potential for developing threat cones and view sheds.
3) Classify vegetation types along transportation lifelines as a possible deterrent to concealment.
4) Detect, classify, and analyze temporal and spatial changes in surface features.
5) Identify facilities where topography or identifiable hazards (e.g., nuclear, chemical, fuel facilities), place communities at risk.
6) Analyze environmental factors quickly and effectively.
7) Merge real-time sensor output (video, bio-chemical sensors) with archived geospatial data.
8) Identify, characterize, and analyze a wide variety of risks to transportation networks through a gradual program of gathering image intelligence along rights-of-way.
9) Create detailed maps of an area that has suffered attack to assist in response.

As Horita seen, SDSSs have been used to assist in the management of disasters. In parallel, VGI has emerged as an important potential source of data and information to mainly assist phases of response and recovery, in the outcome of disasters. However, to the best of our knowledge, the available literature still lacks studies and research that address the effective integration of these VGI and SDSS to support decision-making in the management of disasters and crisis events [27].

The integration of Geographic Information Systems (GIS) and Artificial Intelligence (AI) will assist decision-making process special for disaster management. World has witnessed the soaring use of Artificial Intelligence (AI) for operations management (OM) with the purpose of decision support [28].

From the previous, we can see that Geospatial and intelligent systems play a critical role in all phases of disaster management. Geospatial solutions like remote sensing and mobile applications help to determine natural disaster, the impact of this disaster and learn for the future in all phases of disaster management. There are many new remote sensing tools, positioning systems and geospatial information can assist to rapid recovery and assessment in this disaster. Also the web based GIS, Volunteer Geographic Information (VGI) and some mobile applications that are based on GPS can assist for rapid response. Moreover the use of Artificial Intelligence (AI) can play a vital role to improve the disaster management, assessment and recovery.

V. USING GEOSPATIAL IDSS IN DISASTERS IN DEVELOPING COUNTRIES

In developing counties, there are many factors high population growth, intense urbanization and in crowded and disorderly occupation promote the presence of high-density populations in risk areas, which may be responsible for the increase in natural disasters [29]. Also in many developing countries the population resides in rural area rather than in urban areas. Therefore decision-makers require efficient GIS tools that will assist in the natural disasters.

There are many previous studies presented the adoption to the geospatial information and wireless technologies to assist in the disaster management in many developing countries such as Ghana , India, Philippines and Pakistan. But the use of SDSS is still limited in developing countries.

As Zimin Zhang and Qi Li presented infrastructure service platform for digital city in China. This infrastructure makes resources from different organizations necessary to decision making, for example, data and models, are able to be integrated into the system easily. As a result, with little difficulty, the DSS can be extended to give supports to new emergencies. This digital city infrastructure service platform (CyberSIG) that is developed as a underpinning system for digital city enables the sharing of resources of multiple organizations, and therefore provides a well framework described above for emergency DSS. The DSS is composed of a decision support subsystem and three systems of CyberSIG, spatial database management system (SDMS), CyberSIG service bus (CSB) and integrated simulation modeling system (ISMS) as seen in figure 4[30].

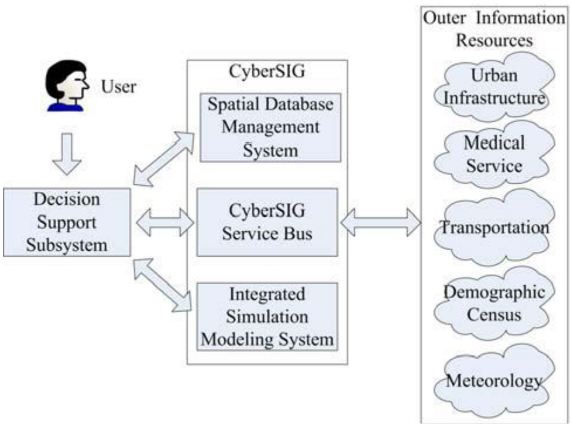

Fig 4: Digital City Infrastructure Service Platform (CyberSIG) [30]

Also, Mohamad Dbouk et al. are designed system to deal with abnormal activities ranging from simple car accidents up to complex actions like terrorist attacks. It combines and inter - operates, for this purpose, heterogeneous standalone pre-existing operational systems; e.g. banks, hospitals, cellular and landline phone management engines, customs, police-stations, video surveillance networks, etc as seen in figure 5[31].

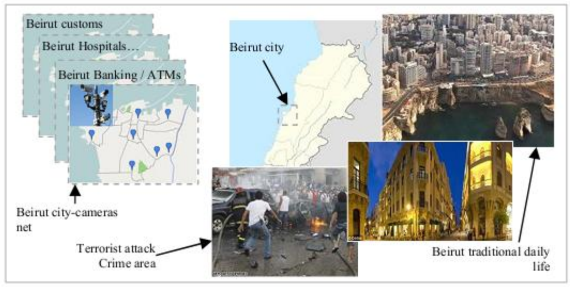

Fig 5: Typical city activities, case of Beirut -city, Lebanon [31]

From these previous, SDSS models that presented in different developing countries the suitability of using geospatial systems and DSS technology in developing countries is helped to face many challenges in disaster management. Also the use of cellar phones and wireless technologies assisted many developing countries to recover many disasters.

VI. GEOSPATIAL INTELLIGENT DECISION SUPPORT SYSTEM CONCEPTUAL FRAMEWORK FOR DISASTER MANAGEMENT

The main objective of this paper is developing a geospatial intelligent decision support system conceptual framework. This framework is divided into multiple components. It contained the integration of data warehouse, geospatial intelligent decision support system and user interface with the phases in the disaster management life cycle. These components worked on multidimensional to improve the disaster management and provide up to date information at the right time when requested during disaster management.

The data warehouse is divided into two repositories the historical data repository and geospatial data repository that implements in preparedness and warning phases. The historical data repository is contained population data, environment data, disaster data and demographic data. And, the geospatial data repository is contained digital maps, satellite maps and volunteers data that using video and images sequences.

The second component is the geospatial intelligent decision support system. The business intelligent that uses intelligent techniques can assist in decision support system. Geographical information system helps to store, maintain, visualize, simplify and analyse geospatial data. The geospatial IDSS can help in pre-disaster and post-disaster phases. The pre-disaster contains warning, mitigation and prevention. Also, for the post disaster contains response, recover, development and reconstruction.

Therefore, the geospatial IDSS provides historical, current and predictive views, the functions of geospatial IDSS are reporting, online analytical processing, analytics, data mining, process mining, complex event processing, disaster management, and predictive analytics during and after disasters. Also, spatial analysis and mapping functionality are included into the geospatial IDSS.

The last component is the user interface through mobile applications and the websites. The user interface depends on the mobile communications within mobile devices, applications, and wireless networks. So the user interface concept is mobile communication from any place at any time by users.

The use of mobile applications and the web services-based decision support system developed through Integrating GIS, global positioning system (GPS) and general station mobile (GSM) technologies. The geospatial information are available through mobile mapping systems and internet services send by the volunteers and active users to rapidly acquire detailed geospatial. So, Mobile application and web service-based spatial DSS (SDSS) will assist decision makers.

Specially, in developing countries this geospatial intelligent decision support system conceptual framework for disaster management can assist to save lives, reduce properties damage, and learn for the future to help in prediction of the disasters. That will help managers in the decision-making process of sections and various levels of disaster management. In order to view data related to disaster planning, response, and recovery through websites and mobile applications to fully understand disaster impacts and support decision-making.

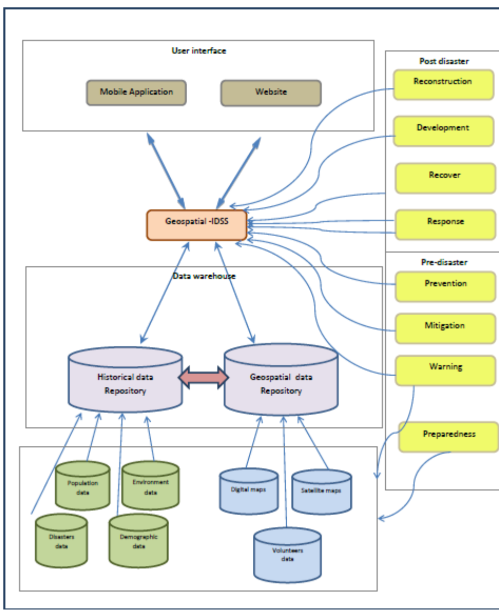

Fig 6: Geospatial Intelligent Decision Support System Conceptual framework for disaster management

This geospatial intelligent decision support system conceptual framework can help in dynamic monitoring, increasing of communication links, fast access of data, data collection and integration, automated data processing and communication for decision makers.

VII. CONCLUSION

The lack of up-to-date geo-spatial information and many limitations presented the difficulty of manipulating the spatial information with the traditional systems to plan, recover and predict specially in disasters. The SDSS and intelligent systems can play a vital role in all phases in the disaster management. There is also the need to share rapidly up to date information for long in order to take actions.

Therefore, this paper recommends the geospatial intelligent decision support system conceptual framework for disaster management in developing countries. So it will increase the diffusion of spatial technologies and intelligent systems in disaster planning and recovery. It's desired to use the geospatial intelligent decision support system to predict the disaster in advance in order to take the right decision in the right time. There for this conceptual framework can provide decision makers direct decision support to make right decisions that can save lives, reduce properties damage, and learn for the future to help in predicting of disasters. So, we can prevent lives and properties to be loss and disruption of social and economic environment caused by the disasters especially in poor communities.

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