GENERAL PERSPECTIVES ON APPLICATION OF DECISION SUPPORT SYSTEM (DSS) FOR METROPOLITAN INTELLIGENT FLOOD MANAGEMENT IN NIGERIA

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ABSTRACT

Climate change has had a great impact on man and his environment. In recent years, climate change has aggravated levels of extreme events such as floods, drought, heat waves, cyclones, hurricanes, tornadoes and wildfires. Though the nature and extent of this impact vary across the globe, no region is immune from the effect of the change. Attempts have been made over the years to address or mitigate the effects. To this end, flood defense has been approached in terms of preparedness, mitigation, response and adaptation to various degrees of success. The measures taken are not only limited to structural but also institutional (knowledge-based and collaboration). The failure of some of these methods is highly attributed to the stochastic nature of the flood phenomenon. To address this, different methods have been adopted to address the menace, among which is the Decision Support System (DSS). The application of DSS entails the decomposition of the distinct the nature of flood phenomenon. In view of this, an attempt was made in this paper to put the application of DSS in perspective considering its general application and robustness for flood study since it is derived from the concept of Artificial Intelligence (AI) System. Generalization of the application of DSS is founded on the concept of intuitive knowledge-based science and engineering, hence its potential for real-time application. The problem associated with the DSS is entrenched in the difficulties in quantifying data, network failure, collection of required data, lack of technological knowledge by the user, information overload, subjectivity, cost of development as well as fear of implementation of new technology by users. Thus, there is a need for a new approach based on AI-DSS that encompasses a language system (problem processing and knowledge base), a functional approach which includes the data, a model dialogue module and a tool-based approach. This basically requires modelling by taking into account the non-crispy nature of the variables.

Key words: Decision Support System, Climate Change, Flood, Intelligent, Metropolitan,

INTRODUCTION

It is no longer news that climate change is one of the serious challenges that the world is facing today. Globally, it has brought about a lot of disasters; human, infrastructural and livestock losses resulting in billions of dollars (Animashaun *et al.,* 2018). Some of these hazards are attributed to the extreme events such as floods, drought, heat waves and cyclones. Floods are among the most devastating natural disasters in the world, claiming more lives and causing more property damage than any other natural phenomenon in most parts of the Western world (Glago, 2020). In Nigeria, though may not be leading in terms of claiming lives, flood affects and displaces more people than any other disaster (Okafor, 2020). It has shattered both the built-environment as well as millions of properties. One prominent feature about it is that it does not discriminate, but marginalizes whosoever refuses to prepare for its occurrence (Adebayo, 2014). Flood risk is now being recognized as a great threat due to climate change in many parts of the world.

Over the years, there have been techniques used for flood control; such methods include the installation of rock berms, rock rip-raps, and sandbags, maintaining normal slopes with vegetation or application of soil cement on steeper slopes and construction or expansion of drainage channels, watershed, open levees and paddy field dams (Matsui, 2023). Despite all the approaches that have been put in place to solve the problem of flooding, a desirable result has not been achieved. This, therefore, necessitates the use of a Decision Support System (DSS) (Sahoo and Sreeja, 2013). DSS is a set of related computer programs and data which are required to assist with analysis and decision-making concerning flooding. DSS has been developed over the years as a virtual planning tool and can address both engineering and non-engineering issues related to flood management (Ahmad and Slobodan, 2021). DSS can assist in selecting suitable flood damage reduction options using an expert system approach, forecasting floods (using say artificial neural networks approach and fuzzy inference system as well as fuzzy control with simulation), modelling the operation of flood control structures, and describing the impacts (area flooded and damage) of floods in time and space.

2. Flood Phenomenon in Perspective

Recent floods and consequences all over the world are becoming too frequent and a threat to sustainable development in human settlements (Aderogba, 2018). Flood is a situation that results when land that is usually dry is covered with water from a river overflowing or heavy rain, it occurs naturally on the flood plains and also occurs when the river overflows its banks as well as from failed structures like dams. It happens without warning but with a surprise package for the unprepared community. Floods are often caused by heavy rainfall, rapid snowmelt or a storm surge from a tropical cyclone or tsunami in coastal areas. Flood can cause widespread devastation, resulting in loss of life and damage to personal property and critical public health infrastructure (Animashaun *et al.,* 2018).

The effects of flooding can be grouped based on causes as flood based on human resources, natural resources, physical resources, monthly income and monetary asset-based (Rufa’i, 2020). There are three common flood types: fluvial also known as river, pluvial or flash and coastal floods, which are often called storm surges (Láng-Ritter et al., 2022). Each type of flood occurs and is forecast in different ways. Etuonovbe (2011) categorised causes of flooding in Nigeria as natural and human: Natural causes include heavy rainfall, Ocean storms and tidal waves usually along the coast, and lack of lakes and silting. However, Human causes may be a result of burst water from main pipes, dam failures, population pressure (especially in the city of Lagos), deforestation (as in Northern part of Nigeria), trespassing on water storm drains (key cause in Southern Nigeria), unplanned urbanization (which is the key cause of urban flooding), poor sewerage management, neglecting warnings from hydrological system data (major cause of 2012 flooding in Nigeria) and lack of flood control measures (especially by government). Floods can occur within a matter of minutes and their effects can be local, impacting a community and can even go beyond a single community, affecting entire river basins and multiple areas (Mohammed *et al.,* 2022)

On the other hand, floods can be classified according to duration and location (NDMC, 2012). Based on the duration of the flood, there is slow-onset flooding, rapid-onset flooding and flash flooding while flooding based on location could be coastal flooding, arroyo’s flooding, river flooding and urban flooding. (Bariweni *et al*., 2012) classified floods as tidal flooding, fluvial flooding, flash flooding, groundwater flooding, pluvial flooding, flooding from sewers, and flooding from man-made infrastructure. Flooding from rivers, particularly, in recognized floodplains, can usually be predicted with good accuracy. However, flash floods from sudden downpours continue to challenge the capability of detection and forecasting systems. Water with a high velocity of flow may carry debris, particularly in urban locations and can also be very cold. Even travelling at low speeds can make it extremely hazardous to people caught in it. Flooding in Nigeria has damaged properties worth over 17 billion USD with Lagos State recording the largest percentage of flooding while Niger, Adamawa, Oyo, Kano and Jigawa states are also experiencing flooding (Nkwunonwo, 2016). Low-lying areas sitting over aquifers may periodically flood as groundwater levels rise. This type of flooding is often seasonal and therefore can be forecasted with good accuracy, it is often slow from its onset. Pluvial flooding or Surface water flooding is caused by rainwater and run-off from urban and rural land with low absorbency. Increased intensity of development in urban areas has given land with a larger proportion of non-permeable surfaces, a problem often exacerbated by overloaded and outdated drainage infrastructure. In the same context, flooding from man-made infrastructure such as canals and dams can fail causing flooding to downstream areas. Industrial activities, water mains and pumping stations can also give rise to flooding due to failure, though this type of flooding is rare. The need to manage flood hazards stems from the observation that flooding in Nigeria has resulted in loss of lives, sources of livelihoods, property and socio-economic infrastructure (Okoye, 2019). Figures 1 (a-d) illustrate the various types of floods and their consequence.

Figure 1: Flood Event Marks (a) Underground Flooding, (b) Flash (c) Fluvial (d) Man Made

3. Flood Management and Decision Support System

Baky *et al.* (2020) studies aim to introduce a new approach to assessing flood risk, which successfully addresses a critical point in flood risk assessment for a given area in terms of intensity and vulnerability. Flood management requires a variety of techniques; this can be structural and/or non-structural. These management techniques embrace approaches like the development of retention and detection point, dykes and barrages or levees, dams, developments of flood early warning systems, real-time modelling and forecasting system, and decision support system inclusive. Earlier studies (e.g., Amadi *et al.,* 2023) mentioned management of the inter operations and interlinks of flood incident sources by the handling agents, design of database report format and communication media for the system automation. The choice of a particular approach is dependent on the nature and types of flood phenomenon. In this regard, both public and private collaboration can come into play.

The success of a particular flood management type can depend on the degree of science-based information available and bureaucracy on the part of the government. For proper mitigation, the extent to which the role of knowledge-based information can be necessary and important cannot be over-emphasized (Cirella and Iyalomhe, 2018). Flood management protocols over time in a country like Nigeria have largely been more reactionary instead of proactive. Though some government agencies like the National Emergency Management Agency (NEMA), the Federal Ministry of Water Resources (FMWR) and recently, the Ministry of Humanitarian and Disaster Management come in handy, the performance of these agencies to a large extent has not yielded the expected results. This could be attributable to a lack of adequate planning and conflict of interest resulting in decisions being taken without appropriate attention to knowledge-based facts. In the midst of all of these, knowledge-based has become necessary considering the stochastic nature of the flood phenomenon (Sahoo and Sreeja, 2013). In light of this, the application of the Decision Support System which takes into cognisance the fuzzy nature of contributing variables of flood development becomes critical.

3.1 Flood Incidence, Management and Control in Nigeria

3.1.1 Snapshot of flood incidence in Nigeria: As a result of urbanization and the increase in human population, which is the main reason for the settlement and development of floodplains. Natural characteristics, human interventions and activities in river basins influence the amplitude, frequency, duration and impact of floods. Climate change has the potential to exacerbate flood problems in many regions around the world due to its effects on precipitation volume and timing (Animashaun *et al.,* 2023). Population and economic growth are the dominant drivers behind observed increases in flood damage (Etuonovbe, 2011). Table 1 shows a detailed analysis of flood occurrences and the damages attributes based on the state in Nigeria as well as the numbers of people affected which resulted in the loss of life and properties in Nigeria. Table 2 shows that a total of 103 floods were experienced in Nigeria between 2011 to 2020. The recorded flood could be associated with a flash flood or fluvial flood. Table 3 shows the monetary values of the flood in Africa as a whole and the percentage contribution (15.08%) of Nigeria to flooding.

Table 1: Flood occurrences and damages in Nigeria

S/No	State	Associated Hazards	People Affected	Date
1	Abia	Houses and other Buildings destroyed	500	Jul-01
2	Adamawa	Houses and Farmlands destroyed	500	April, 2001

3	Akwa Ibom	367 houses were washed away	4000	Mar-01
4	Bauchi	Houses and Farmlands Destroyed	Not recorded	August, 1988
5	Bayelsa	Houses /Buildings Farmlands submerged	Two third of the Population	1999 and 2001
6	Borno	Houses and Farmlands destroyed	Not recorded	1988, July 2001
7	Delta	Houses, Schools, Markets, Farmlands submerged	Half of the population	Mar-01
8	Edo	560 Houses Destroyed	820	March, 2001
9	Ekiti	Public Schools and 890 Houses destroyed	2100	April, 2001
10	Imo	100 houses, electric poles and Oil pam destroyed	Over 10,000	April, 2001
11	Jigawa	Houses, Farmlands and animals destroyed	35,500 in 1988,450,150 2001	1988, April 2001
12	Kano	Schools, Houses, Farmlands and animals	300,000 in 1988 and 20,445 in 2001	1988, April, 2001
13	Kogi	Houses Schools and Farmlands	1500 displaced	May-01
14	Lagos	Houses destroyed; market submerged	Over 300, 000	1970s till date (annually)
15	Niger	Houses, School and Farmland	200,000 displaced	1999/ 2000
16	Ondo	Houses and Schools destroyed	800 Affected	Apr-01
17	Osun	Houses and Schools destroyed	1700 Affected	Apr-01
18	Oyo	500 Houses and properties destroyed	50,000 affected	1948,1963, 1978,1980 1985,1987 and 1990
19	Taraba	80 houses swept totally and 410 houses destroyed	More than 50, 000 displaced	Aug-05
20	Sokoto	Deaths Houses and Farmlands destroyed	130,000 People	September, 2010
21	Yobe	Houses and Farmlands Submerged animals affected	100,000 affected	Sep-01
22	Zamfara	Buildings submerged and farmlands destroyed	12,398 affected	Jul-01

Source: Etuonovbe, (2011)

Table 2: Summary of numbers of flood occurrences by states in Nigeria 2011–2020.

State (Zone)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Abia			1				1				2
Adamawa		1			1						2
AkwaIbom							1			1	2
Anambra		1			1			1			3
Bauchi		1	1		1			1			4
Bayelsa							2				2
Benue		1			1						2
Borno									2		2
Cross River		1									1
Delta					1			1	1		3
Ebonyi		1	1				1				3
Edo			1				1	1			3
Ekiti							1				1
Enugu							1				1
Gombe		1	1		1						3
Imo	1										1
Jigawa		1	1		1	1			2	1	7
Kaduna		1			1						2
Kano	1	1	1		1				2		6
Katsina	1	1	1		1			1			5
Kebbi		1	1		1		1			1	5
Kogi							1	1	1		3
Kwara							1			2	3
Lagos	2	1					1				4
Nasarawa		1									1
Niger		1			1		1	2	1	1	8
Ogun								1			1
Ondo					1			1			2
Osun							1				1
Oyo	1			1			1				3
Plateau		1					1				2
Sokoto					1		1			1	3
Taraba		1			1				1		3
Yobe		1			1			1	2		6
Zamfara			1		1					1	3
FCT								1		1	2
Total	6	18	10	1	17	1	17	12	12	9	103

Source: Umar and Alison, (2022)

Table 2: Summary of flood impact in Nigeria and for Africa as a whole for the years 2011–2020

Year	Number of People affected		Value of damages ('000 US$)		Numbers of Deaths	
	Nigeria (% contribution in Africa)	Africa	Nigeria (% contribution in Africa)	Africa	Nigeria (% contribution in Africa)	Africa
2011	30,915 -2.19	1,414,579	4,500 -0.45	1,006,500	174 -25.89	672
2012	7,000,867 -75.26	9,302,672	500,000 -49.45	1,011,115	363 -42.81	848
2013	81,506 -3.48	2,345,261	—	147,024	19 -2.59	735
2014	10,000 -1.05	948,522	—	126,000	15 -3.02	496
2015	100,420 -3.99	2,519,490	25,000 -5.46	458,000	53 -6.4	828
2016	12,000 -0.88	1,369,507	—	295,700	18 -1.91	943
2017	10,500 -0.66	1,595,141	—	12,000	20 -5.67	353
2018	1,938,204 -56.09	3,455,250	275,000 -35.8	768,100	300 -40.43	742
2019	123,640 -2.74	4,516,338	—	57,100	36 -3.94	914
2020	193,725 -2.95	6,575,132	100,000 -22.52	444,000	189 -14.09	1,341
Total	**9,501,777** -27.91	**34,041,892**	**904,500** -20.91	**4,325,539**	**1,187** -15.08	7,872

Source: Umar and Alison, (2022)

Figures 2 (a) and (b) show that there is an increase in the occurrence of floods in Nigeria as in Africa as a whole showing the extent of life that has been lost and the number of people affected by the flood. Over 1,600 people lost their lives in Nigeria alone as a result of flooding.

3.1.2 Management of flood and control in Nigeria: The management and control of flood in Nigeria can be classified into two categories or forms namely; (i) General Contextual Flood management and (ii) Structural and Non-structural strategy. Figure 3 below illustrates the general scheme of flood management globally and in Nigeria specifically.

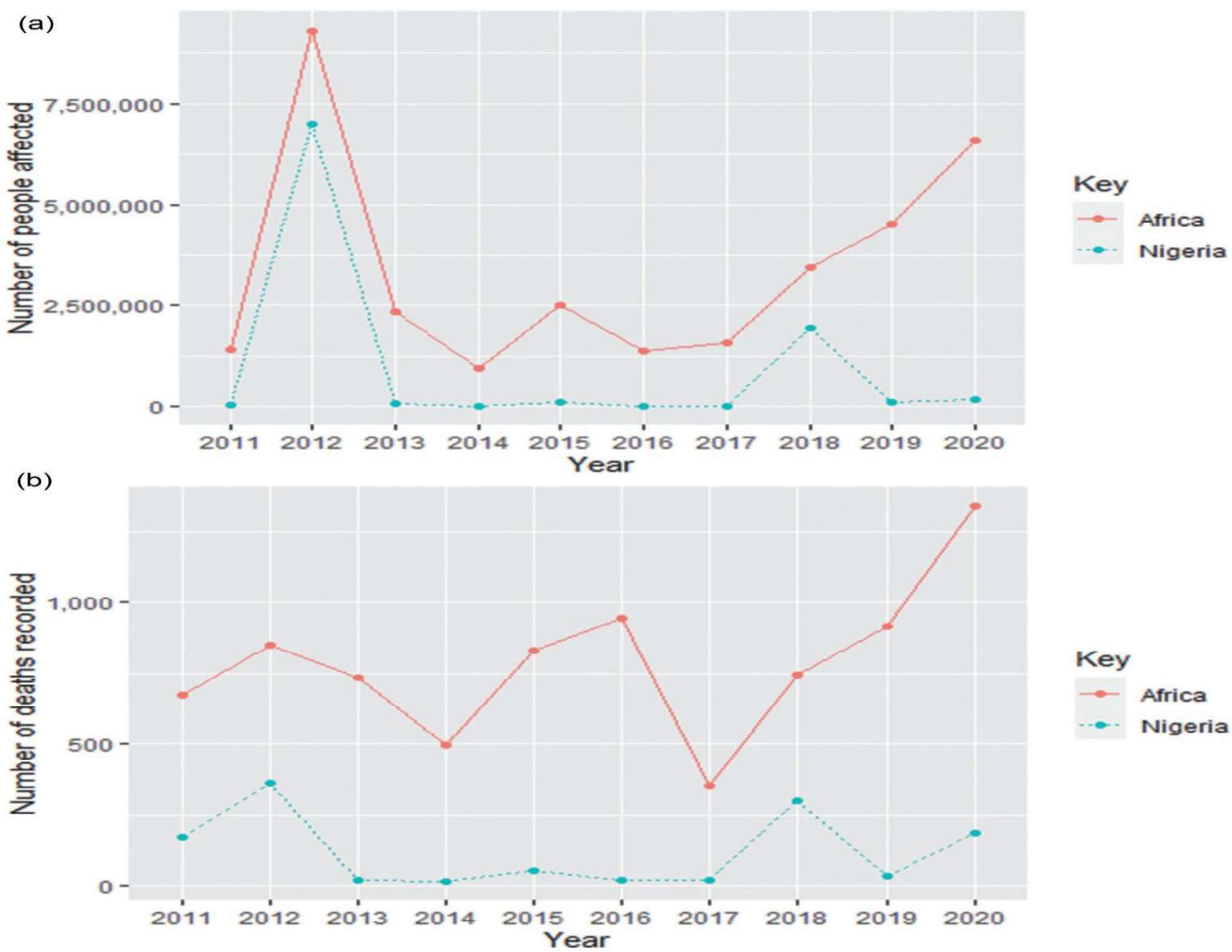

Figure 2 (a) Flood affected person (b) Death in Nigeria and Africa Between 2021 – 2020

Source: (Umar & Alison, May 2022)

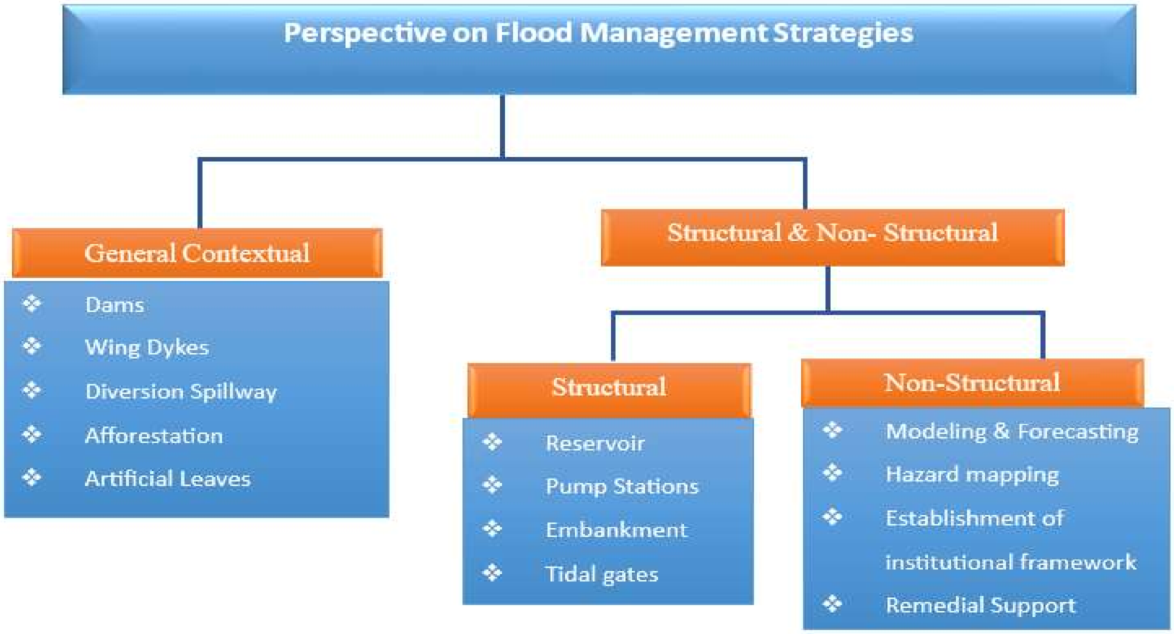

Figure 3: Forms of flood management Strategies in Nigeria.

i. Contextual forms of flood management strategy

The general contextual flood management strategy is used to minimise or prevent the detrimental effects of floods. This method physically restrains water flows and is effective at managing floods. Examples include the building of dams, dykes, diversion spillways, afforestation and artificial levees

ii. Structural and Non-Structural Strategy

(a) **The structural Strategy: This** approach includes keeping water away from the population, for flood hazard reduction, measures include, levees, weirs, seawalls, reservoirs, pump stations, embankments, tidal gates and diversion channels (Chan, *et al.,* 2022).

(b) **Non-Structural Strategy: This** involves the use of human activities such as modelling and forecasting to accommodate the flood hazard through the development of an early warning system, vulnerability and risk assessments, inundation and hazard mapping, the establishment of institutional frameworks like Actionable policy plans, the establishment of agencies or ministries, inter-agency and governmental collaborations and remedial support systems. This approach is easy to implement over a short period of time and is relatively simple and cost-effective (Chan, *et al.,* 2022).

In the midst of all of these, risk management is also taken into cognisance through the establishment of flood control measures. Flood risk management aims at preventing losses and damages by preventing flooding and/or by preventing the exposure of people and property to flooding. The notion of flood risk reduction largely depends on the amount of available information and regional knowledge affecting ongoing events (Cirella *et al.,* 2018). The risk management includes lowering the probability of flooding as well as reducing the vulnerability of the society in flood-prone areas. Consequently, flood risk management may involve a large number of measures; for example, flood defence measures, flood control measures, and also spatial planning and measures aimed at lowering the vulnerability of people and property (Chan, *et al.,* 2022; Cirella *et al.,* 2018; Agbonkhese *et al.,* 2014). This is because single-measure management approaches do not take advantage of the way that various measures can reinforce each other. This concept is illustrated by the schematic diagram below (Figure 4). When the goal of all these elements has been analysed and quantified in objective terms, the results ('risk metrics') can be evaluated in normative terms:

Figure 4: Schematic of general flood management system.

The analysis of flood hazard focuses on the characteristics of all possible floods, small and frequent as well as big and rare. This means there is the need to establish the probability and magnitude of all floods, by investigating the probability distribution of floods of different magnitudes at a particular location taking cognisance of the geographical extent of the flood depth and duration of the flood and the velocity of the flood water. To determine these characteristics, there is a need to use knowledge of floods in the past, but for rare events, this may not suffice and the circumstances – for example, the floodplain area – may have changed (Cirella *et al.,* 2018; Chan *et al.,* 2020). Therefore, it is necessary to investigate the probabilities and magnitudes of all possible floods for effective planning.

3.2 Application of Decision Support System for flood control

Decision Support System helps the decision-makers recognise problems and then formulate supporting data for problem analysis and then the action to facilitate one or all phases (Sozer *et al.,* 2018). DSS is a computerised management advisory system that provides decision-makers with timely management of data by drawing upon databases, models, and dialogue systems (Grigg, 1996). The classical definition of a Decision Support System, by Keen *et al.* (1978) states that "Decision Support Systems couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions. DSS is an interactive system that provides the user with easy access to decision models and data in order to support semi-structured and unstructured decision-making tasks" (Robert, *et. al.,*1984; Rashidi *et al.,* 2018). However, as pointed out by Turban *et al.* (2005), the aspects of support and improvement have been copiously ignored totally or treated with levity. Despite this though, it is imperative to note that DSS provides an efficient planning platform for knowledge-based management activities.

4. Associated Nuances and probable recourse for effective adoption of DSS for metropolitan intelligent flood control

Despite the extensive application of the DSS, in particular flood control, its general adoption has been a round success. This is due to issues that have been mentioned in earlier studies (Muste and Ali, 2016) and the issue includes: (i) Difficulty in Quantifying all data: Basically, the Decision Support system relies on quantifiable data, therefore it is difficult to analyse indefinable data. (ii) Assumptions: Many Users of the Decision Support System are not aware of the assumption that a decision support system has considered when analysing data for certain analyses. Making certain decisions about flooding without considering the factors that cannot be proven is dangerous; in these cases, both tangible and intangible ones. (iii) Network failure: For a web-based decision system, telecommunication networks can have issues due to some technical glitches, and this may lead to an inability in the use the portal at such a material given time. (iv) Difficult in collecting all the required data: Often time, most of the data inputted in the database are not real-time data, as such they are missing data which may be interpolated or extrapolated as the case may be with a high degree of uncertainties in such. (v) Lack of technological knowledge by the user: Many decision support users lack the technical know-how to effectively use the system. (vi) Information Overload: Oftentimes the database (for example MySQLi, that is PHPmyadmin) might be clumsy and the system will be left in a dilemma on what to consider and what not to consider in making a decision. (vii) Devaluation of subjectivity: A decision support system promotes objectivity and rejects subjectivity because of the condition applied in building the logic system (i.e., the algorithm of the "if and only if" statements) which is the conditional statement. (viii) Cost of Development: Some decision support system picks real-time data and the cost of buying sensors to transmit this real-time information to the database is relatively high, thereby increasing the cost of developing the whole process. (ix) Fear of implementation of New Technology: New innovation can be scary for many users and as such acceptance and adoption become issues. The fear of undergoing training in addition towards providing functional skills and the fear of the unknown regarding the implementation of such a new approach.

Though the decision support system is effective, its general efficiency can be mired by the issues stated for metropolitan intelligent flood control in Nigeria. Its application can be effective through the following;

i. **Intelligent decision support approach**: This architecture was developed according to the objectives and properties of sustainable water resource decision-making. It takes advantage of combining two architectures (Computer-based system that uses data, expert knowledge and model for supporting decision-makers) This approach can be routinely modified; the proficiency of this approach is attested to by Simonovic (2021)

The intelligent decision support concept links four basic elements of water resource decision-making: (a) Engineering expertise; (b) A systems approach; (c) GIS; and (d) Artificial Intelligence (AI).

In this environment, the computer is seen as a link between the field expert and the decision-maker, between science and policy. Therefore, the Decision Support System is not only a tool for analysis, but an instrument for communication, training, forecasting, and experimentation. The major strength of this concept is that the products are application and problem-oriented rather than methodology-oriented. In this way, Artificial Intelligence (AI) technology through expert systems, neural nets, fuzzy reasoning, and evolutionary programming is combined with more classical techniques of engineering analysis, data processing and systems analysis.

ii. **Functional approach**: This approach distinguishes three components, which differ according to their functions. The components are: (a) The language system; (b) The problem-processing system; and (c) The knowledge system. The approach does not explicitly represent modelling or data retrieval functions. The user states a problem using the language system, and the system responds by starting the problem processing system and looking up specific information in the knowledge system

iii. Tool-based approach: The main components of the tool-based approach are: (a) The database; (b) The model base; and (c) The dialogue module. A tool-based approach is more general than a functional approach. The Main components support the data retrieval, modelling, and model variables. Tasks such as problem processing or knowledge representation are not included in the model base or the dialogue module.

5. CONCLUSION

Flood control and management are essential today especially in light of global warming with its attendant effects. Though natural hazards such as floods cannot be readily prevented, reference against their deleterious impacts is possible. This can be achieved through preparedness, mitigation, response and adaptation. The partial attainment of this can only be feasible through knowledge-based approaches like the DSS. It provides a platform for real-time data collection and information dissemination for prompt action. Basically, the decision support system has enhanced modelling and forecasting through the development of early warning systems, vulnerability and risk assessments, inundation and hazard mapping and remedial support systems.

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