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An Empirical Study on the Challenges of GIS Application to Emergency Management in South Sudan

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Abstract

South Sudan gained independence from Sudan in 2011. Since 2013 the country then plunged into a civil war that has displaced thousands both internally and externally across borders to neighboring countries. This has created a large-scale humanitarian crisis that still continues to ravage the new nation. The United Nations and other Humanitarian organizations continue to play a leading role in responding to this humanitarian crisis with the goal of alleviating the suffering of the afflicted civilian population and bring an end to the conflict. Through the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA), the United Nations (UN) has established several response mechanisms to ensure a comprehensive response. Information Technology is playing a crucial role through the extensive use of Geographic Information Systems (GIS) for information management, mapping and cartography and data modelling. The purpose of this study is to explore the challenges limiting the application and utilization of GIS for planning, decision support and response in the context of post-independence South Sudan.

The study applies qualitative methods to a purposively selected sample population of individuals working in the humanitarian, Relief and Rehabilitation areas in South Sudan from both the Governmental and Non-Governmental sectors. The findings of this study highlight the major challenges faced by GIS application and practice categorized into: Feature dataset issues, Training and Capacity issues, Technology and infrastructure, Political and Security, and Advocacy challenges.

Keywords*: Geographic Information Systems (GIS), Disaster Management, Emergency Management, South Sudan.*

Introduction

"*The use of geographic information in decision-making tends to go unnoticed, but it is actually present in many of our daily activities.*" -Pucha-Cofrep et al, 2018. Today, vehicles are equipped with Global Positioning System (GPS) applications to guide drivers about which routes to use either based on distance or traffic intensity etc. Modern taxi companies also have GPS applications that clients download and use to hail taxis. These applications enable both the client to input their locations and destinations while on the other hand enabling the taxi drivers to know the location of the clients and where they are destined and therefore make decisions on whether to take the trip or not. This process involves acquiring geographic data, storing the data, analyzing the data and subsequently making decision based on the analysis -When computers do this type of analysis or decision making, it is usually done through what is known as GIS"

Definition

Like the field of geography, the term Geographic Information System (GIS) is hard to define. It represents the integration of many subject areas. Accordingly, there is no absolutely agreed upon definition of a GIS (deMers, 1997). Below are some of the more widely acceptable definitions.

Environmental Systems Research Institute (ESRI) has previously defined GIS as *"A geographic information system (GIS) is a* *framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations helping users make smarter decisions."*

The National Centre for Geographic Information and Analysis (NCGIA) defined GIS as *"a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modelling, representation and display of georeferenced data to solve complex problems regarding planning and management of resources."*

Components

From the definitions above, it can be understood that a GIS comprises of several components that collectively form the system. This therefore implies that the absence of any of this functional component would either render the system dysfunctional or deprives it of the ability to be called a GIS. Figure 1. illustrates the key components and functionalities of a GIS.

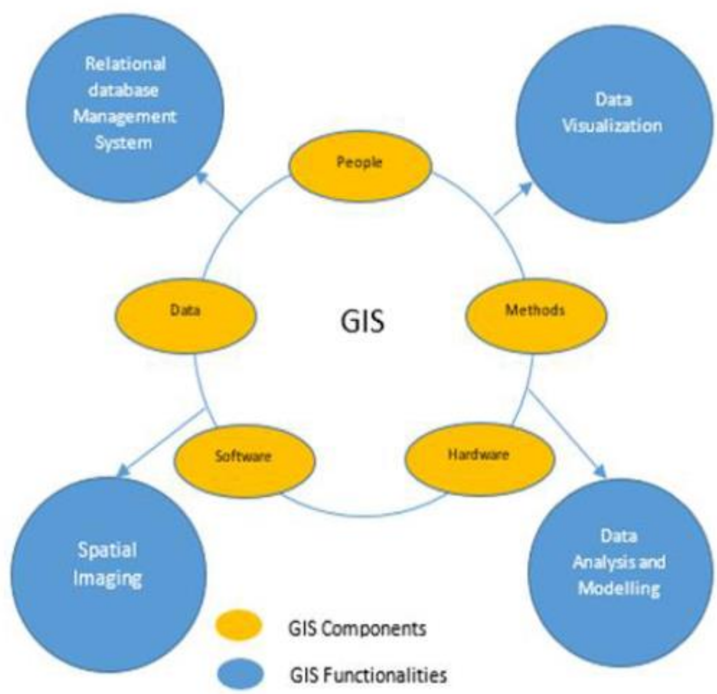

Figure 1. Key components and functionalities of a GIS

The key components of GIS are therefore:

- Hardware: This is the computers and connection devices on which the GIS software runs. These are usually in the form of laptops, desktops, mainframe & mainframe computers, and a variety of network devices.
- Software: This is the coded programs that provide the system the ability to store, manage, analyze, model and visualize the geospatial data. Software includes Relational Database Management system (RDBMS), Data Analysis procedures, Data Modelling procedures, and Data Visualization procedures.
- Data: GIS mainly handles and manipulates spatial or georeferenced data. However, it also has the capacity to integrate other forms of data from the RDBMS for purposes of presentation full information relevant for decision making.
- People: This is the human component of GIS. They represent the expertise required to

operate, maintain the system as well as those who use the system outputs in the dispensation of their work. This component encompasses IT technical experts, geographers, database experts, information specialists, graphics specialists, data analyst and various decision who ultimately use the GIS output information to make life saving decisions and interventions.

- Methods: These represent the procedures and rules that govern the way and purpose for which the GIS is used. GIS has plenty of applications in various spheres of human activity. Some of these applications include but are not limited to weather forecast, environmental monitoring, disaster and emergency management and business marketing.

Emergency management

Definition

The term "Emergency Management" is also often times used interchangeably with "Disaster Management". For purposes of this article the two terms will be used interchangeably to mean the same thing. The US Federal Emergency Management Agency (FEMA) defines Emergency Management as *"the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters."*

Disaster is a source of danger whose evaluation encompasses three elements: risk of personal harm, risk of property and risk of environmental damage, and the acceptability of the level and grade of risk (Kovach 1995; Smith 1996). Hazard is the probability or chance of that hazard posed actually happening. Hazard is the potential (Smith, 1996) and disaster is the actual event (Drabek, 1997).

Risk is combination of likelihood and impact i.e. the probability of a hazard actuating and the impact it would have on the community and the environment. Consequently, risk can be reduced by preparing a suitable risk management strategy. Risk Management is a process consisting of well-defined steps, which when taken in sequence, support better decision making by providing greater insight into risks and their impact (Sai Global 2003). Risk management is important in protecting the community and environment, providing better information to support decisions, enabling better asset management and monitoring, and improving the perception of the community about risks (Abdalla & Esmail 2019).

Emergencies usually stem from disasters and turn into crises. Crises if not well managed usually have a high potential of resulting into other crises. While the most common disasters result from natural causes like earthquakes, fires, tornadoes, floods etc., many disasters and therefore emergencies are man-made. All disasters irrespective of their nature most often result in the loss of human lives, livelihood, animals, property and sometimes extensive damage to the environment. Disasters can be predictable or unpredictable, and their impact can be small scale or large scale, short term or long term. The goal of "Emergency Management" therefore is to determine the risk and to reduce its impact to the minimum possible.

The emergency management cycle

Figure2 depicts a four-stage emergency management cycle developed by the Federal Emergency Management Agency (FEMA). This model has been widely accepted and used in emergency management worldwide. The FEMA emergency cycle comprises of four stages: Mitigation, Preparedness, Response, Recovery.

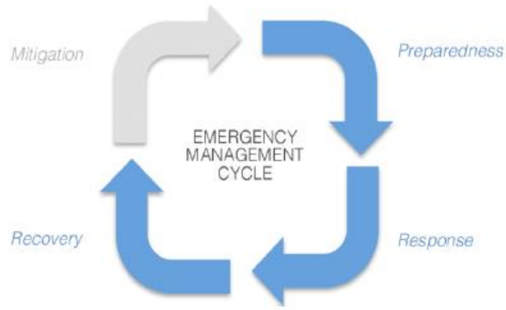

Figure.2. Emergency management cycle (Adopted from FEMA)

Emergency mitigation

This stage involves all actions and activities taken to either prevent the occurrence of a disaster or reduce the impact and consequences in the event of the disaster. Examples might include building dikes or flood barriers in case of floods, building bunkers in case of ballistic attacks, insurance policies to protect against losses etc.

Emergency preparedness

Beyond mitigation, the community must be prepared for the worst. This stage therefore involves all activities that would prepare the community to accept and deal with the disaster when it happens. This usually involves, creating business continuity plans, performing drills and exercises, prepositioning necessary supplies e.g. food, medicines etc., identifying emergency access and exit routes, educating the community on what to do or where to go or how to reach out for help etc.

Emergency response

Response occurs in the immediate aftermath of a disaster. During this stage community life and business are disrupted and all activities are mainly emergency and lifesaving. The length and effectiveness of the response is largely dependent on how well the preparedness stage was done. Activities involved in this stage are mainly activation of the business continuity plans, search and rescue missions, ensuring public and personal safety, and ensuring essential supplies like food and medicines are accessible to the community.

Emergency recovery

Recovery usually follows the response stage. There is, however, no clear-cut timeline between the two stage. Oftentimes the two stages happen concurrently once the initial response is completed. This stage often involves clearing of debris, reconstruction of damaged structures and infrastructure, provision of psycho-socio support to the afflicted communities, economic support to help businesses rebuild etc.

Frameworks for disaster management

The Sendai framework for disaster management was setup by the UN in March 2015, and is a non-binding agreement for UN member states. It is meant to provide guidelines at local, national, regional and international levels for understanding and reducing risk. The overarching goal being a "a substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries" - UNISDR, 2016.

The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) is the primary UN organization designated for promoting space-based information for disaster management. The organization is directly bound to the Sendai Framework and is responsible for providing support to countries based on the priorities expressed in the Framework.

Literature review

GIS continues to gain recognition from Disaster Management practitioners and academic researchers in the field of Disaster Management (Tomaszewski, B. et al., 2015). Plenty of literature has been written on the use of GIS disaster and emergency management. GIS technology has encompassed almost all aspects of disaster management in all its four stages. In terms of where and what GIS technology can solve, Chris Ferner, a Disaster Response Technology Specialist from ESRI, thinks, *"Just about anything that has a 'where' can be collected and information can be shared. It can be used for everything from mapping locations of endangered frog species, to understanding the migration of languages spoken across the world. For natural disasters, it can help us see where the people who need food and water are to where our resources and first responders are being sent. Where isn't mapping technology applicable?"* – adopted from ESRI.

Map-based representations of disaster situations created via GIS are becoming crucial for supporting spatial thinking and maintaining situation awareness and common operating picture (Tomaszewski B. et al., 2015). Therefore, GIS applications in disaster management are progressively turning into a necessary component of disaster management in many parts of the world. Many studies have also highlighted the criticality of timely and accurate information in a disaster management operation. The spatial dimension of geospatial data makes it exceptionally critical for decision makers in the different phases of emergency management operations (Abdalla & Esmail, 2019).

The temporal nature of disasters does not allow policy makers and planners to have the right information at the ideal time to enable them respond and act appropriately and in a timely manner. Therefore, modelled disaster scenarios are used to derive preparedness as well as response measures (Becerra-Fernandez et al, 2008). According to Montoya-Morales (2002), most current tools used for disaster management focus on the temporal component of the four phases of disaster management, leaving an obvious gap in dealing with the spatial element (Abdalla & Esmail, 2019).

Several writers have also dueled on the topic of remote sensing techniques, GIS and GNSS as frequently used tools in disaster management applications for pre- and post-disaster activities. Pre-disaster applications are associated with mitigation and preparedness activities. Mitigation refers to the activities that reduce the vulnerability of a society to the impact of a disaster while Preparedness refers to activities that facilitate preparation for response to a disaster in case it occurs (Mansourian, 2005). According to Abdallah & Esmail (2019), GIS techniques are commonly used to analyze remote sensed data, enabling situation awareness, process comprehension and the identification of relationships between variables. The integration of GIS, Remote sensing and GNSS data may facilitate the comprehension of climate related disasters, the identification of slope instabilities (regional scale), understanding of geological and geomorphologic controlling factors of seismicity and the effects of earthquakes on ground structure and infrastructure. All this information facilitates the compilation of databases on natural disasters and supports humanitarian relief and disaster management activities (Abdalla & Esmail, 2019).

Methodology

In this study primary data was collected from a purposively selected population sample of 11 respondents of varying expertise and experience in the fields of GIS, humanitarian response and Information management. Data was collected through questionnaires sent out to a population of 38 purposively selected respondents out of which 11 responses were received. Since the study concerns itself with identifying the challenges of GIS application to Emergency Management in South Sudan, the research universe was limited to Non-Governmental Organizations (NGOs), the United Nations (UN), Universities and pertinent government departments working in the two fields of Humanitarian action and Disaster Management in South Sudan.

The study used the narrative data analysis method to analyze the data collected. This analysis involved the following steps (Manu Bhatia, 2018):

- Getting familiar with the data: The researcher read through the data to decipher basic observations and patterns.
- Revisiting research objectives: the researcher revisited the research questions to see if they can be answered through the collected data.
- Developing a framework: This step involved coding or indexing, where by the researcher identified broad ideas and concepts and coding them. Coding is helpful in structuring and labeling the data.
- Identifying patterns and connections: Once the data was coded, the researcher identified themes, looking for the most common responses to questions, identifying data or patterns that can answer research questions, and finding areas that can be explored further.

Results

Table 1. illustrates the challenges analysis

The study results were summarized into five broad categories as follows:

C1: Dataset issues

- Cost of acquisition.
- Data accuracy issues in the South Sudan context.

C2: Technical capacity and training

- Lack local technical expertise in the field of GIS.
- No GIS Training centers or facilities in the country.
- Need for strengthened and enhanced training and capacity building sectors.

C3: Technological infrastructure

- Under developed national IT infrastructure.
- High cost of the internet bandwidth
- High cost of GIS software licenses
- high performance computer hardware that can adequately handle GIS processing.

C4: Political, governance and security

- Ongoing political unrest vast areas of the country are inaccessible.
- This inaccessibility impedes the accurate enumeration of the population necessary to accurately feed into national datasets for proper analyses and estimations.
- Disagreement on the number of provincial states. This has complicated the determination of substantive level 2 (state) and level 3 (county) political and geographical boundaries.
- GIS governance: challenge of lack of a governing body to promote and provide guiding policies for GIS usage and application as well as lobby for government support in this crucial area.

C5: Awareness and publicity

- Very few people and decision makers are actually aware of the usefulness and benefits of GIS let alone GIS itself.

Discussion

The challenges identified in this study were summarized into 5 broad categories with each category having a unique set of categories as pointed out by the respondents.

1. Feature dataset issues

"*A feature dataset is a collection of related classes that share a common coordinate system. Their primary purpose is for organizing related feature classes into a common dataset for building a topology, a network dataset, a terrain dataset or a geometric network.*" – desktop.arcgis.com

In this category 45.5% of the respondents felt that South Sudan still grapples with huge spatial data gaps. South Sudan, has been largely inaccessible for a long time given the long history of civil war and political unrest. Respondents, therefore, felt that this poses a major challenge on the availability of accurate datasets about South Sudan, to ensure accurate outputs. Another respondent pointed out that the current shape files are from Administrative level 0 to 2 (i.e. Country – State – County). There are no level 3 (payam level) Administrative shapes, where in fact, most of the humanitarian activities are conducted. This poses a challenge to how accurate humanitarian planning and therefore response can be. Some respondents cited the lack of clear administrative boundaries.

Lastly, respondents also pointed out the challenge of the exorbitant license fees to access reliable data sources with up to date data from the various satellite data vendors worldwide.

Overall, this category contributed 16.1% to the challenges based on the responses.

2. Capacity and training issues

72.7% of the respondents in pointed to the dire lack of capacity and training in the field of GIS in South Sudan. This deficiency is majorly attributed to a combination of factors, listed below:

a. Insufficient internal capacity in terms of technical know-how to advance the GIS discipline.

b. Lack of certified training centers offering Professional GIS certifications.

c. GIS as a discipline is not offered in any of the five national Universities in South Sudan to qualify a generation of professionals in this field.

d. Inadequate availability of GIS laboratories in the country to enhance GIS application and GIS practice.

e. Lack of nationwide capacity building in the field of GIS.

f. Limited capacity among the government staff.

Overall, this category contributed 25.8% to the challenges based on the responses.

3. Technological infrastructure issues

Technologically, South Sudan still faces huge Information Technology challenges. The nation largely depends on terrestrial internet for access to the world wide web. However, efforts are underway to extend the fiber optic cable from the neighboring country of Uganda to the capital city Juba. Accordingly, 63.6% of the respondents indicated challenges in this category. Among the challenges identified in this category are:

g. Underdeveloped internet infrastructure to support GIS activities. GIS is largely dependent on good and fast internet connectivity to support datasets download / upload and analysis.

h. Lack of access to licensed GIS Software. The high cost of GIS licenses poses a big hindrance to the practice of GIS especially at individual level.

i. Limited access to computer hardware with the appropriate capacity to handle GIS datasets, images, and software to run the complex analyses. This hardware is expensive and therefore is not affordable by a large segment of the South Sudan GIS community.

Overall, this category contributed 22.6% to the challenges based on the responses.

4. Political, governance and security issues

In this category, 45.5% of the respondents indicated that the political and security landscape of the country imposed another set of challenges to the proliferation of GIS in South Sudan. In addition to the inexistence or so of the appropriate government regulatory mechanism for GIS, there is a prolonged political dissent among the political actors in the government and nationwide insecurity. These factors have adversely affected the growth and use of GIS and impacted its accurate application in the humanitarian sector specifically. Additional factors cited include:

j. The nationwide insecurity which hinders humanitarian actors' access to the field locations and therefore affects the data collection and validation operations. This therefore means that to obtain data, remote sensing techniques have to be deployed.

k. Inexistence of a government sanctioned GIS regulatory authority to guide the use and growth of GIS in the country.

l. By default, emanating from point b. above, there is a lack of policies that promote the use of GIS.

m. At independence in 2011, South Sudan was administratively divided into ten (10) states. However, after the political fallout of 2013 which led to a protracted civil war, the country was further subdivided into 32 states. The recent political negotiations to end the civil war and political unrest have experienced arguments on the appropriate number of administrative states, with the opposition advocating for a return to the former 10 states administrative structure. Therefore, the changes in the administrative boundaries (from 10 states to 32 states) still causes confusion among GIS users.

Overall, this category contributed 16.1% to the challenges based on the responses.

5. Advocacy issues

The last category of challenges raised by the respondents in this study is the issue of awareness about GIS. Here 54.5% of the respondents indicated that there's little or no awareness at all about the uses and potential benefits of GIS in South Sudan within the Government sector, private sector and the Non-Governmental sector. Respondents acknowledged the importance of GIS as a Decision Support System but felt that it is absent in the various decision-making mechanisms due to acute lack of awareness and publicity, in South Sudan.

Overall, this category contributed 19.4% to the challenges based on the responses.

Conclusion

The goal of this study was to identify and highlight the challenges faced in application and use of GIS for Emergency and Disaster management in the context of South Sudan. A population sample of 11 respondents was purposively selected and the responses narratively analyzed. The findings were grouped into five categories: Feature datasets, capacity and training, technological infrastructure, political, governance and security and finally Advocacy issues. Respondents were assured of non-disclosure and asked not to include their identities on the questionnaires to ensure confidentiality and encourage openness and candidness in the responses.

Although the study highlighted the major challenges, there were a couple of limitations. Firstly, no responses were received from the NGO respondents despite the fact that they are major actors in the humanitarian response structure in South Sudan. Secondly, out of a targeted population of 38 respondents, only 11 responded to the study questionnaire. Although, this does not significantly affect the findings of the study, it would add weight to the conclusiveness of the study.

In conclusion, plenty of literature has been written about the use of GIS for Emergency and Disaster management, however, there has been none with specific focus on the South Sudan context. The findings of this study therefore a modest addition to this vital area of Emergency and Disaster Management.

Figures and tables

Table 1. Challenges Analysis Table

	Respondents												
Challenge	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	Overall Respondents %age proportion	Overall challenge %age proportion
C1:	1	1						1	1	1		45.5%	16.1%
C2:			1	1	1	1		1	1	1	1	72.7%	25.8%
C3:			1		1	1	1	1		1	1	63.6%	22.6%
C4:	1	1					1		1	1		45.5%	16.1%
C5:			1		1	1	1	1		1		54.5%	19.4%

C1: Feature Datasets issue
C2: Capacity and Training issue
C3: Technological Infrastructure issue
C4: Political, Governance & Security issues
C5: Awareness and Publicity issues

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