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Multi-criteria Decision Support System for Prioritizing Challenges of Internet of Things (IoT)

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Abstract: The adoption and utilization of Internet of Things (IoT) technologies such as IoT Platforms, 5G, connected sensors, WAN, etc mostly come with numerous, seemingly complex and expensive challenges for institutions and organisations, particularly in developing countries as they work to fill their fair share of the global IoT market. Multi-criteria decision support systems (MCDSS) can be indispensable tools for evaluating and prioritizing these complex competing difficulties by multi-stakeholder decision makers. While eliminating conventional decision problems such as, human biases, time consumption, cost of decision, etc, MCDSS make it possible for companies to concentrate on solving challenges which their limited resources can cater for. This study presents an approach for design and implementation of a prototype MCDSS for prioritizing challenges that institutions and organizations face while adopting and utilizing IoT technologies using Fuzzy Analytic Hierarchy Process (FAHP) methodology. ASP.Net model View controller (MVC) framework and C Sharp programming Language was used for the GUI and the Logic development. The system's default IoT challenges and dataset were adapted from the works of A.K. Mohammadzadeh (Baseline dataset). The system usability test result obtained shows that the system is friendly and usable. The output weights and rating of the IoT technology adoption challenges/sub-challenges exhibit over 80% similarity when compared to the Baseline dataset. Further studies are recommended to make the system accommodate infinite challenges dynamically and to improve on the knowledge base of the prototype as well as the GUI themes.

Keyword: Internet of Things (IoT), Decision Support system (DSS), Fuzzy Analytic Hierarchy Process (FAHP). Multi-criteria, multi-criteria decision making, Prioritization, Technology Challenges, IoT Challenges, IoT Difficulties.

I. BACKGROUND TO THE STUDY

This research presents an approach for design and development of multi-criteria decision (MCD) support tool for prioritization of challenges of Internet of Things (IoT). It includes design and development technique adopted in producing and basic testing of a web-based, mobile friendly multi-criteria decision making (MCDM) prototype tool which uses Fuzzy Analytic Hierarchy Process(FAHP) to Prioritize input Challenges of Internet of Things (IoT). The prototype system is expected to be an indispensable tool to be used by Policy makers in IoT, IoT industry experts, researchers, etc. It uses scientific method in identifying most influential IoT challenges on which limited resources should be focused on, thereby accelerating development of IoT in IoT businesses, industries, government institutions, to mention but a few in developing countries. Using this prototype support tool therefore would go a long way in promoting achievement of IoT and industry 4.0 dependent sustainable development goals (SDGs) faster and more efficiently (Akpakwu et al., 2017).

A. Multi-Criteria Decision-Making (MCDM)

Multi-criteria Decision-Making (MCDM) refers to act of making decisions when multiple criteria (or objectives/challenges) need to be considered together in order to rank or choose between alternatives. It provides strong decision making in domains where prioritization of the most influential challenge is highly complex (Jamwal, et al., 2021). Tools which aid decision makers in making efficient and result oriented multi-criteria decisions comprise some Decision Support Systems which includes divergent types of applications. While some decision-making support systems consider the consequences of a choice, others focus only on helping people to define the preferences they made. Nowadays, there are a quiet a number of decision support systems. They are basically clustered in five main categories (Rhazali et al., 2019): communications-driven decision support systems; data-driven decision support systems; document driven decision support systems; knowledge- driven decision support systems and model-driven decision support systems (Maksimovic, 2018). Decision-Making is therefore a wide-scale used technique, that assists us to take the best choice among given alternatives in several and important cases (Ngowi, 2020).

B. The Internet of Things (IoT)

The Internet of Things (IoT) is a system of connected computers, mechanical and digital equipment, objects, animals, or people that may exchange data through a network without anticipating inter-communication between humans or between humans and computers. IoT devices are equipped with sensors, actuators, processors for interconnection. Relevant data is captured by the sensors and actuators which is stored and processed intelligently or shared via network or remote server for further action (Ngowi, 2020). As Industry 4.0 and IoT continue to revolutionise the development and utilization of technologies governments, researchers and a host other decision-making stake holders are faced with numerous challenges of adoption and utilization of IoT at various IoT levels (Jamwal, et al., 2021). These challenges pose big concerns for the growth and development of the Internet of Things, technology growth, socio-economic growth, among others. Overcoming them will be the key to creating true lasting productivity and prosperity through these incredible technologies. Unfortunately, IoT technology adoption and development challenges are mostly too numerous, expensive and complex. These challenges could be of various types depending on the institutions concerned and the IoT level. They include Security challenges, Scalability challenges, Energy consumption challenges, Lack of standardization, Connectivity challenges, Compatibility challenges and a host of others. and expensive to address at a go, hence the need to prioritize the ones to address. It is very pertinent to note that overcoming these myriads of IoT challenges in short range of time and within limited resources is nearly impossible (Oerther, S. E., & Rosa, 2020)XToo many alternative challenges can be detrimental to the process of decision-making (Dursin, 2019) Hence the need to have handy tools that aids in simplifying complex decision-making process while enhancing accuracy. IoT is an important technology area with numerous and complex adoption and development challenges that needs to be addressed in a bid to achieve industry 4.0 and internet of things based sustainable development goals (SDGs) by 2030. By 2025, the IoT's economic impact will be around $11.1 trillion - 14% of today's global GDP - the firm projects (Global, 2015)

Achieving these SDG goals would not come easy as Scientists and industry experts have since established that there are fundamental problem or challenges with the harnessing and utilization of the human and material resources needed for rapid industrial and IoT based growth needed in meeting up with the expectations of the SDGs in most of the developing country(Utoikamanu, 2019). In a bit to overcoming these IoT challenges, Quiet a number of MCDM approaches and frameworks for Prioritizing IoT challenges have been designed in recent years. However, their scope mostly ends up on paper as real-world MCDM support tools that are readily accessible and easy to use are limited in supply for decision makers on IoT challenges. However, support tool for identification of IoT challenges and addressing all the challenges IoT faces and prioritizing them seems absolutely necessary in a quest to meeting up with the SDGs by the year 2030 (Everistus & Emmanuel, 2018). This study propose to develop an IoT challenges prioritization model using Fuzzy Analytic Hierarchy Process (FAHP) MCDM approach, develop a web based, mobile friendly MCDM support prototype tool (System) that uses approach in (1) for Prioritizing challenges of IoT and carry output comparison test of the developed prototype system against result obtained from the works of Mohammadzadeh (baseline dataset).

C. Statement of the Problem

Lots of Multi-criteria Decision Making approaches and frameworks for Prioritizing Challenges of IoT have been designed. They mostly look good on paper. Yet, fully developed, readily accessible, easy to use, real-world IoT challenges prioritization tools are seemingly either limited in supply or too technical to use. Real-world IoT “prioritizers” should be commonly available and easy to use by enterprises, government executives, Industrial experts, decision makers, researcher, etc in to accelerate achievement of SDG by the year 2030. Hence this work attempts to develop a usable prototype system that can be used as a support tool for effective and efficient decision making.

D. Aim and Objectives of the Study

The aim of this study is to design and develop a web-based, Multi-criteria decision (MCD) support prototype system that can be used for prioritizing challenges of adoption and utilization of Internet of Things (IoT) technologies using Fuzzy Analytic Hierarchy Process (FAHP).

The specific objectives are to:

1) Design a web based, MCDM support prototype tool (System) that uses FAHP approach for Prioritizing challenges of IoT.
2) Implement the designed prototype system in (i) above.
3) Test and evaluate the prototype system against result extracted from the baseline dataset.

II. LITERATURE REVIEW

A. Conceptual Review

Decision Support System (DSS)

A decision support system (DSS) is a software application designed to enhance an organization's ability to make informed decisions. This system conducts analysis on substantial volumes of data and provides an organisation with optimal available options. Decision support systems (DSS) integrate data and knowledge from diverse areas and sources to offer users with information that surpasses conventional reports and summaries. The purpose of this is to assist individuals in making well-informed decisions.

B. Components of Decision Support System

A conventional Decision Support System (DSS) is composed of three distinct components, namely a knowledge database, software, and a user interface (Gregg et al., 2002).

1) Knowledge Base

A knowledge base is a fundamental component of a decision support system database, encompassing information derived from both internal and external sources. A subject-specific repository of information, the library is an integral component of a Decision Support System (DSS). It serves as a storage facility for information utilised by the system's reasoning engine to ascertain an appropriate course of action.

2) Software System

The software system consists of model management systems. A model is a computational representation of a real-world system designed to gain insights into its functioning and identify potential areas for enhancement. Organisations employ models to forecast the potential changes in outcomes resulting from various adjustments made to the system.

Models can serve as valuable tools for comprehending intricate systems that are impractical, costly, or hazardous to fully investigate in actuality. The concept underlying computer simulations is their utilisation in scientific research, engineering tests, weather forecasting, and various other applications.

Models can serve the purpose of representing and investigating systems that are not currently in existence, such as a proposed novel technology, a planned manufacturing facility, or the supply chain of a business. Businesses employ models to forecast the consequences of various modifications to a system, such as policies, risks, and regulations, in order to facilitate informed business decision-making.

C. User Interface

The user interface facilitates seamless navigation within the system. The primary objective of the user interface of the decision support system is to facilitate user-friendly manipulation of the stored data (Power & Sharda, 2007). Business entities have the capability to employ the interface in order to assess the efficiency of decision support system (DSS) transactions for the ultimate beneficiaries. DSS interfaces encompass various types, such as straightforward graphical windows, intricate menu-driven interfaces, and text-based command-line interfaces.

D. Types of Decision Support Systems

Decision support systems can be broken down into categories, each based on their primary sources of information.

1) *Data-driven DSS:* A data-driven decision support system (DSS) is a computer programme that utilises data from internal or external databases to inform decision-making processes (Power, 2008). A data-driven decision support system (DSS) commonly employs data mining techniques to identify and analyse trends and patterns, thereby facilitating the prediction of future events. Data-driven decision support systems (DSS) are frequently employed by businesses to facilitate decision-making pertaining to inventory management, sales analysis, and various other operational aspects of the organisation. Certain tools are employed to facilitate decision-making in the public sector, such as forecasting the probability of future criminal conduct.
2) *Model-driven DSS:* Model-driven decision support systems are designed based on a foundational decision model. These systems are tailored to specific user requirements that have been predetermined. Their purpose is to assist in the analysis of various scenarios that align with these requirements (Aqelet al., 2019). A model-driven decision support system (DSS) can be utilised to facilitate tasks such as scheduling or generating financial statements.

3) *Communication-driven and Group DSS:* According to Power et al. (2007), a communication-driven and group decision support system employs diverse communication tools, including email, instant messaging, and voice chat, to facilitate collaborative work on a shared task. The objective of this particular decision support system (DSS) is to enhance collaboration between users and the system, thereby enhancing the overall efficiency and effectiveness of the system.
4) *Knowledge-driven DSS:* The decision support system under consideration is characterised by the presence of a knowledge base, which serves as the primary source of data for the system. This knowledge base is subject to regular updates and maintenance, facilitated by a knowledge management system, as outlined by Shahmoradi et al. (2017). A knowledge-driven decision support system (DSS) offers users information that aligns with a company's business processes and knowledge.
5) *Document-driven DSS:*A document-driven decision support system (DSS) is an information management system that employs documents as a means of retrieving data. According to Abdullah et al. (2020), Document-driven decision support systems (DSS) empower users to conduct searches on webpages or databases, facilitating the retrieval of desired information based on specific search terms. The types of documents that can be accessed by a document-driven Decision Support System (DSS) encompass policies and procedures, meeting minutes, and corporate records.

E. The Internet of Things (IoT)

The concept of interconnected devices can be traced back to the year 1832. The advent of the first electromagnetic telegraph facilitated the establishment of direct communication between two machines via the transmission of electrical signals. However, the history of the Internet of Things can be traced back to the late 1960s when the Internet was first invented. During that time, the concept was commonly referred to as "embedded internet" or "pervasive computing". The aforementioned phrase was initially employed as the title for several presentations pertaining to an ongoing project focused on the development of a novel sensor. Subsequently, it gained popularity and became widely recognised (Gregg et al., 2002).

F. How IoT Works

The Internet of Things (IoT) exhibits vast potential across various industries, surpassing the limited scope of applications such as smart fridges. However, could you please explain the operational mechanisms of the Internet of Things (IoT) and outline the essential elements that constitute a functional IoT system?

The initial requirement entails the utilisation of sensors and devices possessing the capacity to gather, retain, transmit, and receive data. Next, we consider connectivity, which involves the transmission of collected data to other machines. In this context, the internet serves as the predominant and most efficient means of achieving this communication. In the typical scenario, Internet of Things (IoT) sensors and devices establish communication with applications and services hosted in the cloud. This connection is usually established through the public internet, although in certain cases, a private network may be utilised depending on the specific cloud model being employed (Igbinovia, 2021).

The subsequent stage involves the processing of data. After the data has been transferred from the device to the cloud, the installed software can commence its analysis. As an illustration, the data transmitted from the intelligent residential air conditioning system will undergo analysis to verify the conformity of temperature measurements with predetermined acceptable thresholds (Igbinovia, 2021). The true value and benefits of Industrial Internet of Things (IoT) systems and applications are found in the processing of data. This is due to the vast number of devices that transmit data, which can offer crucial and immediate insights into the current condition of the system.

G. Technical Challenges of IoT

The information requirements in developing countries are distinct from those in advanced countries. Internet of Things (IoT) systems intended for implementation in developing countries typically necessitate distinct design requirements and technological frameworks.

According to the report titled "Internet of Things Guidelines for Sustainability" by the World Economic Forum, the maximum impact of the Internet of Things (IoT) in promoting sustainable development is realised when sustainability considerations are incorporated during the design stage of IoT initiatives.

According to Igbinovia (2021), the statement emphasises the importance of prioritising infrastructure solutions as a means to enable business models and facilitate scalability.

1) *Inadequate Research:* In the year 2013, the number of publications in peer-reviewed journals per one million individuals residing in African Least Developed Countries was limited to only 7. Nevertheless, within the member nations of the Organisation for Economic Co-operation and Development, there was an average publication rate of approximately 1,100 scientific and technical journal articles per 1 million individuals (Utoikamanu, 2019). The development impacts of mobile services have been significant in the field of health. Airtel 321 in Malawi offers mobile phone-based information on maternal and child nutrition in the local language. A novel SMS-based application has been developed in Tanzania to enhance the efficiency, cost-effectiveness, and accessibility of the birth registration process for parents. In October 2016, Zipline, a multifaceted company involved in drone manufacturing, logistics services, and public health-care consulting, initiated the utilisation of drones for the purpose of delivering medical supplies to isolated health clinics in Rwanda. The collaboration between Zipline and the Government of Rwanda has significantly decreased the duration required for the transportation of crucial medical supplies. The message conveyed in the Secretary-General's Strategy on New Technologies is presented through a series of principles. These principles provide us with a suitable framework to advance our endeavours and guarantee that the advantages of new technologies are effectively utilised for the purpose of achieving fair and sustainable development. It is imperative to exercise caution and refrain from hastily pursuing the most recent and advanced developments, as this may lead to the marginalisation of certain groups and the potential exclusion of the least developed countries (Daniel, 2018).
2) *Simple and Cost-effective Technology:* In the context of developing countries, where resources are limited, it may be more appropriate to consider simpler and cost-effective solutions. One such solution is the deployment of a dedicated infrastructure for IoT data, utilising Low Power Wide Area Network (LPWAN) technologies. This approach complements the existing infrastructure for voice and human-oriented Internet. (Igbinovia, 2021)LPWANs exhibit technical stability; however, there is a growing disparity between hardware and service providers in the commercial domain (Ciuffoletti, 2018). An alternative approach involves utilising well-established technologies such as Wi-Fi or 3G. From a technical perspective, these two entities have minimal similarities. However, they both possess the fundamental ability to transmit or receive small data fragments, operating solely when necessary. In the initial sub-stream, Walid Balid and his team conduct research on traffic and road surface control utilising a compact device that incorporates various sensors, such as a GPS receiver and an accelerometer (Balid & Refai, 2017). The paper lacks mention of experimental findings or specific information regarding the implementation process for creating the device. The estimated cost of the study is $30, and it originates from the United States.
3) *Lack of Modern Infrastructure:* Developing countries face greater limitations in terms of stable and reliable power supply systems. Similarly, the issue of data centre availability is also observed (Scherf, 2016).
4) *Connectivity:* According to the International Telecommunication Union (ITU) estimation in 2016, approximately seven billion individuals, accounting for 95% of the global population, reside within the coverage area of a mobile network. Based on a report by the Groupe Speciale Mobile Association (GSMA), it was found that in 2014, 63% of individuals in Africa had access to enhanced water supply, while 32% had access to electricity. In comparison, 82% of the population had access to GSM coverage. In rural areas of Africa, the use of GSM/GPRS and 3G/4G networks for IoT devices can be prohibitively expensive (Nique & Opala,). Instead, a more cost-effective approach can be achieved by utilising short-range technologies such as IEEE 802.15.4, which can be implemented through multi-hop routing. Wireless communication devices, known as transmitted-receivers, consume a significant quantity of power within a radio node. Given the substantial power requirements for long-distance transmission, employing multi-hop routing may offer a more energy-efficient alternative to single-hop routing (Wu et al., 2020).
5) *Internet Connectivity:* The establishment of internet connectivity is a crucial factor in facilitating the functionality of the Internet of Things (IoT). The rate of internet adoption in developing nations is on the rise. In the majority of developing nations, the cost of mobile broadband is comparatively lower than that of fixed broadband services. In developed nations, the Internet is utilised by 94% of individuals between the ages of 15 and 24, while in developing countries, this figure stands at 67%. In the least developed countries (LDCs), only 30% of young people in the same age group have access to the Internet. According to Hong et al. (2014), the global population of young people who have access to the internet is estimated to be 830 million. Among this population, it is observed that 320 million individuals, accounting for approximately 39%, reside in China and India.
6) *Power Supply:* In situations where objects are in motion and lack a direct power connection, their intelligent functionality necessitates a self-sustaining energy source to power their operations. However, the provision of a dependable power supply poses a significant obstacle to the implementation of the Internet of Things (IoT) in many developing nations. According to Dasari et al. (2021), solar and wind energy are considered viable solutions to address this challenge.

7) *Lacking Local IoT Expertise:* A significant obstacle faced by developing nations is the scarcity of personnel with technical expertise, which can be attributed to the need for regular maintenance, updates, and functional testing of Internet of Things (IoT) systems (Singh et al., 2020). The prospect also presents a multitude of challenges. In developing nations, the administrative and financial systems are predominantly lacking integration and automation. The utilisation of technology is currently at a low level, and the allocation of resources towards research and development is significantly limited. In the subsequent sections, we will examine the specific challenges related to the Internet of Things (IoT) in developing countries.

H. Review of Related Works

The examination of existing literature demonstrates that numerous authors have made substantial contributions to the advancement of multicriteria decision support systems throughout the years.

One of the relevant studies is titled "Decision Support System for Prioritising Internet of Things Challenges Using Analytic Hierarchy Process (AHP) Method" authored by Putra and Dewi in 2021. The author employs the Analytic Hierarchy Process (AHP) technique to establish a prioritisation of the primary and subordinate challenges associated with Internet of Things (IoT) technologies. The anticipated outcomes of this study are anticipated to assist institutions in allocating their limited resources towards addressing the most impactful challenges of the Internet of Things (IoT). The AHP algorithm yields valuable outcomes for individuals requiring assistance. However, a deficiency that has been observed in this system pertains to the utilisation of the multi-criteria analysis technique. The Analytic Hierarchy Process (AHP) technique has been extensively utilised in multicriteria decision support systems on a global scale. However, it is acknowledged that AHP has limitations in accurately and comprehensively capturing the accurate judgements of decision-makers. According to the study conducted by Achimugu et al. in 2016,

In their study, Mohammadzadeh et al. (2018) introduced the Fuzzy Analytic Network Process (FANP) methodology as a means of prioritising challenges related to the Internet of Things (IoT). This study utilises a comprehensive methodology called fuzzy analytic network process (FANP) to identify and prioritise the key challenges in the development of Internet of Things (IoT) technology in Iran. The aim is to determine the challenges that have the greatest impact on the rapid adoption and prioritisation of IoT in Iran. The approach that was implemented considered several key factors that influence the development of IoT technology. These factors include technological considerations, privacy and security concerns, business-related factors, legal and regulatory challenges, and cultural elements. Additionally, the presence of multiple correlations among the aforementioned classes was also considered. The findings suggest that the challenges related to technology and privacy/security have the greatest impact on the Internet of Things (IoT). Moreover, the sub-factors of "business model," "architecture and design," and "education and training" were ranked as the most significant in terms of consideration.The FANP (Fuzzy Analytic Network Process) is a highly effective and extensively utilised approach for multi-criteria decision analysis that has been widely adopted by researchers worldwide. Nonetheless, the research paper failed to address the development of a practical system that includes a clearly defined user interface, intended for utilisation by decision makers. An effective decision support system should possess a user interface that facilitates input, output, and navigation functions.

In their study, Bhuiyan and Hammad (2023) devised a hybrid multicriteria decision support system with the purpose of identifying the optimal sustainable structural material for the construction of a multistorey building. The researchers utilised the fuzzy analytic hierarchy process (FAHP) methodology to determine the optimal material for constructing multi-story buildings with a focus on sustainability. The technique employed is widely recognised as one of the most frequently utilised approaches for facilitating effective and efficient decision-making processes. While the system is deficient in a knowledge base, which is a crucial component of a Decision Support System (DSS), it does possess a user interface and model management system. This meets one of the requirements outlined in standard DSS25. However, the system is tailored specifically for implementation in the context of building construction, rendering it unsuitable for prioritising challenges related to the adoption of IoT.

The literature reveals that many prioritisation techniques have not been fully applied in real-life situations, as evidenced by the research conducted on the application of Fuzzy Analytic Network Process (FANP) for prioritising challenges related to the Internet of Things. The work does not possess a knowledge base, user interface, and data management system, which are essential components typically found in decision support systems.

III. METHODOLOGY

The study involves using fuzzy analytic hierarchy process (FAHP) analysis technique to develop multi-criteria decision support system for prioritizing IoT technology adoption and development challenges or factors.

A. Benefits of the Proposed Decision Support System

1) *Eliminates Vagueness:* In IoT challenges prioritization results by adopting Fuzzy Analytic Hierarchy Process (FAHP) multi-criteria decision-making analysis technique in its algorithm instead of the Analytic Hierarchy Process (AHP).
2) *Scalable:* The proposed multi-criteria decision analysis Fuzzy Analytic Hierarchy Process (FAHP) that would be used in the system being developed would address the scalability challenges discussed in section 2.3 in chapter two.
3) *Fully Implemented Decision Support System:* The proposed system implements a standard decision support system with the user interface, Knowledge base and software system as discussed in section 2.1.3.20. This presents a real-world decision support system with user interface that the end user uses to navigate the system.

- The MCDSS has the ability to add new projects, IoT challenges and sub-challenges, users Prieto, etc. User inputs are always validated at all given scenarios.
- It saves cost – With the proposed MCDSS, data is saved and maintained in centralized database which are readily accessible.
- It saves time – End users of the MCDSS are able to create, search or edit projects by using few mouse clicks within stipulated time.

B. Requirement Analysis of the MCDSS

Requirement analysis is divided into two which are functional requirements and non-functional requirements.

C. Functional Requirements of the Proposed System

The functional requirements for a system describe what the system should do. They are observable tasks or processes that must be performed by the system under development.

The functional requirements for this system are highlighted as follows:

1) Login Page

The login page allows the system user to login into system. It is required to provide field for user id and password before a typical user is given access to the menu page. The provided userid and passwords must be successfully validated against onboarded valid users in the database before access can be granted to the system. Otherwise, invalid credentials do not provide system access to the user.

2) Add Project Page

This page allows the system user to add or create new IoT challenges prioritization project(s) in system.

a) The MCDSS must be able to validate user inputs for corresponding fields
b) Mandatory data fields such as Project name, Organization Name, etc. must be provided before a project is created.
c) The system should be able to allow addition of stakeholder(s) while creating a project.
d) The system should have record duplication control mechanism by utilizing unique record id.

3) Projects List Page

This page should list all the projects that are added to the system.

a) Displays all the projects that are entered in the system.
b) Displays the list of columns such as Project ID, Project Name, User Name, Assigned Status, Date of the project information and many more.

4) Add User Page

This screen allows addition/deletion of users to the system. Users can either be ordinary stakeholder or administrator for each institution.

a) System should be able to validate all user inputs against each corresponding mandatory fields
b) The access level assignable to each of the user is use rid defined while creating new user by the system administrator.

5) Add/Modify IoT Challenges Page

This Page allows user to add/modify IoT challenges for his organization depending on his permission level.

a) System must be able to add new IoT challenges/Sub challenges to the system apart from the default challenges adopted.

b) The system should be able to validate the user inputs for corresponding mandatory fields

6) IoT Challenges List Page

This screen displays all created/adopted IoT challenge/sub-challenges with required information in the system.

a) System should be able to allow the system administrator carry out edit/delete action

b) The Edit functionality allows administrator to modify the IoT challenges related information

c) Delete function should allow the system administrator to delete the IoT challenges from the system.

7) Decision Data Input Page

This page should allow the user to answer all the pairwise comparison questionnaires based on the pairwise comparison questionnaire embedded in the system.

D. Reports

This page displays the of reports that shows ranked or prioritized IoT challenges based on the pairwise comparison choices made by stakeholders. System should allow access to reports to the system users.

E. Non-Functional Requirement of The MCDSS

Non-functional requirements are often called qualities of a system, it includes:

1) Authentication of Users to send and retrieve data

2) Maintainable and Fault Tolerant

3) To have an attractive User Interface (UI) design

4) Easy to use so as to enhance the User Experience (UX)

5) Responsive and mobile friendly

F. Software Development Tools Used

Microsoft's Visual Studio 2022, C#, ASP.NET MVC

IV. SYSTEM DESIGN

A. Data Flow Diagram of Proposed Multi-criteria Decision Support System (MCDSS)

The data flow of our proposed multi-criteria decision support system (MCDSS) is depicted in figure 3.4 below;

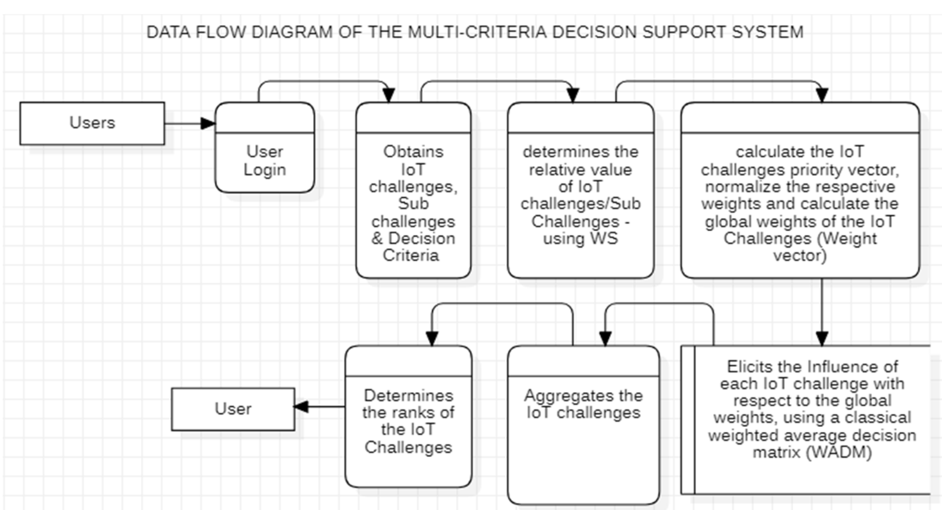

Figure 1 Data Flow Diagram of MCDSS

1) *Entity Relationship Diagram;* Entity-Relationship (ER) diagram is used to represent the information structure of the system. This is shown in Figure 2 the ER is used to how data is conceptualized in the context of managing feedbacks, feedback categories, decisions that have been made over time and the stakeholders in the designed system.

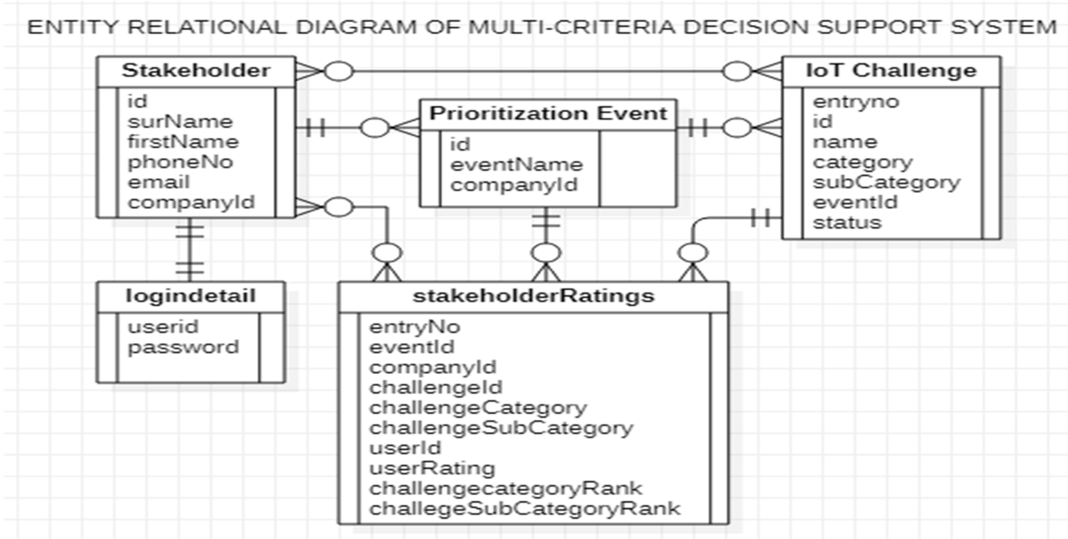

Figure 2 Entity Relational Diagram of MCDSS

B. Architecture of the Multi-criteria Decision Support System (MCDSS)

The architecture of the MCDSS as shown in Figure 3 explains the major interactions among the various sub units of the MCDSS. The system adopts ASP.NET MVC Architecture.

1) *Model:* Model gives the shape of the data in the application. A class in C# programming language usually describes a model. Model objects store data obtained from the database.
2) *View:* View in ASP.NET MVC is made up of HTML, CSS, and some special syntax (Razor syntax) that makes it pretty easy to inter-communicate with the model as well as controller.
3) *Controller:* The controller processes the request and returns the appropriate view as a response.

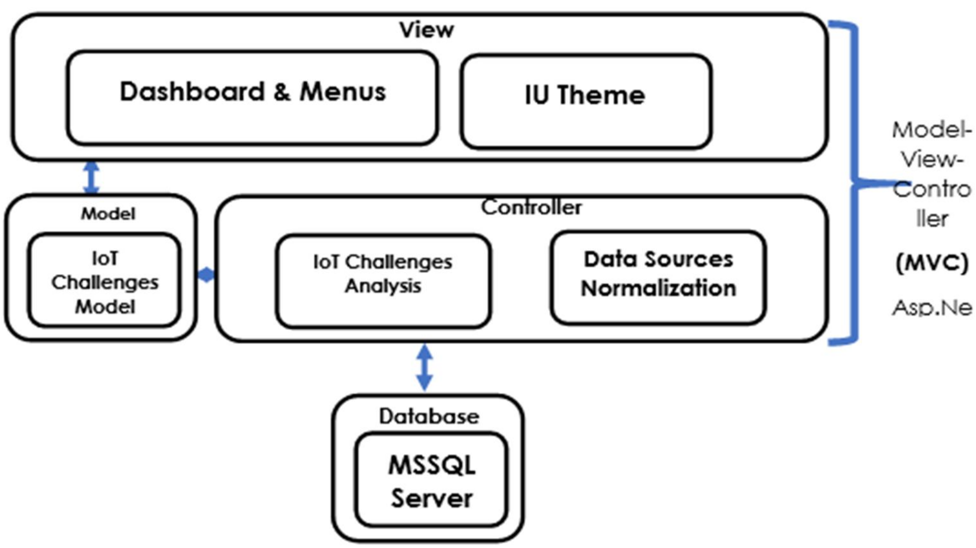

Figure 3 Architecture of the MCDSS

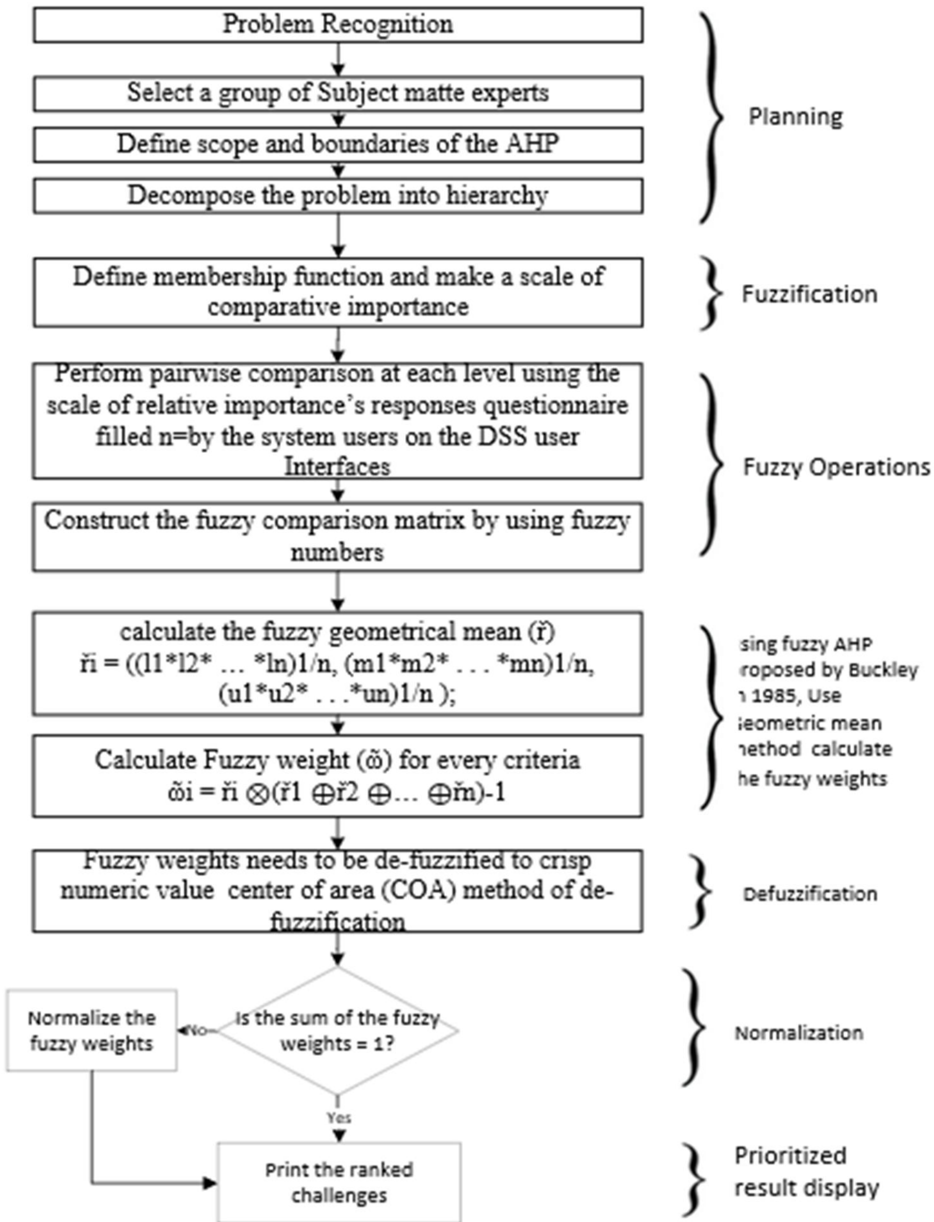

Figure 4: Flowchart of the Proposed Multi-Criteria Decision Process Based on Fuzzy Analytic Hierarchy Process (FAHP) Technique

V. IMPLEMENTATION AND DISCUSSION OF FINDINGS

A. Deployment Environment of The Multi-criteria Decision Support System

The nodes of our deployment environment are as follows:

1) *Web Server:* This node represents the Web server. It receives user requests and send responses from the application. Back to the user.
2) *Application Server:* The application server node processes user requests from the Web server and send application responses back to the Web server is represented by this node. The application server node will host the different components of the Courseware Management System, such as View, Controller, Model, and Database Access.
3) *Server:* The database server node will host the database server used by the components in the application server node to store and retrieve the data used by the Courseware Management System.

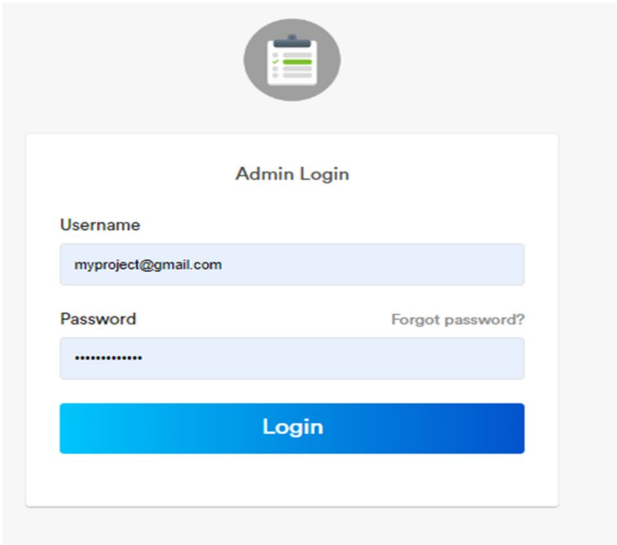

Figure 5:Login Page

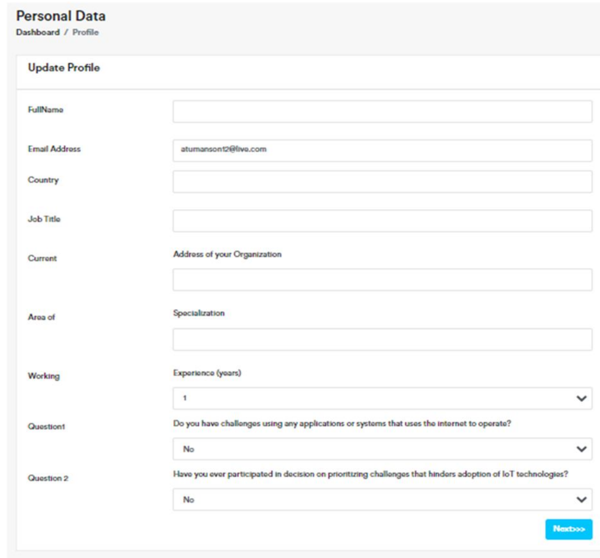

Figure 6: User profile Update Page

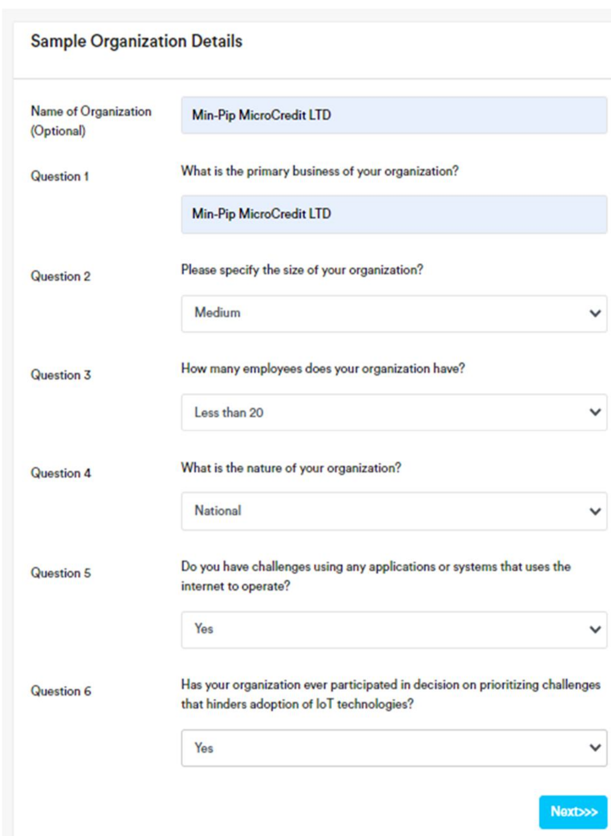

Figure 7: Organisation Update Page

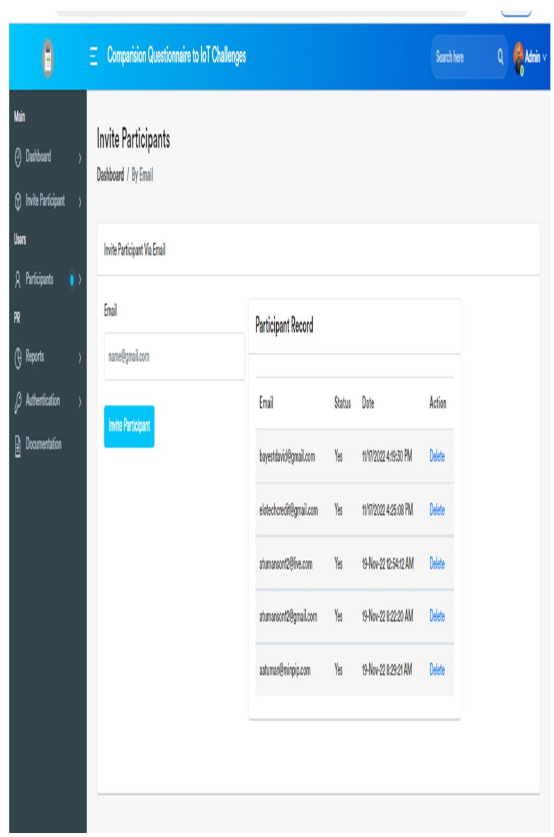

Figure 8: Landing and Navigation Page

B. System Usability Test and User Feedback

System Usability Test – User Selection Criteria

All test users who participated in answering the multi-criteria decision making pairwise comparison questionnaire were also invited to fill no the system suability test online questionnaire. A total number of 10 users who were selected at random to answer the questionnaires were asked to also give feedback on their experiences with the MCDSS developed in this thesis work.

C. System Usability Test Method

Microsoft forms online survey app was used to design the system usability test feedback form. Appendix II shows the layout and the content of the usability test feedback questions asked. The system usability test questionnaire was published by Microsoft on the following link: "https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAN__q5WMC9UMUlRNUs0OU1XTjNQRVRTRzdZNUFMN1ROQy4u"

All users who were invited to till the pairwise comparison questionnaires for prioritizing challenges of IoT technology adoption also received the link for the custom online system usability test. They were required to also fill the online feedback forms upon completion of the questionnaire sessions.

The usability test feedbacks provided by the users were monitored and downloaded at the end of the tests.

D. System Usability Test Result

A total of 6 out of the 10 test users who completed the pairwise comparison questionnaires for prioritizing challenges of IoT technology adoption were able to fully fill in the feedback forms.

Data Result Obtained MCDSS

The result obtained is now sorted in systematically descending order such that IoT challenges/sub-challenges that carries highest weight are placed on top while challenges that carry lowest weights are placed at the bottom.

Table 1below shows the summary of the Ranked fuzzy weights of challenges of IoT technology adoption and development obtained from the system. While table 4.2 shows comparative weights of the challenges of IoT technology adoption and development obtained from the MCDSS with that of the weights obtained in the baseline research[2].

Ranked Fuzzy Weights of Main Challenges of IoT Technology Adoption and Development

IoT Main Challenges	Fizzy Weights Calculated	Crisp Weights Calculated	Normalised Weight	Rank
Technological	0.226, 0.234, 0.228	0.229	0.230	1
Privacy	0.220, 0.216, 0.242	0.226	0.226	2
Legal	0.196, 0.183, 0.173	0.184	0.185	4
Business	0.171, 0.199, 0.204	0.191	0.191	3
Cultural	0.185, 0.169, 0.151	0.168	0.169	5

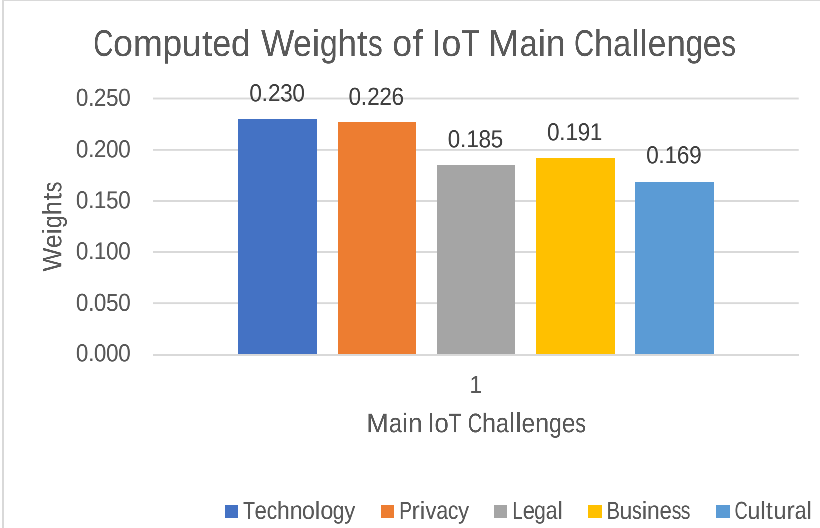

Figure 9: Chart of Weights of Main Challenges of IoT Technology Adoption and Development

Table 1 shows weights of the IoT technology adoption challenges as well as the raking for each of the challenges. Also figure 9 shows chart of weights of the main challenges of IoT technology adoption obtained from the MCDSS. The weight of each challenge indicates how influential the challenge is in terms of how important it is to solve it at the expense of other competing challenges as well as how easy it is to solve it at the expense of other competing challenges. From the result, technological challenge (0.230) or factor is the most influential main challenges followed by privacy and security (0.226) main challenge. However, cultural challenge (0.169) is the least influential. Comparison between the base research result obtained and the output obtained from MCDSS was made by virtue of the weight of each of the IoT main challenges and the ranking computed for each of the main challenges.

Comparisons based on weight shows that there are minute variabilities in weights: Privacy has the largest difference of 0.012, while technological challenge lowest difference between the two outputs of -0.053. Table 2 and figure 10 show compared weights of main challenges and chart of compared weights of main challenges respectively.

However, comparison based on their ranking indicate 100% accuracy with all the ranks being the same from the two different outputs.

Table 2 Compared Weights of Main Challenges of IoT Technology Adoption and Development with Similar Category of Result of the base research result used in this thesis.

IoT Main Challenges	Calculated Weight	Weight in the Baseline Dataset	Weight Variance	Current Rank	Rank the Baseline Dataset
Technological	0.229	0.282	-0.053	1	1
Privacy	0.226	0.202	0.024	2	2
Legal	0.185	0.176	0.009	4	4
Business	0.191	0.183	0.008	3	3
Cultural	0.169	0.157	0.012	5	5

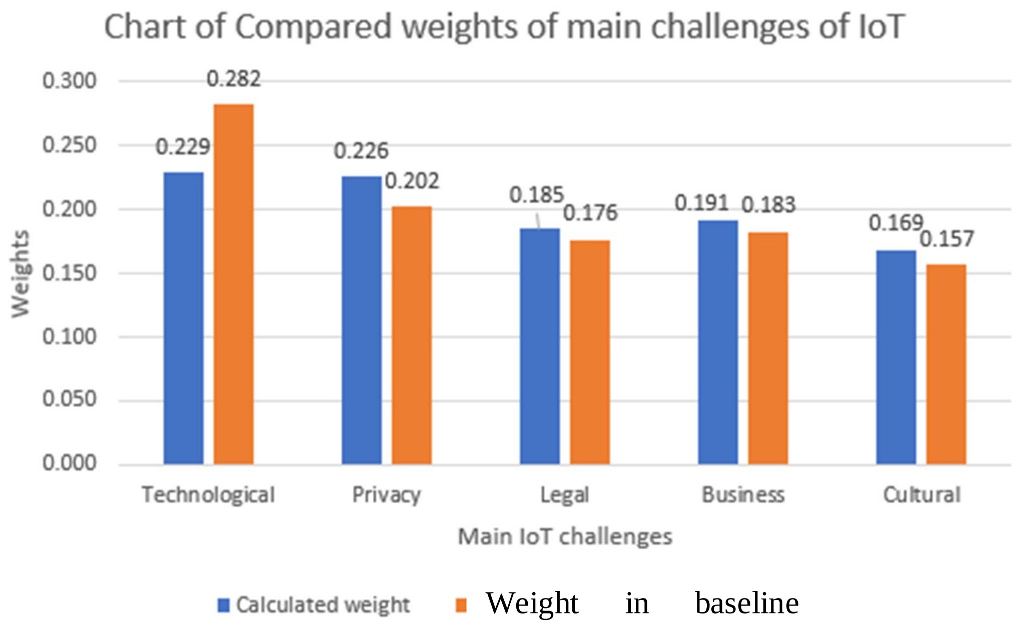

Figure 10:Chart of Compared Weights of Main Challenges of IoT Technology Adoption and Development Source

Table 3 below shows the summary of the Ranked fuzzy weights of technology based sub-challenges of IoT technology adoption and development obtained from the MCDSS. Also, table 4 shows comparative weights of the technology based sub-challenges of IoT technology adoption and development obtained from the MCDSS with that of the weights obtained in this Thesis' base research.

Table 3 Ranked Fuzzy Weights of Technological Sub-challenges of IoT Technology Adoption and Development

Technological Sub-Challenges	Fizzy Weights Calculated by MCDSS	Crisp Weights Calculated	Normalised Weight	Rank
Hardware construction	0.151, 0.152, 0.147	0.150	0.150	6
Fault Tolerance	0.144, 0.171, 0.140	0.152	0.152	5
Devices heterogeneity	0.174, 0.163, 0.182	0.173	0.173	2
Architecture and design	0.209, 0.187, 0.191	0.195	0.196	1
Ubiquitous data mngt.	0.166, 0.163, 0.173	0.167	0.168	3
Addressing	0.158, 0.163, 0.165	0.162	0.162	4

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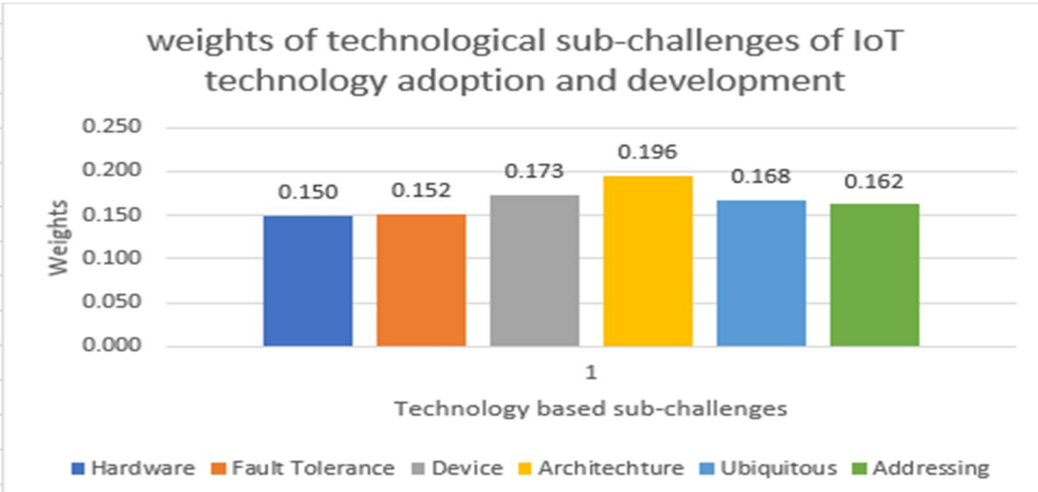

Figure 11: Chart of Weights of Technological Sub-challenges of IoT Technology Adoption and Development

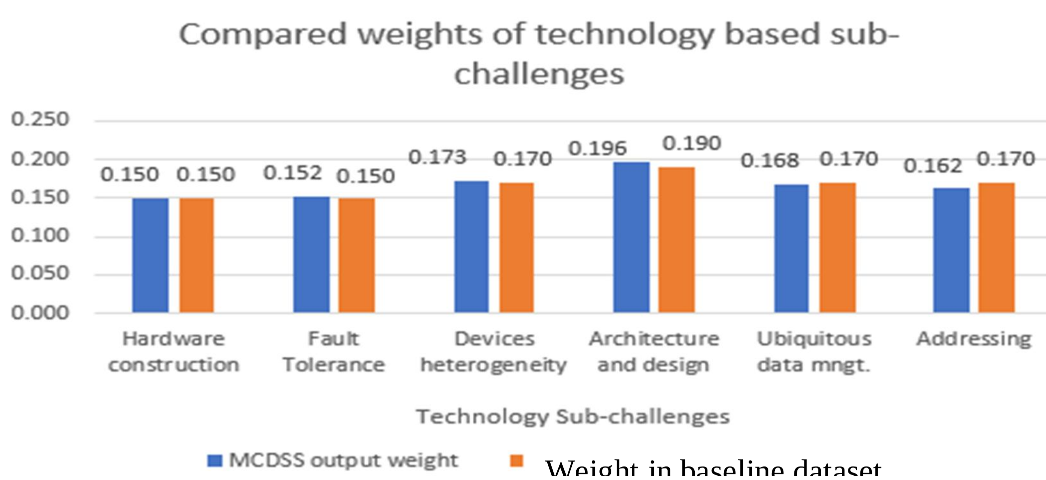

Figure 12: Compared Weights of Technology Based Sub-challenges

Table 4. Compared Weights of Technology Based Sub-challenges of IoT Technology Adoption and Development with Similar Category of Result Obtained in the base research used in this thesis

Technological Sub-Challenge	MCDSS Output Weight	Weight in the Baseline Dataset	Weight Variance	MCDSS Rank	Rank in the Baseline Dataset
Hardware construction	0.150	0.150	0.000	6	5
Fault Tolerance	0.152	0.150	-0.002	5	5
Devices heterogeneity	0.173	0.170	-0.003	2	2
Architecture and design	0.196	0.190	-0.006	1	1
Ubiquitous data Mngt.	0.168	0.170	0.002	3	2
Addressing	0.162	0.170	0.008	4	2

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Table 5 below shows the summary of the Ranked fuzzy weights of Privacy and security based sub-challenges of IoT technology adoption and development obtained from the MCDSS. Also, table 6 shows comparative weights of the privacy and security based sub-challenges of IoT technology adoption and development obtained from the MCDSS with that of the weights obtained in the baseline research used.

Table 5 Ranked Fuzzy Weights of Privacy and Security Based Sub-challenges of IoT Technology Adoption and Development

Privacy and Security Based Sub-challenges	Fizzy Weights Calculated by MCDSS	Crisp Weights Calculated	Normalised Weight	Rank
Conflict of interests	0.209, 0.183, 0.185	0.192	0.192	3
			0.192	3
Network security	0.209, 0.216, 0.230	0.218	0.218	2
IoT devices' safety	0.197, 0.169, 0.161	0.176	0.176	5
Data confidentiality	0.214, 0.234, 0.217	0.222	0.222	1

Table 6 Compared Weights of Privacy and Security Based Sub-challenges of IoT Technology Adoption and Development with Similar Category of Result Obtained in the baseline research.

Privacy and Security Based Sub-challenges	Calculated Weight by MCDSS	Weight in Baseline Dataset	Weight Variance	Rank by MCDSS	Rank in Baseline Dataset
Conflict of interests	0.192	0.140	-0.064	3	5
Transparency	0.192	0.210	0.007	3	3
Network security	0.218	0.230	-0.001	2	2
				5	4
Data confidentiality	0.222	0.240	0.005	1	1

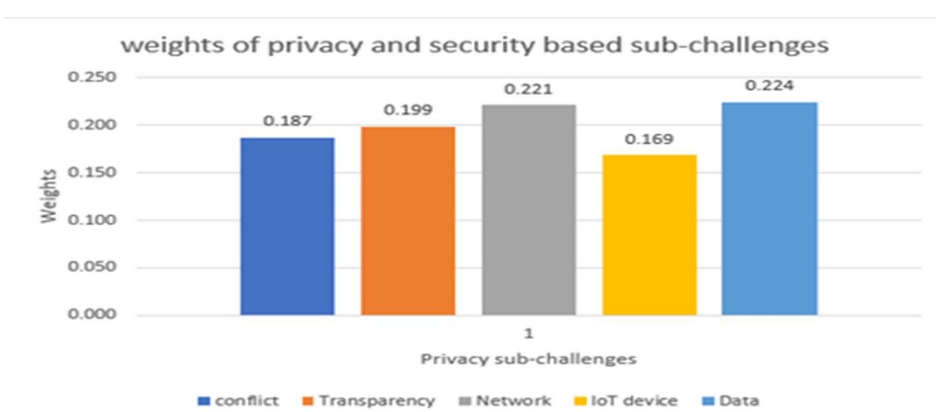

Figure 13: Chart of Weights of Privacy and Security Based Sub-challenges

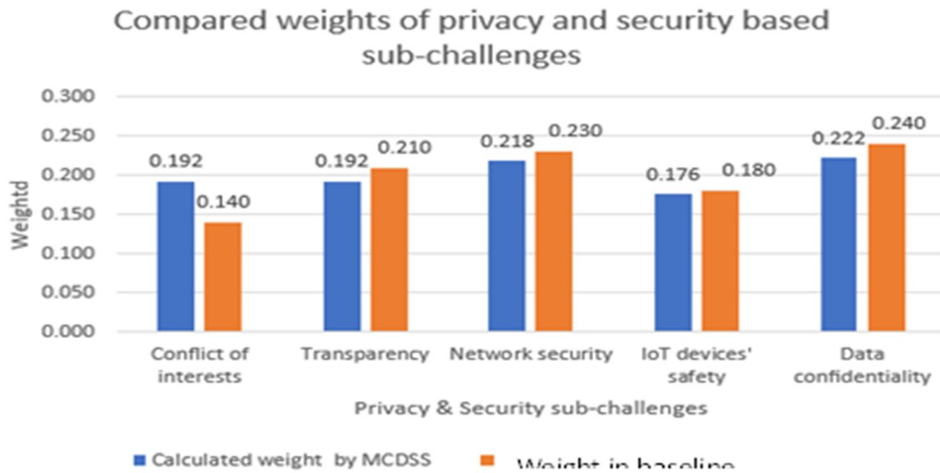

Figure 14: Chart of Compared Weights of Privacy and Security Based sub-Challenges

Table 7 below shows the summary of the Ranked fuzzy weights of legal and regulatory sub-challenges of IoT technology adoption and development obtained from the MCDSS. Also, table 8 shows comparative weights of the legal and regulatory sub-challenges of IoT technology adoption and development obtained from the MCDSS with that of the weights obtained in the baseline research.

Table 7 Ranked Fuzzy Weights of Legal and Regulatory Sub-challenges of IoT Technology Adoption and Development

Legal & Regulatory Sub-challenges	Fizzy Weights Calculated by MCDSS	Crisp Weights Calculated	Normalised Weight	Rank
Ownership	0.207, 0.185, 0.214	0.202	0.202	3
Standardization	0.185, 0.213, 0.190	0.196	0.196	4
Cross boarder data flows and Global cooperation	0.196, 0.230, 0.202	0.209	0.209	2
Liability	0.175, 0.171, 0.166	0.170	0.170	5
Data usage	0.238, 0.201, 0.226	0.222	0.222	1

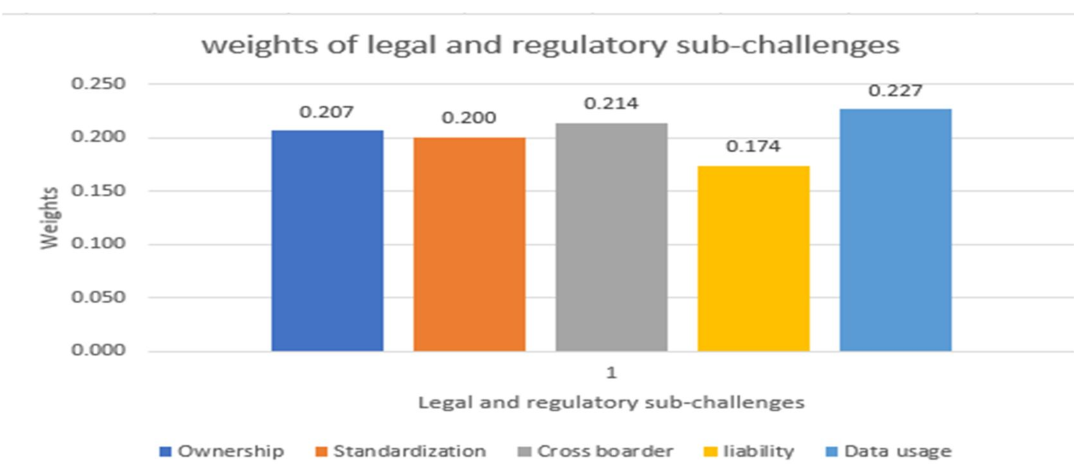

Figure 15: Chart of Weights of Legal and Regulatory Sub-challenges.

Table 8:Compared Weights of Legal and Regulatory Sub-challenges of IoT Technology Adoption and Development with Similar Category of Result Obtained in the Baseline Research[2].

Legal & Regulatory Sub-Challenges	Calculated Weight by MCDSS	Weight in Baseline Dataset	Weight Variance	Rank by MCDSS	Rank in Baseline Dataset
Ownership	0.207	0.200	-0.007	3	2
Standardization	0.200	0.200	0.000	4	2
Cross boarder data flows and Global cooperation	0.214	0.200	-0.014	2	2
Liability	0.174	0.017	-0.157	5	5
Data usage	0.227	0.230	0.003	1	1

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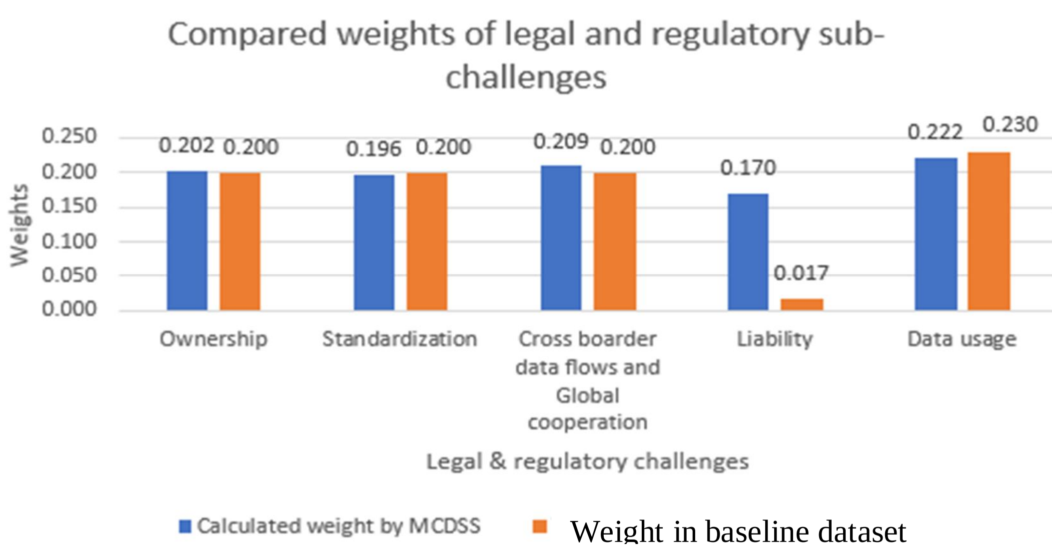

Figure 16: Chart of Compared Weights of Legal and Regulatory Sub-

Table 9 below shows the summary of the Ranked fuzzy weights of business based sub-challenges of IoT technology adoption and development obtained from the MCDSS. Also, table 4.10 shows comparative weights of the business based sub-challenges of IoT technology adoption and development obtained from the MCDSS with that of the weights obtained in the Baseline Research[2].

Table 9 Ranked Fuzzy Weights of Business-based Sub-challenges of IoT Technology Adoption and Development

Business Sub-challenges	Fizzy weights Calculated by MCDSS	Crisp Weights Calculated	Normalised Weight	Rank
Economic & development	0.226, 0.238, 0.228	0.231	0.230	3
Investing	0.243, 0.263, 0.271	0.259	0.259	2
Business model	0.320, 0.263, 0.291	0.291	0.291	1
Customer expectations	0.210, 0.238, 0.212	0.220	0.220	4

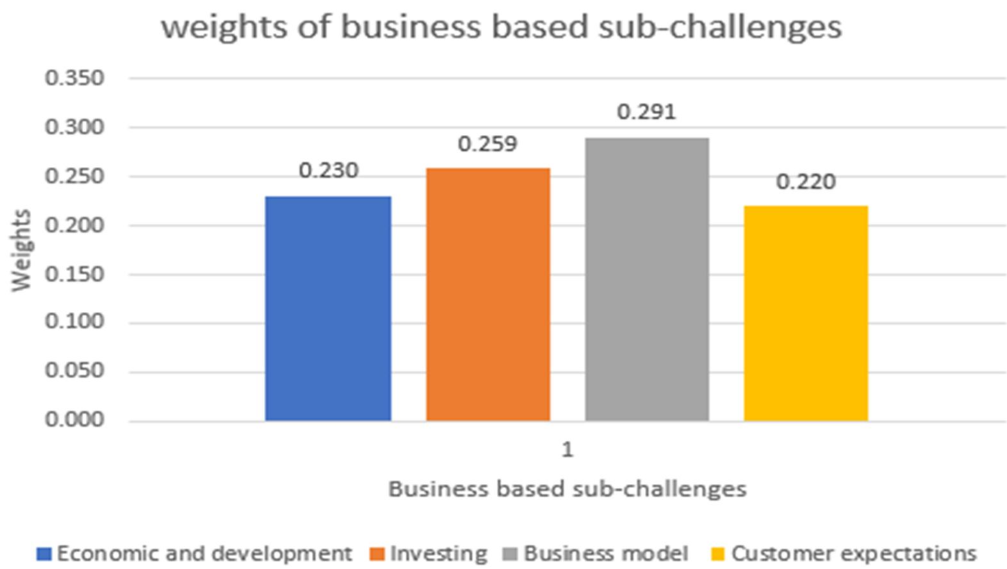

Figure 17: Chart of Weights of Business Based Sub-challenges

Table 10: Compared Weights of Business-based Sub-challenges of IoT Technology Adoption and Development with Similar Category of Result Obtained in the Baseline Research

Business sub-challenges	Calculated Weight by MCDSS	Weight in Baseline Dataset	Weight Variance	Rank by MCDSS	Rank in Baseline Dataset
Economic & development	0.230	0.230	0.000	3	3
Investing	0.259	0.260	0.001	2	2
Business model	0.291	0.300	0.009	1	1
Customer expectations	0.220	0.210	-0.010	4	4

Source: Research Design, 2023

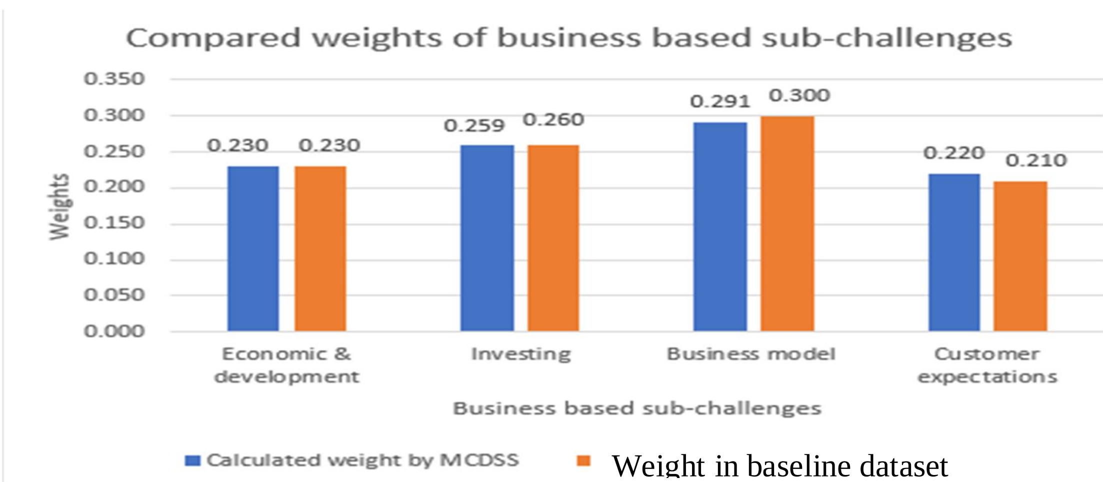

Figure 18: Chart of Compared Weights of Business-based Sub-challenges

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Table11 below shows the summary of the Ranked fuzzy weights of cultural sub-challenges of IoT technology adoption and development obtained from the MCDSS. Also, table 4.12 shows comparative weights of the cultural sub-challenges of IoT technology adoption and development obtained from the MCDSS with that of the weights obtained in the baseline research.

Table 11: Ranked Fuzzy Weights of Cultural Sub-challenges of IoT Technology Adoption and Development

Cultural Sub-challenges	Fizzy weights Calculated by MCDSS	Crisp Weights Calculated	Normalised Weight	Rank
Trust	0.243, 0.224, 0.245	0.237	0.238	2
Education and training	0.320, 0.304, 0.291	0.305	0.305	1
Vandalism	0.226, 0.224, 0.228	0.226	0.226	4
Ethics	0.210, 0.248, 0.234	0.231	0.231	3

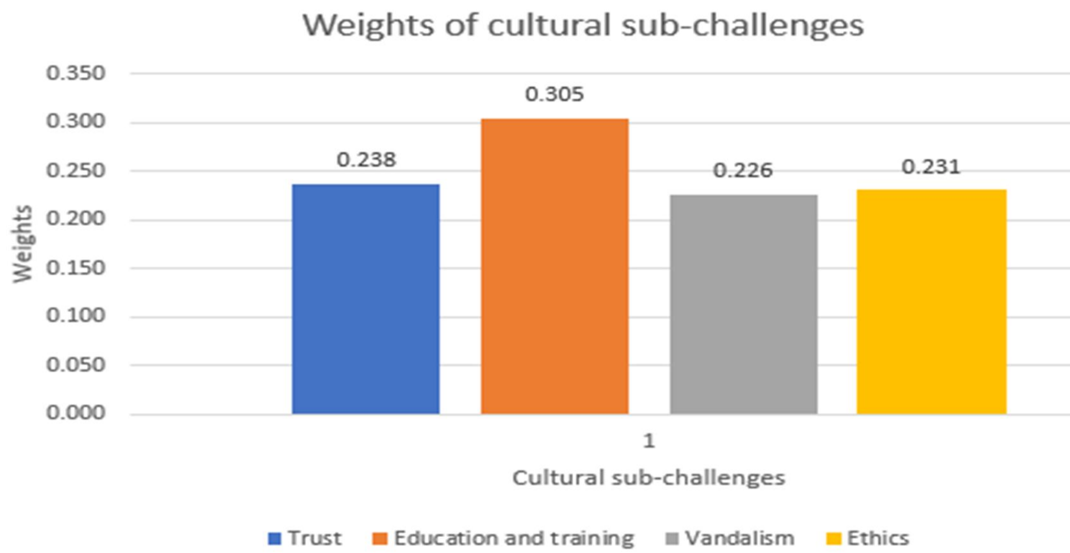

Figure 19: Chart of Weights of Cultural Sub-challenges

Table 12: Compared Weights of Cultural Sub-challenges of IoT Technology Adoption and Development with Similar Category of Result Obtained in the Baseline Research.

Cultural sub-challenges	Calculated Weight by MCDSS	Weight in Baseline Dataset	Weight Variance	Rank by MCDSS	Rank in Baseline Dataset
Trust	0.238	0.220	-0.018	2	3
Education & training	0.305	0.310	0.005	1	1
Vandalism	0.226	0.220	-0.006	4	3
Ethics	0.231	0.250	0.019	3	2

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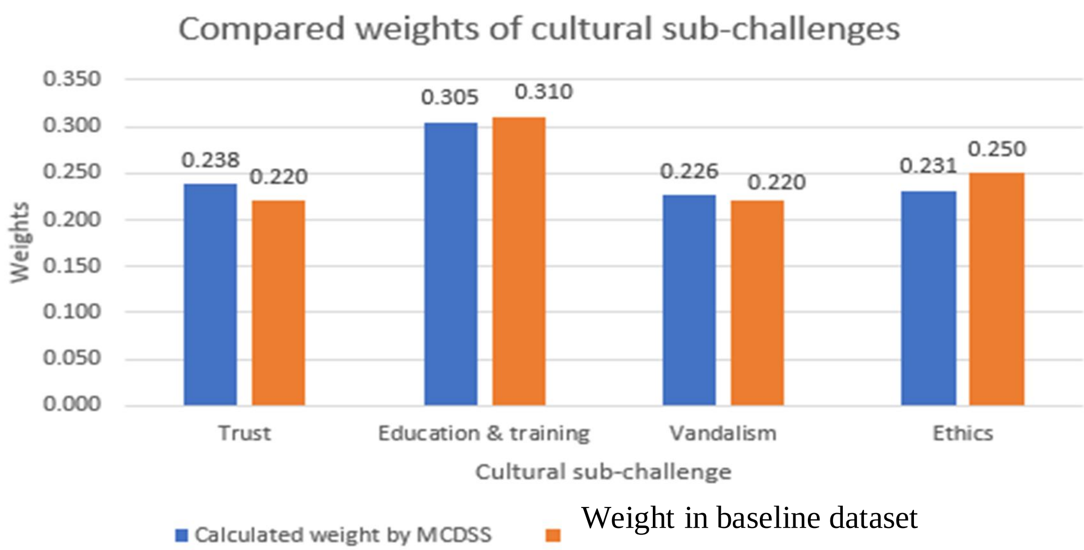

Figure20: Chart of Compared Weights of Cultural Sub-challenges

E. Global Weight and Rank for Factors (Main Challenges) and Sub-factors (Sub-challenges)

Table 13 Global Weights and Ranks for IoT Challenges and Sub-challenges

Main Factors	Sub Factors (Sub-challenges)	Global Weights	Rank
Technological	Hardware	0.0345	23
(0.230)	Fault Tolerance	0.0350	22
	Device	0.0398	13
	Architecture	0.0451	6
	Ubiquitous	0.0386	17
	Addressing	0.0373	20
Privacy & Security	Conflict of interests	0.0434	8
(0.226)	Transparency	0.0434	8
	Network security	0.0493	5
	IoT devices' safety	0.0398	14
	Data confidentiality	0.0502	3
Business	Economic & development	0.0439	7
(0.191)	Investing	0.0495	4
	Business model	0.0556	1
	Customer expectations	0.0420	10
Legal & Regulatory	Ownership	0.0383	18
(0.185)	Standardization	0.0370	21
	Cross boarder data flows and Global cooperation	0.0396	15
	Liability	0.0322	24
	Data usage	0.0420	11
Cultural	Trust	0.0402	12
(0.169)	Education and training	0.0515	2
	Vandalism	0.0382	19
	Ethics	0.0390	16

Source: Research Design, 2023

VI. DISCUSSION OF FINDINGS

The ultimate goal of this thesis is to develop a real-time prototype multi-criteria decision support system that assists decision makers in prioritizing challenges of IoT technology adoption and development.

The developed system was subjected to two categories of tests namely:

1) System usability test
2) Output data accuracy test

VII. OUTPUT DATA ACCURACY TEST

The same input dataset extracted from the baseline research was used as input data in the designed MCDSS. Output weights of the challenges and sub-challenges were printed from the system based on the input dataset adopted.

The output weights of IoT challenges/sub-challenges obtained from the system was compared with output obtained in the baseline research.

A. *Analysis of Main IoT Challenges*

Table 1 shows weights of the IoT technology adoption challenges as well as the raking for each of the challenges. Also figure 9 shows chart of weights of the main challenges of IoT technology adoption obtained from the MCDSS. The weight of each challenge indicates how influential the challenge is in terms of how important it is to solve it at the expense of other competing challenges as well as how easy it is to solve it at the expense of other competing challenges.

From the result, technological challenge (0.230) or factor is the most influential main challenges followed by privacy and security (0.226) main challenge. However, cultural challenge (0.169) is the least influential.

Comparison between the base result obtained in the baseline research and the output obtained from MCDSS (table 2 and figure 10) was made by virtue of the weight of each of the IoT main challenges and the ranking computed for each of the main challenges.

Comparisons based on weight shows that there are minute variabilities in weights: Privacy has the largest difference of 0.012, while technological challenge lowest difference between the two outputs of -0.053. Table 2 and figure 10 show compared weights of main challenges and chart of compared weights of main challenges respectively.

However, comparison based on their ranking indicate 100% accuracy with all the ranks being the same from the two different outputs.

B. *Analysis of Technological – Sub-challenges*

Analysis of technological sub-challenges of IoT (table3 and figure 11) shows that Architecture with local weight of 0.196 is the most influential, followed by Ubiquitous sub-challenge which has local weight of 0.168. in the same vein, hardware (0.150) is the least influential sub challenge of technological factor.

Comparative analysis between the out output obtained (table 4 and figure 12) by from the base study and the one obtained from MCDSS show that, in terms of the respective weights of the technology sub challenges, there was no difference for hardware sub challenge. While Addressing has the highest difference of 0.008, Architecture and design has the lowest difference in weight of -0.006. Generally speaking, all the differences are minute. By virtue of their ranking, Architecture and design, Devices heterogeneity and Fault tolerance have similar ranks of 1,2 and 5 respectively. However, it can be observed that the defences arise as a result of observed ties in the ranking of some of the sub-challenges of technology.

C. *Analysis of Privacy and Security – Sub-challenges*

For Privacy and security sub-challenges of IoT (table 5 and figure 13) analysis, data confidentiality with local weight of 0.224 is the most influential, followed by network security sub-challenge which has local weight of 0.221. in the same vein, IoT devices safety (0.150) is the least influential sub challenge of privacy and security factor.

Comparative analysis between the out output obtained (Table 6 and figure 14) by from the base study and the one obtained from MCDSS show that, in terms of the respective weights of the privacy and security sub challenges, transparency has the highest difference of 0.007. conflict of interest has the lowest difference in weight of -0.064. Generally speaking, all the differences are minute. By virtue of their ranking, data confidentiality, network security and Transparency have similar ranks of 1,2 and 3 respectively. This shows accuracy in ranking of 67%.

D. Analysis of Legal and Regulatory – Sub-challenges

Table 7 and figure 15 show weights of legal and regulatory sub-challenges and chart of weights of legal and regulatory sub-challenges respectively. It can be seen that data usage with local weight of 0.227 is the most influential sub-challenge, followed by Cross boarder data flows and Global cooperation sub-challenge which has local weight of 0.214. in the same vein, liability sub-challenge of legal and regulatory (0.174) is the least influential.

Comparative analysis between the (Table 8 and figure 16) output obtained from the base study and the one obtained from MCDSS show that, in terms of their weights, standardization sub-challenge has zero difference. Data usage sub-challenge has the highest difference of 0.003 while liability sub-challenge has the lowest difference of weight of -0.157. Generally speaking, all the differences are minute and negligible. By virtue of their ranking, data usage, Cross boarder data flows and Global cooperation and liability sub-challenges have similar ranks of 1,2 and 5 respectively. This shows accuracy in ranking of 67%.

E. Analysis of Business – Sub-challenges

Table 9 and figure 17 show weights of business sub-challenges and chart of weights of business sub-challenges respectively. It can be seen that business model with local weight of 0.291 is the most influential sub-challenge, followed by investing sub-challenge which has local weight of 0.259. Similarly, customer expectation sub-challenge of business (0.220) is the least influential.

Comparative analysis between the (Table 10 and figure 18) output obtained from the base study and the one obtained from MCDSS show that, in terms of their weights, economic & development sub-challenge has zero difference. Business model sub-challenge has the highest difference of 0.009 while customer expectation sub-challenge has the lowest difference of weight of -0.010. Generally speaking, all the differences are minute and negligible. By virtue of their ranking, There was accuracy in ranking of 100%.

F. Analysis of Cultural – Sub-challenges

Table 11 and figure 19 show weights of cultural sub-challenges and chart of weights of cultural sub-challenges respectively. It can be seen that education and training with local weight of 0.305 is the has the highest priority, followed by trust sub-challenge which has local weight of 0.238. Similarly, vandalism sub-challenge (0.226) is the least prioritized.

Comparative analysis between the output obtained (figure 20) from the base study and the one obtained from MCDSS show that, in terms of their weights, ethics sub-challenge has the highest difference of 0.019 while trust sub-challenge has the lowest difference of weight of -0.018. Generally speaking, all the differences are minute and negligible. By virtue of their ranking, There was accuracy in ranking of 25%

VIII. CONCLUSION

Summary from the system usability test feedback from test users that interacted with the system can be analysed as follows

1) Total Number of completely filled feedback form: 5
2) Size of institution: 11 – 50
3) Gender distribution: 1 Female, 5 Male
4) Description of observed system quality: Very good = 2, Exceptional = 2, Excellent = 1
5) Level of satisfaction with the system workflows: 5 (on a scale of 1-5)
6) No of bugs found: 0
7) No of errors found: 0

Based on the result obtained from the system, for the main IoT challenges, technological challenge with computed weight of (0.230) or factor is the most prioritized main challenges followed by privacy and security (0.226) main challenge. However, cultural challenge (0.169) is the least prioritized based in its weight.

There was 100% ranking similarity between the output from MCDSS and that of the baseline research.

Analysis of the system output for sub-challenges of each of the main challenges has it that:

a) For technological sub-challenges, Architecture with local weight of 0.196 is the most prioritized, followed by Ubiquitous sub-challenge which has local weight of 0.168. in the same vein, hardware (0.150) is the least influential sub challenge of technological factor.
b) For Privacy and security sub-challenges of IoT, data confidentiality with local weight of 0.224 is the most prioritized, followed by network security sub-challenge which has local weight of 0.221. in the same vein, IoT devices safety (0.150) is the least prioritized sub challenge of privacy and security factor.

c) They system output for legal and regulatory sub-challenges shows that data usage with local weight of 0.227 is the most prioritized sub-challenge, followed by Cross boarder data flows and Global cooperation sub-challenge which has local weight of 0.214. in the same vein, liability sub-challenge of legal and regulatory (0.174) is the least prioritized.
d) It was observed that, for sub-challenges of business, business model with local weight of 0.291 is the most prioritized sub-challenge, followed by investing sub-challenge which has local weight of 0.259. Similarly, customer expectation sub-challenge of business (0.220) is the least influential/prioritized.
e) For cultural sub-challenges, It was seen that education and training with local weight of 0.305 has the highest priority, followed by trust sub-challenge which has local weight of 0.238. Similarly, vandalism sub-challenge (0.226) is the least prioritized.

In general, the observed similarity in ranking between the output of this MCDSS and the result obtained in the baseline research was averaged at 80%.

Based the above, it can therefore be concluded that, the system was well accepted by the sample test users. The comparative output similarity was significant enough for the system to be adopted for prioritizing challenges of IoT technology adoption to be solved.

A. Recommendations

The prototype system designed and developed in this thesis work is no doubt a work in progress. It therefore requires more studies and improvements in the following recommended areas:

1) The system should be augmented to accommodate dynamically added infinite number of IoT technology challenges instead of restricting the challenges to the ones adopted from the datasets only.
2) The system should be improved further my integrating a more comprehensive imbedded knowledge base system instead of only providing instructions via emails during decision stakeholder invitation.
3) The system should be equipped with dynamic colours and themes in the user interface to suit convenience of users.

B. Suggested Area of Further Research

The following are the suggestions for further research: The use of the prototype system designed and developed in this study work is limited to prioritization of challenges that institutions face in their effort to adopt and/or use IoT technologies. further studies be carried out with a view to expanding the scope and capability of the prototype system to other key areas of technology, administration, business, etc where multi-stakeholder strategic, tactical, and operational decisions need to be simplified, unbiased and accurate.

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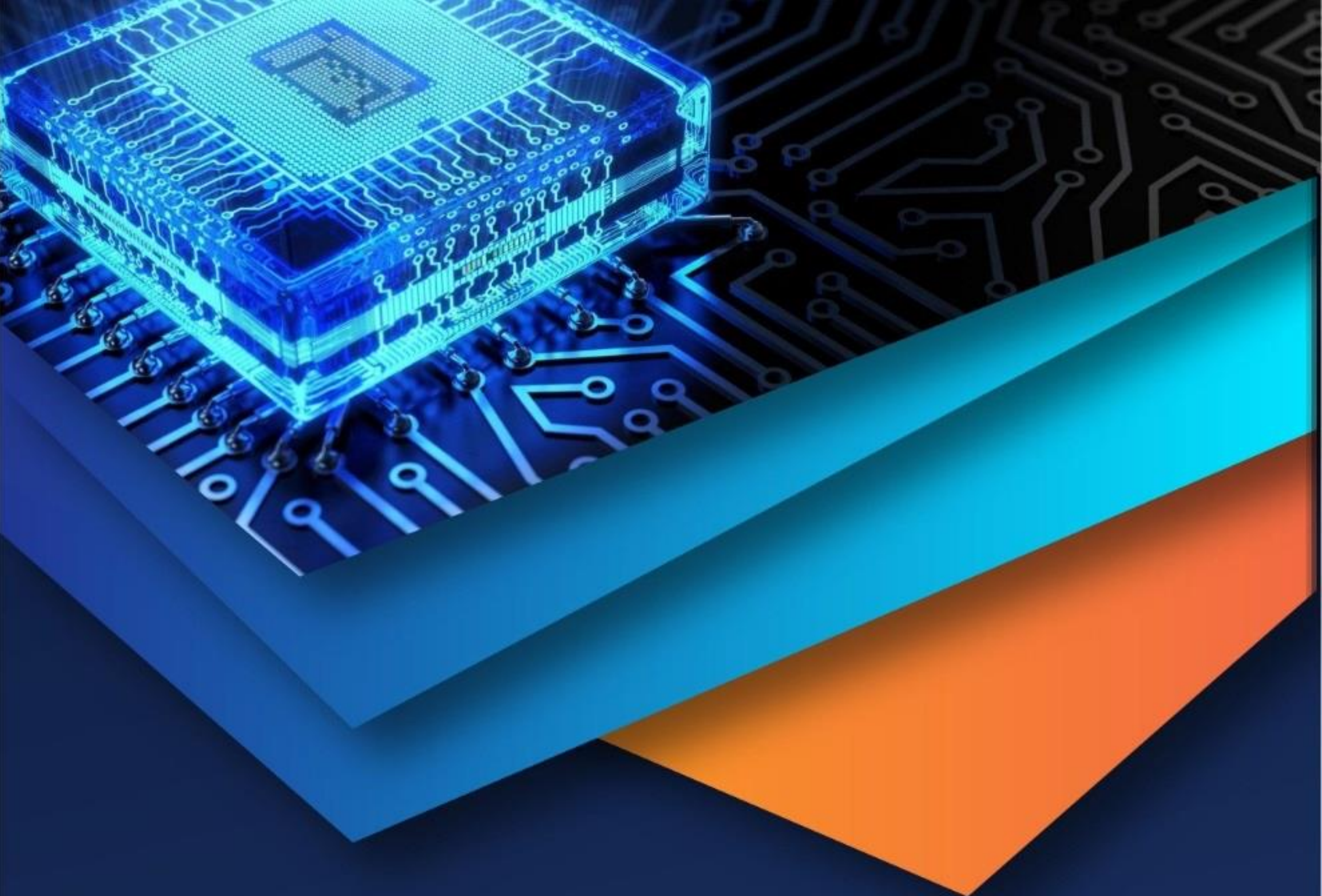

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