Leveraging Intelligent Decision Support System to Promote Inclusive Remote Teaching and Learning in Institutions of Higher Education in East Africa: Prototype Development

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Abstract

The need for an intelligent system to support the decision-making process on remote teaching and learning during pandemics was realized during Covid-19. It was learned that during the pandemic most higher learning institutions could not respond as rapidly as the situation manifests to protect academic activities from disruptions. The objective of this paper is to describe the proposed prototype of an intelligent decision support system (IDSS) to inform the current and future remote teaching and learning in East African Higher Education in response to pandemics such as COVID-19. The research adopted the design science research approach to analysis, design, and development of the prototype. The development was preceded by understanding the situation where Strengths, Weaknesses, Opportunities, and Challenges (SWOCs) were analyzed. From the analysis, the requirements for the system were identified. Three stages were followed to develop the prototype. First, the development of a web interface or landing website, then designing the prototype framework with stakeholders' evaluation and actual development of the prototype. The SWOC analyses showed varying enabling environments within institutions in a country and between institutions in East Africa. Inadequate policy and legal and regulatory provisions for a rapid switch to remote teaching and learning during the pandemic were compounded by inadequate infrastructure, trained human resources, and organized rapid decision-making. Based on these findings, a prototype framework was then designed to support the decision-making on remote teaching and learning amid the pandemic in East Africa. The preliminary evaluation of the framework suggests that the system has great prospects to inform the decision-making process in the wake of pandemics thereby achieving the rapidity and efficiency of decisions. Further development and evaluation are ongoing.

Keywords: *Decision Support System, Intelligent System, Higher Learning Institution, Remote Learning, Covid-19, DSS Prototype, Decision Making Model*

1. Introduction

Higher Learning Institutions (HLIs) in East Africa suffered during the COVID-19 outbreak like many other similar educational entities worldwide. Evidence shows that the Covid-19 pandemic, which disrupted most of the world systems from the last quarter of 2019, sped up digital transformation and technologies (McKinsey, 2020; EU, 2022, WHO, 2020a, UNHABITAT, 2020, Bud et al., 2020). HLIs were among the educational entities that were compromised by the onset and prevalence of Covid-19. The disruption resulted in a variety of responses from institutions and countries. Some countries locked down HLI functions by closing the institutions; others allowed partial continuations, while others did not close their institutions. Despite the varying responses to HLIs, Covid-19 acted as a catalyst of digital innovations and technologies (Kativhu, 2021) that

enabled the continuation of core business functions in remote environments or as per the health guidelines (WHO, 2020b).

There were both induced and organic push and pull toward the blended mode of teaching and learning, accelerating digital innovative and technological solutions (Mukolo & Brian, 2021; McKinsey, 2020; Kativhu, 2021). The push for digital innovations and technologies was a response to fill a gap created by COVID-19 restrictions, including lockdowns (Gamede, Ajani, & Afolabi, 2022; Mahmud, 2021; Peace, 2021; Koh, 2020; Li & Lalani, 2020; Scull, et al, 2020; Tumwesige, 2020). On the other hand, the pull was a demand from HLIs' stakeholders to sustain the business processes. These processes included the provision of educational services amid several prevention measures such as mask-wearing in public indoor spaces, distancing from one another, avoiding crowded gatherings, socializing outdoors, avoiding close contact with sick persons, and even total lockdown (WHO, 2022; NCIRD, 2022, GoK, 2020). During the pandemic, most HLIs could not respond as rapidly as the situation manifested, leading to an inability to protect academic business processes from total disruption. The decision-making processes were slow due to inadequate data, inappropriate data processing tools, and insufficient information. HLIs needed an intelligent tool to simplify the decision-making process while providing quality results. These results provided reliable options and mechanisms to guide the selection of the best option on time. The tool would enhance decision-making thereby sustaining critical business processes during future disruptions to ensure continuity of teaching and learning. In addition, the tool is designed to perform without compromising the institutional mandates, existing policies, and legal and regulatory frameworks.

This paper describes the processes followed to develop an Intelligent Decision Support System (IDSS) prototype that promotes inclusive remote learning and teaching in East African Higher Education.

2. Materials and Methods

The study utilized a Design Science Research Methodology (DSRM) while utilizing qualitative data. The DSRM was selected as it provided a rigorous process for developing a robust decision support system. The research was conducted at eight academic institutions located in Kenya and Tanzania. The institutions in Kenya included Africa Nazarene University (ANU), Kenyatta University (KU), Maseno University, and Riara University. The universities in Tanzania were the University of Dodoma (UDOM), Open University (OUT), the State University of Zanzibar (SUZA), and Aga Khan University (AKU).

A pilot test of the data collection instruments was conducted at Daystar University and Multimedia University (MMU) in Kenya, and St John's University, and the University of Dar es Salam (UDSM in Tanzania (Figure 1).

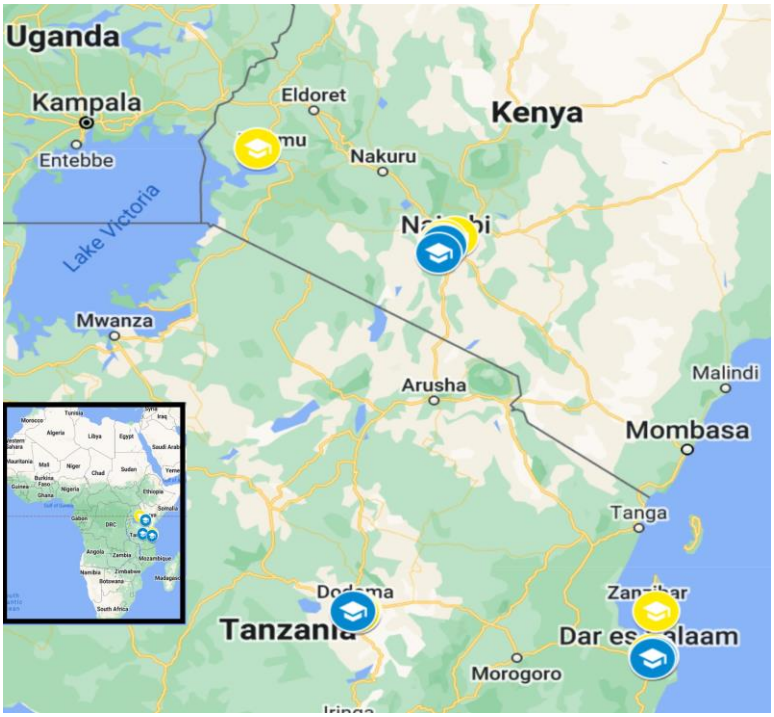

Figure 1: Location of the Study Sites

(Detailed location of the study sites: https://tinyurl.com/idss4)

In addition, baseline data was collected from stakeholders within the Ministry of Education in Kenya and Tanzania. Data was collected through interviews, focus groups, questionnaires, and desktop research. Moreover, policy documents adopted by various institutions were reviewed. Collected data from Tanzania was transcribed from Kiswahili and later translated into English. Thematic analysis was conducted on the data to retrieve common themes across both countries. Further, a strengths, weaknesses, opportunities, and challenges (SWOC) analysis was carried out. Results from the SWOC were used to complement the requirements for the initial prototype development of the intelligent decision support system. Figure 2 shows the context diagram of the IDSS system.

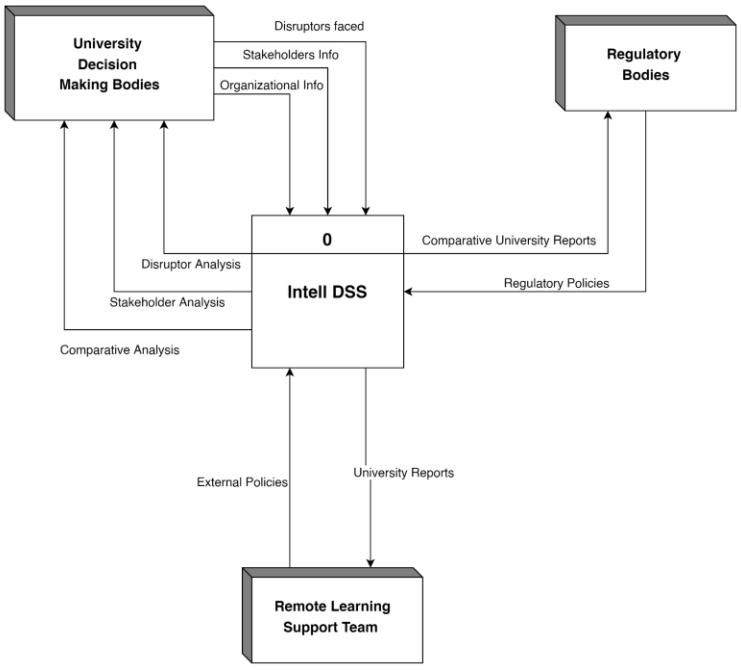

Figure 2: Context Diagram for the IDSS system

IDSS prototypes were developed along with a website that provides the basic information about the project as well as a gateway to the system. Before embarking on prototyping, a decision making model was developed, tested and adopted. The decision making was customized to universities within Tanzania and Kenya. The initial design thinking model was a rational model that did not factor the various decision making groups within a higher institution. This first model was presented to stakeholders alongside the first prototype during a workshop in Tanzania in July 2022. The prototype and the decision making model was analyzed during the workshop, and stakeholders provided rich feedback.

This feedback informed the subsequent prototype and decision making model design. An agile iterative decision making model was proposed as the subsequent prototypes were developed. This updated version was presented during a stakeholder dissemination workshop held in Kenya in November 2022. Both workshops attracted stakeholders from participating institutions; higher education policymakers and regulators; and the media. During the workshop in Kenya, the prototype was rigorously tested, and the stakeholders provided further feedback. The feedback informed several iteration processes in improving the prototype versions. The presentation within this paper focuses on the two prototypes developed and tested during the dissemination workshops.

3. Preliminary Results and Discussions

3.1 The Requirements Analysis

The SWOC analysis reviewed three (3) main sections: Policy and regulatory provisions, the decision-making processes, and the facilitation of learning and teaching. First, there was a

distinction between Kenya and Tanzania regarding government regulatory provisions. At the time of research, the first distinction was the existence of a government policy specific to using information and communication technology (ICT) for online or blended learning. Kenya's Commission of University Education (CUE), in its 2014 policy framework, issued a directive requiring adherence to quality learning and teaching for any online or blended courses. Tanzania's Commission of Universities (TCU) only had a policy framework in 2022 through its Guidelines for Online and Blended Delivery Modes of Courses framework. However, for both policy frameworks, there is a deafening silence about the adherence to quality learning and teaching specific to remote learning. The project team contends that any policy or regulatory framework should provide how the marginalized, through a lack of access to connectivity or digital devices, can participate in the learning process and how their participation should be catered for. This provision should inform support that will allow remote access, and this may include what government partnerships can be galvanized to ensure increased access.

Regarding policies by and for universities, the SWOC analysis exposed that all Kenyan Universities within the study relied on CUE's 2014 policy framework, with ANU developing a more directed framework to enforce quality online and blended learning and teaching. Two (2) of the four (4) Tanzanian universities have personal frameworks for online and blended learning. Again, no provisions supported remote learning and teaching for all developed university policy frameworks. The SWOC analyses showed varying enabling environments within institutions in a country and between institutions in East Africa. Inadequate policy and legal and regulatory provisions for a rapid switch to remote teaching and learning during the pandemic were compounded by inadequate infrastructure, untrained human resources, and non-existent infrastructure to support rapid decision-making. Based on these findings, a prototype framework was designed to support rapid decision-making specific to remote teaching and learning for disruptions similar to the COVID-19 pandemic.

Specific to the system's build, the team used the FURPs Model (Nakajo et al., 1989; Abubaker et al., 2015) to determine system and user requirements. FURPs Model refers to the following: - Functionality, Usability, Reliability, Performance, and Security. With more time, the research team would have used the fuller version of the model, FURPS+. Instead, these requirements were extrapolated from the data collected.

Functionality: These requirements speak to both functional and non-functional requirements. For the functional requirements, the research team determined the system activities and what information would be managed. The functional requirements identified included: -

i. Account Registration;
ii. User login;
iii. Forgot password;
iv. Create, edit or delete a Disruption Project;
v. View the defined project;
vi. Create, edit, or delete organizational information;

vii. Determine decision period;
viii. Determine if there are external entities that need to ratify the decision made;
ix. Create, edit, or delete the organization's stakeholders;
x. Definition of the organization's stakeholders Power Interest categories;
xi. Definition and categorization of the disruption;
xii. Collating policy documents associated with the decision that needs to be made, if they exist.

A dashboard to help visualize the disruption such that an analysis has been done and alternatives specific to the defined disruption are clearly highlighted

As for the non-functional requirements of the system, these will be clearly articulated once the system is launched and the team is able to document system efficiency as it pertains to the response time.

Usability: Refers to the operational characteristics related to users. The research team ran two stakeholder sessions to ensure aspects specific to the use of the system, such as the user interface, navigation, clarity of instruction, aesthetics, and ease of use, to name but a few, were considered, and all appropriate feedback was incorporated. To better support this requirement, a User Manual will be provided.

Reliability: This speaks to how dependable the system is and the risk of a system's crash. Software-as-a-Service (SaaS) cloud options were used to mitigate any risks associated with reliability. In addition, the system's database was built using cloud resources, implying the ability to scale depending on the number of people accessing the system, thus reducing the likelihood of a system's crash and ensuring an almost immediate system response.

Performance Requirements: As indicated above, using SaaS cloud computing options to support the build will ensure high information throughput and near-immediate system response, regardless of the user's bandwidth.

Security Requirements: This team used the Secure Software Development Lifecycle to ensure system security. During system implementation the following aspects were considered:-

- Passwords: Encryption using Bcrypt and the rehashing of weak passwords.
- Routes: Route filters were applied to allow only authenticated users access, thereby protecting the routes.
- Guards: Authenticated users are assigned specific resources depending on their user level.
- CSRF Tokens: CSRF protection by the use of tokens for all forms built and for validation on each form submitted.
- Authentication Drivers: The use of database and eloquent authentication drivers.

Further to the above, during implementation, there have been multiple code reviews and threat modeling. As for system vulnerability assessment, the research team will be carrying out penetration testing in addition to constant monitoring.

The team used an agile methodology that facilitated the development of a website and two prototype versions. Agile methodology was selected due to its incremental and iterative strategy to design implementation, as it allows for testing, stakeholder feedback and error corrections. Within the following sections, we will review the website where the prototypes can be accessed, the decision-making model and the prototype development.

3.2 The Website

The project website (https://www.inteldss.org/) was developed to share the information about the project as well as providing the gateway to the IDSS. The website contains the basic pages including Home Page, About the Project, User Interface with Login Page and Contact Us Page (Figure 3)

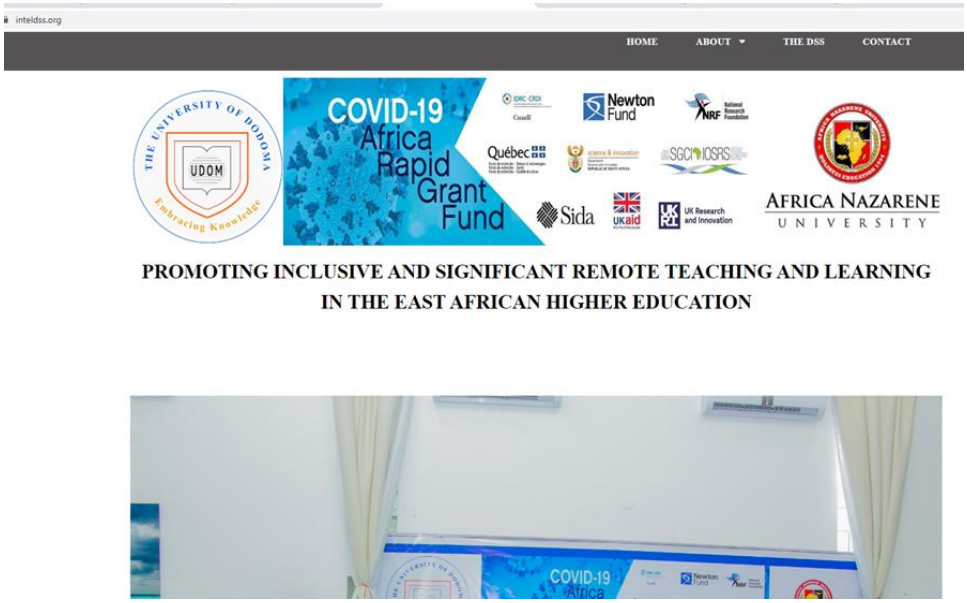

Figure 3: IDSS Website

3.3 The Decision Making Model

Prior to the development of the prototype, a design thinking model was developed that reflected decision making within the universities. Universities within Kenya and Tanzania follow similar decision making structures. An agile iterative decision making model (Figure 4) was developed to create the prototype.

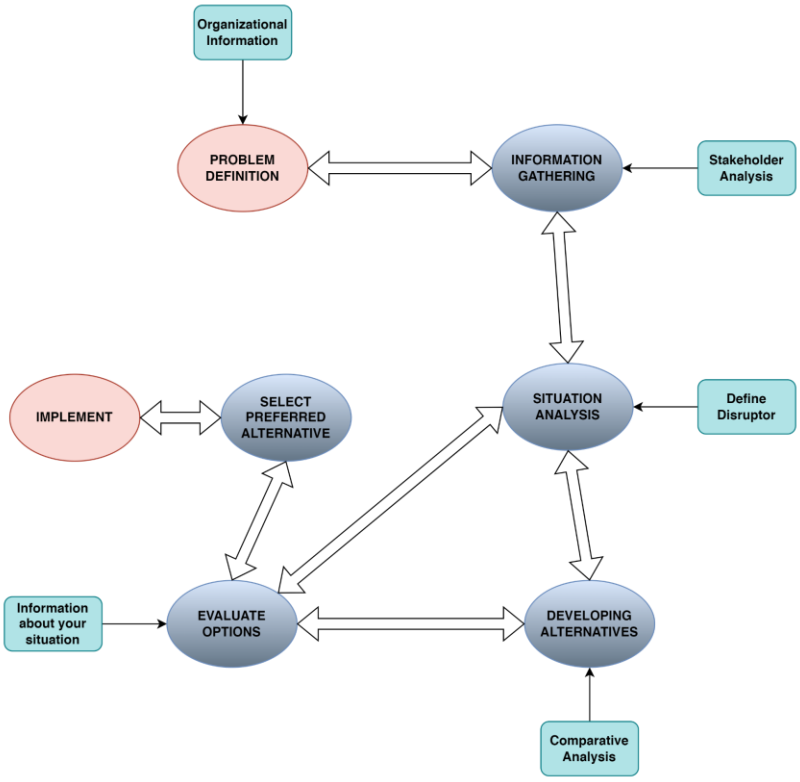

Figure 4: Agile Iterative Decision Making

The agile iterative decision making model stemmed from the need to develop a customised model that works for institutions of higher learning. The model includes five core components fed by various inputs. Information gathering represents the first component. This component is involved with defining the problem which includes gathering relevant organisational information and defining timelines for the decision. In addition, institutions of higher learning will need to factor whom (stakeholders) the decision will inevitably affect. This component then lends to the situation analysis. Based on the problem, the institution needs to define the disruptor and rank it. Depending on the ranking of the disruption, institutions will convene committees to deal with it. The benchmarking process is one of the core decision-making processes used in universities and is represented in the model in which alternatives are developed through a comparative analysis involving other universities.

The options from the comparative analysis are evaluated either by the decision making body or through reviews and a selection of the preferred alternative is selected. The preferred alternative is then presented to the final decision maker, who could then request for a review or implementation. As a whole, the decision making model presented describes how higher education institutions in Kenya and Tanzania generate decisions iteratively. The prototype is modelled after the model as a tool to aid the decision making process.

3.3 The IDSS Prototype

The design of the IDSS incorporated the basic need of any decision support system including the user interface, the dashboard, the databases and backend management. The user interface provides the user with a data collection module including data about the organisation, stakeholders' analysis, disruptors and comparative analysis (Figure 5).

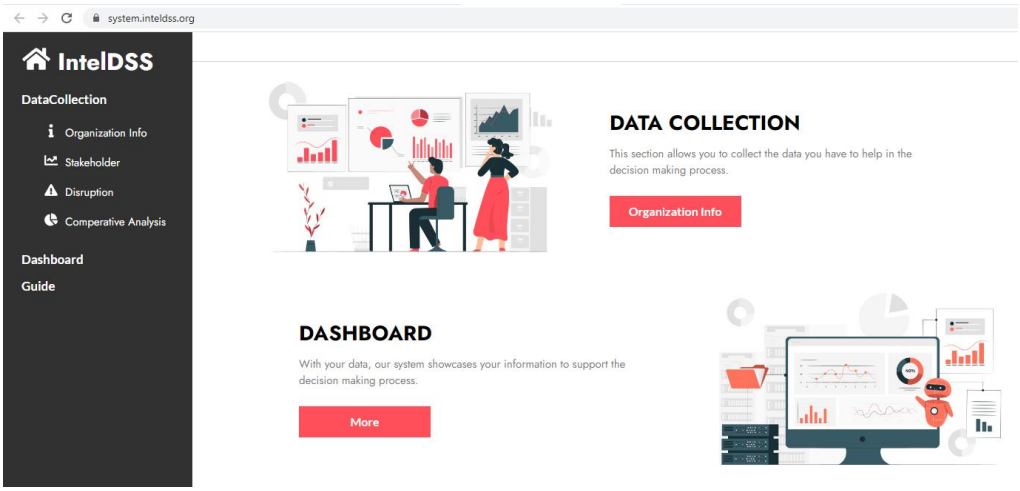

Figure 5: The IDSS Interface to Data Collection and Dashboard

The data points introduced into the system sought to address gaps andas well as supplement existing policy and regulatory frameworks by both government and HEIs. The data points introduced are:

i. About infrastructure,
ii. About capacity,
iii. About access,
iv. About social culture, and
v. About quality learning.

The dashboard provides a summary descriptive analysis of the data collected on organization, stakeholders, disruptors and their comparisons (Figure 5).

The Database provides for data management and knowledge base where the users' data, project data, login details, user management tables and weighing tables are stored (Figure 6).

Finally the admin backend model management is designed to provide, in the future, the content management as well as enhancing the automating some responses via Artificial Intelligence tools.

4. Conclusion and A Way Forward

The preliminary evaluation of the framework suggests that the system has great prospects to inform the decision-making process in the wake of pandemics thereby achieving the rapidity and efficiency of decisions. Proposals and feedback from the stakeholders suggest implementing Artificial Intelligence (AI) as part of the prototype. The AI would be used within the system to provide a comparative analysis of organizations and institutes of higher learning that had faced similar disruptions and provide them with a wide range of decision alternatives during the descriptive analysis. Additionally, the AI would help to trawl through policies uploaded during the situational analysis and give back information during the descriptive analysis. Further development and evaluation are ongoing.

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