Fuzzy AHP Based Decision Support System for Prioritizing Challenges of Adopting Internet of Things (IoT) Technologies

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Certification

This is to certify that Ayuba ATUMAN with matriculation number LCU/PG/002023 carried out this research work titled "Multi-criteria Decision Support System for Prioritizing Challenges of Internet of Things (IoT)" in the Department of Computer Science, Faculty of Natural and Applied Sciences, Lead City University, Ibadan, Oyo state, for the award of Master Degree (MSc) in Computer Science and that this has not been previously submitted.

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Dedication

This research work is dedicated to Almighty God for his mercies and grace in abundance upon my life and to my family members.

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Abstract

The adoption and utilization of Internet of Things (IoT) technologies present numerous, complex, and expensive challenges for developing countries as they work to fill their share of the global IoT market. Multi-stakeholder decision makers rely on multi criteria decision support systems (MCDSS) as essential tools for evaluating and prioritizing complicated competing options such as the above. This paper presents an approach for design and development of a web-based prototype Mult Criteria Decision Support System (MCDSS) for prioritizing these difficulties associated with the adoption and utilization of Internet of Things (IoT) technologies. The prototype Decision Support System (DSS) is expected to be an essential tool to be used by Policy makers in IoT, IoT industry experts, researchers, and other stakeholders in IoT. The majority of work done over time by academics, researchers, and industry specialists to construct MCDSS specific for prioritizing challenges adoption and utilization of IoT technologies has levels of mismatch: most of their work ends up on paper without a real-world application wo work with; Some applications are too complex for typical decision-making stakeholders; most of solutions are not explicitly designed to prioritize IoT concerns. The goal of this work is to develop a prototype MCDSS for prioritizing difficulties associated with the adoption and exploitation of IoT technology. As the core logic component of the Decision Support System (DSS), Fuzzy Analytic Hierarchy Process (FAHP) multicriteria decision analysis approach was employed. 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.

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.

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Chapter One

Introduction

1.1 Background to the Study

This thesis 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.

Decision making can be defined as the process of making choices among competing alternative by identifying a decision goal, gathering relevant information, and evaluating alternative resolutions[1].

People make decisions in order to direct their behaviour and commitment towards a future goal. In other words, using a logical or systematic decision-making process can assist a decision maker in making more deliberate, thoughtful decisions by organizing relevant information and defining alternatives[2]. In making decisions, there must me pre-conditions: for instance, if alternatives do not exist, if choices are not there to be made, if there is no other way-out of a situation, then decision making is not needed[3].

Decision making however, entails committing the organization and its human and non-human resources to a particular choice of course of action that is assumed to be efficient and effective in achieving some predetermined objective[4].

Quiet a number of decisions can be made quickly and easily, more especially if they involve considerably small number of alternatives to work with. However, in most cases, there's always several factor that influences your choices.

The important thing about making decisions is that decision elements have different weight. Sometimes one of them is essential that it is the only one to consider (Single-criteria decision). For every component you need to assess the huge benefits it brings, the brand-new opportunities it can make and the expenses related to it. Every one of these trade-offs and evaluation points are an excessive amount of for the mental faculties of mankind to handle in a rational way[5].

During these instances, individuals use their unique instincts or rationality to get the best results, requesting friends for suggestions, collecting different thoughts, or accepting choices popular among people who may turn out to be more knowledgeable throughout the area. Often there are also many parameters to evaluate so that they prefer to produce random choices just like flipping and throwing oracle cards.

When choices affect or involve group in individuals, like during politics, consensus building, group polarization, range voting, etc., it is not really possible to use instinct or randomly choice. This is because the decision in such cases suffer from problems such as social compromise, politics, unclear responsibility, and insufficient accountability that may impair the creativity of decision. Decision making that affects group of individuals thus must have all the competing alternatives (multi-criteria) analyzed in details. That is a major predisposing factor that necessitated the development of “decision making” processes and algorithms over the years[6].

Decision making techniques have been employed in many fields, nevertheless the major field where these kinds of processes originated was first economics. The economic system is intricate and requires strategies to make options[7].

Multi-criteria Decision-Making (MCDM), therefore 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[8].

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[17].

The concept of decision support system (DSS) can be traced back to 1940s and 1950s with the emergence of operations research, behavioral and scientific theories of management and statistical process control, much before the general availability of computers. During that time, quiet a number of people see the field of Decision Support Systems from divergent vantage points which made them to report unique accounts of what occurred and what was pertinent. As time goes on, different decision-making system were developed that focused on new computer technologies. As a result, researchers inside the universities started to evaluate and deliberate on methods and solutions pertaining to decision making. In the 1980s, a number of industrial companies developed and implemented some decision-making algorithms in their organizations, this aided rapid development and use of decision-making support systems[9].

Nowadays, there are a quiet a number of decision support systems. They are basically clustered in five main categories[10]:

- 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[11].

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[12].

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[13]. 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[14].

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[15]. 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[16].

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[17].

No business or administrative system succeeds without the ability to identify strategic growth challenges, prioritize them and then execute them. The problem is, the larger the organization, the more complex the consideration of challenges and the more uncertainty in making the right choices. This leads to a costly process that may produce insecure decision making. This is true because too many alternative challenges can be detrimental to the process of decision-making[18]. 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[19].

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[20].

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[21].

In this study we propose to:

1. To Develop an IoT challenges prioritization model using Fuzzy Analytic Hierarchy Process (FAHP) MCDM approach.

2. To develop a web based, mobile friendly MCDM support prototype tool (System) that uses approach in (1) for Prioritizing challenges of IoT.

3. To Carry output comparison test of the developed prototype system against result obtained from the works of Mohammadzadeh (baseline dataset).

The prototype system can help decision makers (scholars, researchers, industrial experts, industry executives, stakeholders in IoT decision making) to:

- Gather/garner relevant data in one-stop on challenges of IoT technology adoption and utilization,
- help decision makers to prioritise their IoT technology adoption and utilization challenges, and reduce chances on concentration of limited human and non-human resources in solving non influential IoT challenges.
- preserve and re-use previously collected IoT challenges-based data, from scholars, researchers, industrial experts, industry executives, stakeholders in IoT decision making in relevant institutions etc.
- predict possible issues of observations or actions in advance, and learned wisdom (e.g., issues encountered) from previous IoT challenges prioritization experience to help data interpretation and decision making[22].

Throughout this write-up, the works of Mohammadzadeh from which datasets used in this thesis is obtained is referred to as *baseline data sets*.

1.2 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.

1.3 Aim and Objectives of the Study

The aim of this thesis 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:

i. design a web based, MCDM support prototype tool (System) that uses FAHP approach for Prioritizing challenges of IoT.

ii. implement the designed prototype system in (i) above.

iii. test and evaluate the prototype system against result extracted from the baseline dataset used in this thesis[23].

1.4 Significance of the Study

This thesis aims to contribute to the embodiment of knowledge by meeting up with the limitations of IoT based challenges prioritization approaches garnered in the literature: As it can be seen, a lot of techniques e.g., AHP suffer scalability problems and are therefore only suitable for prioritizing small number of IoT development challenges.

To address scalability issues, Fuzzy Analytic Hierarchy Process approach is adopted in this study work.

Most of the IoT development challenges prioritization research works' scope 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. The Decision Support prototype tool proposed in this study work is a step ahead in that regard.

Among other things, this thesis work would form the bases for more improved research on IoT challenges prioritization decision support tools. The prototype system proposed in this thesis work would be expected to assist in:

- determining alternative challenges of adoption and utilization of IoT technology,
- data management of potential challenges of IoT technology adoption and utilization and
- data management of the most influential IoT challenges outputted from the decision support system.

1.5 Scope of the Study

The scope of this thesis includes the development of fuzzy analytic network process based IoT challenges prioritization model. The developed model would be adopted in the development of a web-based, mobile friendly prototype tool for prioritizing challenges of IoT.

1.6 Limitation of the Study

In consideration of the time frame of this thesis work, Testing of the developed system would be limited to benchmarking output result of the system with that of the baseline dataset used in this thesis[23].

1.7 Outline of the Thesis

This thesis is composed of the following parts: first Chapter 1 contain a general introduction of the Multi-criteria decision making (MCDM) support tool. This provides a magnificent overview of the entire project work.

Next, the process and methods with examples of multi-criteria decision-making analysis garnered from the existing literature are listed and annotated in Chapter 2. This is grouped into conceptual review, review of related literature and summary of gaps in literature.

Third, within Chapter 3, different analyses with respect to the methodology used in the design and development of the MCDM support prototype system for prioritizing challenges of internet of things (IoT) in this study work is covered. Section 3.2 deals with system design. Requirement specification is covered in section 3.3. while the specific methods and algorithmic stages adopted in the design of the prototype system is depicted in section 3.4.

In Chapter 4, testing and evaluation of the designed work is covered. Results and discussion of findings is also made.

Finally, summary of findings, recommendations for future work, and contributions of this

1.8 Operational Definition of Terms

IoT: - Internet of Things

SDG: - Sustainable development goals

MCDM: - Multi-criteria decision making

DSS; - Decision support system

FAHP: - Fuzzy analytic hierarchy process

FANP : - Fuzzy analytic network process

Baseline Data set: - Baseline data (or simply baseline) is data that measures conditions before the project starts for later comparison. In other words, baseline dataset used in this thesis provides IoT challenges and Sub-challenges as well as the dataset for which the output of the prototype system developed in this research work is benchmarked[23].

Endnotes

1. B. Silva, G. Akpakwu, Hancke, M. Adnan & P.Gerhard, *A Survey on 5G Networks for the Internet of Things: Communication Technologies and Challenges,* **IEEE Access Institute of Electrical and Electronics Engineers Inc.**, December 2, 2017, https://doi.org/10.1109/ACCESS.2017.2779844.

2. M. Osuri & P. Gade, *Evaluation of Multi Criteria Decision Making Methods for Potential Use in Application Security*, 2014, 1–63, https://www.diva-portal.org/smash/get/diva2:831025/FULLTEXT01.pdf.

3. C. Jain & J. Kacprzyk, *Handbook on Decision Making: Techniques and Applications*, ed. **Intelligent Systems Reference Library**, Volume 1, vol. 1999, Springer-Verlag Berlin Heidelberg, 2006, https://doi.org/DOI 10.1007/978-3-642-13639-9 Intelligent.

4. D. Kiran, I*nternet of Things - an Overview,* **ScienceDirect Topics***,* 2019, https://www.sciencedirect.com/topics/engineering/internet-of-things.

5. World Econimic Forum, ***Internet of Things Guidelines for Sustainability,*** **IoT for Sustainable Development Project,** 2018, http://wef.ch/IoT4D.

6. W. Donald, *Industry 4.0 and IoT are key elements of the digital revolution*, 2021, https://www.bearingpoint.com/en/our-success/insights/industry-4-0-and-iot-insight/

7. H. Boshuizen, P. Beers, P. Kirschner & W. Gijselaers, **"*Common Ground, Complex Problems and Decision Making*," Group Decision and Negotiation** 15, no. 6, 2006: 529–56, https://doi.org/10.1007/s10726-006-9030-1.

8. A. Jamwal, M. Sharma, R. Agrawal & V. Kumar, *Review on Multi-Criteria Decision Analysis in Sustainable Manufacturing Decision Making*, Https://Doi.Org/10.1080/19397038.2020.1866708 14, no. 3, 2020: 202–25, https://doi.org/10.1080/19397038.2020.1866708.

9. I. Usman, Y. Amrozi & M. Ali, *History of Decision-Making: Development and Its Applications*, **Journal of Physics: Conference Series** 1573, no. 1, 2020, https://doi.org/10.1088/1742-6596/1573/1/012010.

10. A. Rhattoy, I. Chana, M. Lahmer, Y. Hadi & Y. Rhazali, *A Model Transformation in Model Driven Architecture from Business Model to Web Model*, **IAENG International Journal of Computer Science 45**, no. 1, 2018: 104–17.

11. M. Maksimovic, *Greening the Future: Green Internet of Things (G-IoT) as a Key Technological Enabler of Sustainable Development,* 2018, 283–313, https://doi.org/10.1007/978-3-319-60435-0_12.

12. K. Dona, N. Aji, Priatno, S. Arman & Wibisono, *Decision Support System For The Best Student Selection Recommendation Using Ahp (Analytic Hierarchy Process) Method*,**International Journal of Educational Research & Social Sciences**, 2021, 1210–17, ISSN: 2774-5406,.

13. Bearing Point, *Industry 4.0, IoT in Digital Manufacturing, Creating Smart Factories,* **BearingPoint**, 2020, https://www.bearingpoint.com/en/our-success/insights/industry-4-0-and-iot-insight/.

14. P. Honest, *Reflections on The Implications of The Fourth Industrial Revolution (Fir) on Taxation*, **Financ.Dev**, vol. 1, August 18, 2020, www.ngowitv.co.tz.

15. A. Jamwal, M. Sharma, R. Agrawal & V. Kumar, *Review on Multi-Criteria Decision Analysis in Sustainable Manufacturing Decision Making*., **International Journal of Sustainable Engineerin**g, 30 Dec 2020., https://doi.org/10.1080/19397038.2020.1866708

16. International Telecommunication Union, *ICT Facts and Figures 2017*, 2017, moz-extension://1660c496-045a-4211-85b3-d2879d15cc70/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fwww.itu.int%2Fen%2Fitu-D%2FStatistics%2FDocuments%2Ffacts%2FICTFactsFigures2017.pdf.

17. United Nations, ***The 17 Goals | Sustainable Development*, Department of Economic and Social Affairs,** 2015, https://sdgs.un.org/goals.

18. D. Dursun, A*n Overview of the Human Decision-Making Process | Introduction to Business Analytics and Decision-Making,* **InformIT**, 2019, https://www.informit.com/articles/article.aspx?p=2992600&seqNum=2.

19. McKinsey Global Institute*, The Internet Of Things: Mapping The Value Beyond The Hype,* 2015, 2015, https://www.mckinsey.com/mgi.

20. United Nations, *Closing the Technology Gap in Least Developed Countries,* **United Nations**, 2021, https://www.un.org/en/chronicle/article/closing-technology-gap-least-developed-countries.

21. Z. Everistus & U. Emmanuel, *Issues and Challenges in Security and Privacy of Internet of Things (IOT) Automation View Project Access Control System View Project Issues and Challenges in Security and Privacy of Internet of Things (IOT)*, **International Journal of Latest Technology in Engineering**, vol. VII, 2018, www.ijltemas.in.

22. A. Olorundare, J. Olorundare & S. Sayyadi, *Internet of Things Prospect in Nigeria: Challenges and Solutions,* in 2017 **IEEE 3rd International Conference on Electro-Technology for National Development, NIGERCON 2017**, vol. 2018-January, Institute of Electrical and Electronics Engineers Inc., 2018, 736–45, https://doi.org/10.1109/NIGERCON.2017.8281942.

23. A. Mohammadzadeh, A. Mohammadian, B. Mahbanooei, S. Ghafoori, R. Ghasemi & R. Mohammadkazemi, *A Fuzzy Analytic Network Process (FANP) Approach for Prioritizing Internet of Things Challenges in Iran*, **Technology in Society**, 53 2018, 124–34, https://doi.org/10.1016/j.techsoc.2018.01.007.

Chapter Two

Literature Review

2.1 Conceptual Review

The contents of this chapter present historical developments in the approaches that deal with Multicriteria decision making in general and the concept of scientific prioritization.

In the section 2.1, an introduction to the general process of solving science prioritization problem demonstrates a sound background for the Multi criteria decision making support prototype system designed in this study work.

Analysis of related works carried out by other researchers concerning methods for multiple criteria science prioritization are discussed in section 2.2.

Some examples from the literature illustrate the past approaches on by other researchers were analysed .

After discussing the successes and failures of the historical approaches, in the last section, specific considerations for the current research integrating past work with the proposed research are discussed.

2.1.1 Decision Making

Decision making is the process of making choices by identifying a decision, gathering information, and assessing alternative resolutions. Using a step-by-step decision-making process can help you make more deliberate, thoughtful decisions by organizing relevant information and defining alternatives.

Organizations' executives and decision-making stakeholders at all hierarchies make decisions most of the times and fix problems. Decision making is a systematic procedure of narrowing observed gaps between current situation and a projected situation which is usually done via problem solving processes and at the same time, taking advantage of emerging opportunities.

At the end, a conclusion is normally a task that's taken with the intention of attaining the most well-liked goal[1].

George Terry reported that different scholars have defined Decision making in their own words. These definitions, seem to convey virtually similar meanings.

> "Different management scholars have defined Decision making as follows:
>
> **George Terry**
>
> Decision making is the selection based on some criteria from two or more alternatives.
>
> **Heinz Weihrick and Harold Koontz**
>
> Decision making is defined as the selection of a course of action among alternatives, it is the care of planning.
>
> **Louis Allen**
>
> Decision making is the work a manager performs to arrive at conclusion and judgement".

2.1.1.1 Characteristics of Decision-Making

Decision making has some features that describe what it is and what it stands for. The following are some of the common characteristics of decision making.

1. Decision Making is an Intellectual and Mental Process

Decision Making is not guesswork, instead, it is an intellectual process and mental process because it entails creative reasoning and thinking, sound and judgmental imagination, and not guesswork. whatever choices are arrived at in decision making, are purely based on systematic deliberations to make them fairly objective. These are mostly borne of good knowledge, expertise, high intellectual ability, a good educational level, and high mantal mental faculty[2].

2. *Decision Making is a Process*

Decision making is a continuous process of problem solving. They are an ongoing process that entails:

- evaluating situations, problems, challenges,
- considering existing alternatives,
- making choices based on relative weights of competing alternative, and
- following the choices made with the necessary actions.
- Establishing controls and evaluation systems.

At times, the decision-making procedure is considerably short, and mental reasoning invested is instantaneous. In other instances, the decision-making process can linger on for days, weeks, months or even years. interestingly most decision-making processes are based on available information to the decision makers at best suited times[3].

3. *Decision Making is an Indicator of Commitment*

Commitment is the ability to adhere to the decision-making process and following the choices with the necessary actions until completion. When decision makers do not adhere with the processes involved in making decision, implementing the decision becomes almost impossible. The result of that can be costly or devastating to the institution[4].

4. *Decision Making is a Best Selected Alternative*

Before making any decisions, all alternatives should be judiciously evaluated. The advantages and disadvantages of choosing each of these alternatives are known. This helps immensely in making best choices among the alternatives. In making alternative choices, the following should be put into considerations[5].

- First, the alternative chosen should align to the goals and objectives of the institution or company.
- Second, the alternative decided upon should be relevant to the currently assessed strengths of the institution.
- Third, opportunities need to exist for the alternatives chosen.
- Lastly, the alternative chosen should be effective and efficient in comparison with other alternatives.

5. Decision Making can be Positive or Negative

the decision of implementing any plan to do some work is positive, whereas the decision not to do any work or not to implement and plan is negative.

For instance, if a decision made is such that an action is not taken based on quest to avoid likelihood of occurrence of negative consequences, such a decision can be referred to as a negative decision. Conversely, if a decision is such that an action is taken based on what is expected to happen, or a resulting goal to be achieved, such decision can be termed as a positive decision. In this case, it's a goal oriented, wants oriented or needs oriented decision.

> "My contention is that if you make positive decisions, you will find that the majority of the negative perceptions you held that caused you to make a negative decision either never eventuate or are able to be countered as a result of the positive decisions you make. However, if you make negative decisions, the positive outcomes you could have achieved rarely eventuate"[6].

Negative decisions are equally as good and rewarding as positive decisions. In the same vein, while making decisions, the voice of inner mind is very important, along with the intellectual logic of the decision maker.

6. *Decision Making is the Last in Planning Process*

Decision making regarded as the final stage of every planning process since the outcome of the work is derived from it.

This result is usually obtained after comprehensive systematic deliberations on many possible competing alternatives.

For this purpose, decision-making, which is usually the last process, is the last stage of the discussions, intellectual analysis, ponderings, relative and analytic study of the competing alternatives.

7. *Decision Making is a Dynamic and Continuous Process*

As discussed in (2) above, decision making is a continuous process because they are Weinrich to be taken systematically and continuously within the life circle of decision making in business organizations, for Everyday jobs or special tasks.

Apart from being a continuous process, decision making is also dynamic, due to the fact that situations and circumstances around each decision are different from circumstances and of the past decisions.

8. *Decision Making is a Pervasive Function*

One pertinent characteristic of Decision making is that it is a pervasive function owing to the fact that it's application cuts across all business and non-business institutions, for virtually all administrative activities, at all the levels of Organization, and in all nations, etc.

AS a pervasive function, quiet a number of intellectuals regard decision making and management as synonymous. Without making decisions any kinds of function are practically nearly impossible[7].

9. Decision Making is a Measurement of Performance

The success or failure or execution or non-execution of certain decisions taken by the managers depends play vital roles in success or failure off an organisation in the achievement of its goals. This makes decision making an important bases for a measurement of performance of an organization's management or decision makers.

Hence, the emergence of the efficiency of decision makers is possible by measuring the effects of the decisions they have made[8].

10. Decision Making is a Human and Social Process

In the process of making effective decision, all human factors are expected to be factored into considerations. These are expected to be done before arriving at selection of best-fit alternative(s). Similarly, decision making includes the use of intuition and Justice. All these are human and social in nature.

11. Decision Making is in Art and Science, Both

Decision making can be said to an art because decisions are specifically taken for achieving firm pre-decided aims. This can only be done by using knowledge, imagination, talents, and foresightedness of the decision maker.

In addition, decision making is also a science, because in decision making, certain systematic stages are used in a particular sequence[9].

12. Other Characteristics of Decision Making

1. New decision arises from the decision-making process.
2. Decision-making is tantamount with Management.
3. Decision-making is part of planning process.
4. The forecast is part of decision-making.
5. Decision-making is different from the decision.

2.1.1.2 Elements of Decision Making

Elements of decision making are fundamental factors that should be put into consideration when making decision. They have tendencies of influencing decisions positively or negatively. Many scholars identify these elements differently. The following are some factors that should be put into consideration for effective Decision Making[10]:

- ***Information and Decision Rules*** – these are statements that identify the conditions in which decisions are expected to be made. It specifies how decisions are made. The following are six rules that can be used as guidelines for successful decision making[11]:
    - Clearly define the decision to be made.
    - Identify the obstacles you face in making this decision.
    - Compare at least 2 alternatives.
    - Get accurate information before you make a decision.
    - Know your most important values and rank them in terms of what is most important to you.
    - Don't let others or events decide for you
- ***Short Term and Long-Term Impact*** – while making effective decision, the decision makers should be aware of the short-term and long-term impacts of the decisions they make.
- ***Decision maker or Decision-making Body*** – Another element to be considered in effective decision-making is a well identified decision-maker or decision-Making

body who is authorised and responsible for making decision. A good decision maker yields positive results while a poor decision maker can complicate issues.

- ***Communication*** – Another important factor to be considered in decision-making is communication efficiency: ensure that the decision, once made, is known to all concerned stakeholders. – It is important that the effective communication takes place between the team who make decisions, those who implement the decision as well as the individuals that are affected by the decisions made.
- ***Decision Timing*** – To be useful, a decision must be done at the right time. – It should be made to meet the needs of the moment. In the same vein, important decision should not be unnecessarily delayed.

Other effective decision-making elements are:

- The decision goal(s).
- The Attitudes, values norms as well as personal goals of the person(s) making the decision.
- Assumptions regarding to future occurrences and things.
- The environment within which decision is made.
- Available alternatives with their imagined or estimated outcomes.
- Analytical results in the whole perspective.
- The constraints.
- The act of selection or choice.

2.1.1.3 Importance of Decision Making

In virtually any situation of your existence, you make decisions: we make more than 20,000 decisions daily, as a result, this skill of decision making is especially pertinent in an organization. However, as it pertains to a business or an organization, the essence of decision making cannot be over emphasized. Not only does making decision assist your organization in competing favourably with its competitors, but it also assists in redefining the visions of the organization as well as achieving its goals [12].

The following are the various benefits that can be derived from making effective decision-making[13].

1. It Saves Time and Money

Time management is one of the most important aspects in effective management. Top-notch decision-makers know that and that is why they always take time management seriously. Inefficient decision-making does not only waste a lot of time, it also drains away motivation.

The quicker the necessary decisions are made, the more time you save. This is particularly very important in organizations because time to them means money. So, time being wasted is no less than losing your money.

2. It Boosts Productivity

Good decision-making is known to have the potentials of boosting productivity in an organization in many ways.

In the first place, the employees will be motivated to put in more since they know the direction that the institution is heading towards. Their motivation to work will stem from the realization that their invested efforts would not go in vain. This increased commitment of employees to work goes a long way in increasing the institutions productivity.

3. It Makes the Best Use of Resources

In institutions that have large pools of resources, the management needs to put them in areas where they can contribute better for in the achievement of the company's goals and objective.

This helps the company to achieve its potential by not letting the resources go scarce and also reduces the waste of resources.

In effectives and top-tier decision making, resources are placed in the right places and directed from places where they are not needed.

4. It Enhances Efficient Costing

Good decision making enhances the management in putting products at a realistic cost. This in turn determines the future of the institution in the long-run. It governs where your institution is headed and the market segment the company is targeting.

If the company fails to deliver the correct decision and misses the right cost-plans even by small margins, there will be a lot at stake.

5. It Helps in Identifying Opportunities

Opportunities exists everywhere; however, the real deal is for the decision maker to identify them and make the best use of them. Albeit, poor decision-making does not only make opportunities slip through the hands of the decision maker, it often makes the opportunities appear as if they do not even exist.

6. It Establishes Achievable Goals

Decision makers that are able to establish attainable short and long-term goals are often more important than individuals who act on the goals. This is so owing to the fac that if you fail in identifying achievable goals, it becomes impossible to accomplish them no matter the effort you put on them. Instead, you will end up be wasting your precious time, money, and other resources.

In essence, sound management with excellent decision-making skills help immensely in analyzing and defining realistic goals while keeping the institution's vision in mind. This will ensure that you are moving in the precise path. It also sees to the fact that the places you're heading to aren't just dead-ends.

7. It Comes Up with New Products/Services

Expanding a company's products or services is a task that is usually not easy to more come by because it usually requires a good number of manpower and resources. Besides, a lot of risk factors are mostly involved. It is capable of bringing either a significant profit or huge loss. Therefore, the management needs to have creditable decision-making skills and techniques to pull this off.

8. Employee Hiring

As newcomers are hired to join the workforce of an institution, they do not only need to have the required technical skills knowledge and attitude, there are many more aspects that you'd need to look for as well. Soft-skills, background checks, and many more things require thorough analysis and decision making. So, decision-making plays a huge role here. Hiring the right candidate is very important, and quality decision-making in this case cannot be neglected as it is a necessary ingredient.

9. Better Marketing Strategies

Marketing strategies often puts an institution out in the open to gain recognition. If brands are not marketed well to customers, chances are that companies would find it difficult to reach its expected potential no matter how brilliant the company's products or services are.

10. Conflict Prevention

Failure to make strong and fair choices at the management level can often predispose conflicts in the lower tiers. Employees resort to disagreeing among themselves if the decisions are left unclear or aren't taken at all by the decision makers. So, to circumvent reaching to this situation, the organization needs to take strong and quick decisions.

2.1.1.5 Types of Decision Making

Decisions can be categorized under divergent groups. The grouping can be based on the scope of the decision, the importance of the decision as well as the impact that such decisions may create in the company. The different types of decisions are analyzed below:

A. Programmed and Non-programmed Decisions

Programmed decisions and Non-Programmed decisions are basically the two types of decisions made by executives. These decisions usually depend on the authority they have to make such decisions, their responsibilities, and rank in the organizational decision-making hierarchy[14].

Programmed Decision-making are usually repetitive, routine in nature and easier to make. They are common within the institution and largely automated. Programmed decisions are usually known as Procedures, Policies, or Rules. As a result, they usually do not require advanced degree of analysis and calculation. They surely do not need executives to supervise each of the decision-making process.

On the other hand, Non-programmed decision is innovative, go-getting, and often partial in nature. Since they are unique and usually non-recurring in nature, the decision makers must generally go through many steps in the standard decision-making process to make choices. In particular, the decision makers must analyse the problem at hand, identify competing alternatives, and make a choice of the best alternative.

The following table depicts the fundamental differences between programmed decision and non-programmed decisions.

Table 2.1 Programmed Decisions vs Non-programmed Decision

	Programmed Decisions	Non-programmed Decisions
1. Nature of Problem	Structured/Routine/Well-defined	Unstructured/Novel/Ill defined
2. Recurrence of Problem	Repetitive	Non-repetitive
3. Method of solving	Policies/Standards/Rules	Managerial Initiative
4. Judgment	Objective	Subjective
5. Probability of outcome	Some degree of certainty is involved	Uncertain
6. Level of management	Middle/Lower-level	Top-level
7. Types	Organisational/Operational/ Research/Opportunity	Personal/Strategic/Crisis Intuitive/Problem-solving

Source: [16].

Types of Programmed Decisions and Non-programmed Decisions:

Based in their individual characteristics in table 2.1 above, Tanuja classified the following types of decision as types of programmed decision and non-programmed decision types.

Table 2.2. Types of Programmed and Non-programmed Decisions.

Programmed decision	Non-Programmed decisions
• Organizational decisions • Operational decisions • Research decisions, and • Opportunity decisions.	• Personal decisions, • Strategic decisions, • Crisis intuitive decisions, and • Problem-solving decisions.

Source: Research Design, 2023

Although programmed decisions and non-programmed decisions have been defined differently, it was noted that:

> "there is no clear line of demarcation between programmed and non-programmed decisions. Decisions are neither totally programmed nor non-programmed. They are a combination of both and lie on continuum of decision; between totally programmed decisions at one end of the continuum and totally non-programmed decisions at the other end".

B. Description of Types of Programmed and Non-programmed Decisions:

1. Organisational and Personal Decisions:

Organizational decisions usually reflect the use of authority. Decisions that are taken in the interest of the entire institution or organization are generally referred to as organizational decisions. Conversely, decisions that are taken for personal interests are known as personal decisions. While organizational decisions can be delegated, personal decisions cannot be delegated.

Managers usually have the authority by default to make organizational decisions but they ideally lack the powers to make personal decisions (decisions that are based on personal sentiments or biases). For instance, firing an employee for not conforming to rules of the organization is an organizational decision but firing due to personal animosity is a personal decision. Table 2.3 C below depicts the differences between Organizational decision and personal decision[15].

Table 2.3 Organizational Decision vs Individual Decision

Table 1 Organizational decisions differ from individual decisions

Qualities	Organizational decision makers (managers, teams, work groups)	Individual decision makers (homelife, private professional practice)
Nature of work	Work with and through others	Personal choices/solo practitioners
Political influences	Strong political pressures can block or constrain decisions	Some but fewer political pressures
Accountability	Accountable for decisions by self and others	Accountable for own decisions
Decision types	Make many kinds of decisions, often concurrently	Make fewer kinds of decisions
Stakeholder diversity	Many stakeholders affect and affected by decisions	Fewer stakeholders affect and affected by decisions
Levels of uncertainty	Greater uncertainty due to missing information, difficulty interpreting situations, and environmental change	Uncertainty can vary, often low to moderate
Decision supports	Typically few decision supports and protocols	Professionals often have decision supports an protocols (e.g., checklists)

Source: [43].

2. Operational and Strategic Decisions:

These decisions reflect scope of decision-making processes. Operational decisions are usually routine in nature relating to daily operations carried out in the organisation. They are aimed at achieving short-term objectives of the company. Such decisions are usually taken by middle as well as lower-level managers. They align to the context of policies and procedures of the institution while allowing restricted use of discretion by managers. They have short-range with limited impact.

These decisions follow already laid down policies and procedures of the company. Example of operational decision is purchase of stationery, toiletries, raw materials, etc. these are part of day-to-day decisions taken by authorized individuals which affect only the purchase department are taken based on laid down procedures for the purchase department[15].

If decisions are important, yet non-recurring in nature, they are called strategic decisions. Unlike operational decisions, strategic decision require managerial skills in which critical judgment are used to make such decisions. They are made with long term goals of the organization in mind. They seek to define relationship between the organization and the environment and are risky in nature. Such decisions are usually taken by top-level decision makers or executives. Decisions to update the technology, select and prioritize challenges, launch a new plant or change the policies of an organisation are strategic decisions.

Strategic decisions usually organisation wholly or partially. More so, they contribute directly to the objectives of the organization. They usually bring am improvement on current situational experiences. They involve taking decisions like expansion of business in global markets, broadening, change in advertising mix etc.

3. Research and Crisis-intuitive Decisions:

These decisions reflect urgency of decision-making. Decisions which involve regular survey of the market are research decisions and decisions made under situations of crisis or emergency are crisis — intuitive decisions. For example, decision to allocate funds to Research and Development for product designing is a research decision; decision to increase production of medicines because of earthquake or war is a crisis-intuitive decision[15].

4. Opportunity and Problem-solving Decisions:

These decisions reflect foresightedness. Managers forecast opportunities to promote organizational growth. The decision to grow and diversify (market penetration and market development) is an opportunity decision.

Problem-solving decision solves a specific problem. For example, decision to enter into new markets even when the company is making profits in the existing market is an opportunity decision and decision to drop a product line because it is unprofitable is a problem-solving decision.

2.1.2 Multi-criteria Decision Analysis (MCDA)

2.1.2.1 What is MCDA?

MCDA, also known as Multi-criteria Decision Making (MCDM) is a structured process for evaluating options with conflicting criteria and choosing the best solution. Most decisions made by individuals and groups that involve ranking or choosing between alternatives (including people) are amenable to MCDA / MCDM. It is similar to a cost-benefit analysis but evaluates numerous criteria, rather than just cost[16].

As a practice, MCDA has applications in a number of fields, including business, government and everyday life. Here are some mainstream examples of MCDA / MCDM applications from the worlds of business, non-profits, government, health, education and personal decision-making:

- Short-listing job applicants
- Selecting projects or investments for funding
- Picking microfinance or aid programmes for support
- Prioritizing local or central government spending
- Prioritizing patients for access to health care.
- Ranking researchers or students for research grants or scholarships
- Choosing a new home, car or smartphone, etc
- Prioritizing challenges of Internet of things technology development.

2.1.2.2 Intuitive Decision-Making vs Multi-criteria Decision Making

Intuitive decision making is the way people make decisions naturally, without the use of formal tools and procedures.

Some talk about intuition as happening without any thought at all. Like "trusting your gut" or "using the force" in a sixth sense kind of manner.

The general idea is that experts make most of their decisions by matching them to their past experiences.

If they are in a familiar situation, the decision is automatic. They recognize a situation as being like ones they've encountered before, and an option comes to mind. In this sense, the decision feels intuitive at the "gut level."

Thus, your intuitive decision making is often done by matching situations to relevant past experiences, and quickly using them to draw conclusions[17].

In contrast, MCDA / MCDM, a sub-discipline of operations research with foundations in economics, psychology and mathematics, is concerned with formally structuring and solving decision problems. Most MCDA methods, which are increasingly supported by specialised software (e.g., 1000minds), involve the explicit weighting of criteria and the trade-offs between them.

Overall, MCDA is intended to reduce biases from decision-makers relying on their 'gut feeling', and also group decision-making failures (e.g., 'groupthink'), that almost inevitably afflict intuitive approaches. By making the weights and associated trade-offs between the criteria explicit in a structured way, MCDA results in better decision-making.

2.1.2.3 Multicriteria Decision Making Techniques

1. **Analytic Network process (ANP)**

ANP is a generalization of AHP which represents a decision-making problem as a network of elements (including criteria and other alternatives) that are grouped into clusters. In ANP, a network can incorporate feedback and complex inter-relationships within and between clusters which means all the elements in the network can be related in a possible way. This mechanism can provide a more accurate modelling of complex settings[18].

The ANP is a multicriteria theory of measurement used to derive relative priority scales of absolute numbers from individual judgments (or from actual measurements normalized to a relative form) that also belong to a fundamental scale of absolute numbers.

2. **Analytic Hierarchy Process (AHP)**

The Analytic Hierarchy Process (AHP) is a method for organizing and analysing complex decisions, using math and psychology. It was developed by Thomas L. Saaty and has been refined since then. It contains three parts: the ultimate goal or problem you're trying to solve, all of the possible solutions, called alternatives, and the criteria you will judge the alternatives on[19]. AHP provides a rational framework for a needed decision by quantifying its criteria and alternative options, and for relating those elements to the overall goal.

Stakeholders compare the importance of criteria, two at a time, through pair-wise comparisons. Example, do you care about job benefits or having a short commute more, and by how much more? AHP converts these evaluations into numbers, which can be compared to all of the possible criteria. This quantifying capability distinguishes the AHP from other decision-making techniques.

In the final step of the process, numerical priorities are calculated for each of the alternative options. These numbers represent the most desired solutions, based on all users' values.

Fuzzy Theory

Fuzzy sets theory is a simple yet very powerful, effective and efficient means to represent and handle imprecise information (of vagueness type) exemplified by tall buildings, large numbers, etc[20].

Fuzzy set theory allows that objects belong to a set, or couples of objects belong to a relation to a given degree. It allows partial membership of an object to different classes and also takes into account the relative importance of each neighbour with respect to the test instances[21].

A fuzzy set in X is an $X \rightarrow [0,1]$ mapping, while a fuzzy relation in X is a fuzzy set in $X \times X$.

2.1.2.4 Multicriteria Decision Analysis in Group Decision Processes

Group decision making is involved in the vast majority of consequential decisions where there is a need to choose which one out of many of alternative courses of action should be pursued, in view of the multiple objectives that are seen as important by the group members. Even if the decision is ultimately taken by a single individual, the decision may affect several stakeholders whose interests need to be recognized. In these situations, too, it may be instructive to organize consultation processes where the stakeholders' preferences are systematically charted, with the aim of informing the decision maker how the alternatives are perceived by the stakeholders[22].

The literature on multicriteria decision analysis (MCDA) offers numerous methods which help decision makers address problems characterized by multiple objectives. Fundamentally, these objectives represent the subjective values that are important in the decision-making situation. The articulation of these values in terms of corresponding objectives can be useful for many reasons: for instance, it fosters the identification, elaboration and prioritization of alternatives that contribute to the realization of values[23]. For example, the value of safety may suggest objectives such as reducing the number of accidents, reducing the severity of injuries in accidents, or providing faster access to first-aid services, which can be examined further to derive suggestions for alternative courses of actions for the improvement of safety. Indeed, the systematic concretization of objectives in terms of corresponding evaluation criteria and attendant measurement scales offers an operational approach for assessing how the alternatives contribute to the decision objectives and thus the realization of values. MCDA methods thus offer systematic frameworks that help synthesize both subjective and objective information, in order to generate well-founded guidance for decision making[24].

2.1.3 Decision Support System (DSS)

The information and/or data that we obtain from the real world often are complex, and comprise various kinds of noise. Besides, real-world information and/or data often are incomplete and ambiguous, owing to uncertainties of the environments. All these make decision making a challenging task.

To cope with the challenges of decision making, researchers have designed and developed a variety of decision support systems to provide assistance in human decision-making processes.

A decision support system (DSS) is a computer program application used to improve a company's decision-making capabilities. It analyzes large amounts of data and presents an organization with the best possible options available.

Decision support systems bring together data and knowledge from different areas and sources to provide users with information beyond the usual reports and summaries. This is intended to help people make informed decisions.

Typical information a decision support application might gather and present include the following:

- comparative sales figures between one week and the next;
- projected revenue figures based on new product sales assumptions; and
- the consequences of different decisions.

A decision support system is an informational application as opposed to an operational application. Informational applications provide users with relevant information based on a variety of data sources to support better-informed decision-making. Operational applications, by contrast, record the details of business transactions, including the data required for the decision-support needs of a business.

2.1.3.2 Components of Decision Support System

A typical DSS consists of three different parts: knowledge database, software and user interface[25].

1. **Knowledge Base.**

A knowledge base is an integral part of a decision support system database, containing information from both internal and external sources. It is a library of information related to particular subjects and is the part of a DSS that stores information used by the system's reasoning engine to determine a course of action.

2. **Software System.**

The software system is composed of model management systems. A model is a simulation of a real-world system with the goal of understanding how the system works and how it can be improved. Organizations use models to predict how outcomes will change with different adjustments to the system.

For example, models can be helpful for understanding systems that are too complicated, too expensive or too dangerous to fully explore in real life. That's the idea behind computer simulations used for scientific research, engineering tests, weather forecasting and many other applications.

Models can also be used to represent and explore systems that don't yet exist, like a proposed new technology, a planned factory or a business's supply chain. Businesses also use models to predict the outcomes of different changes to a system -- such as policies, risks and regulations -- to help make business decisions.

3. **User Interface.**

The user interface enables easy system navigation. The primary goal of the decision support system's user interface is to make it easy for the user to manipulate the data that is stored on it. Businesses can use the interface to evaluate the effectiveness of DSS transactions for the end users. DSS interfaces include simple windows, complex menu-driven interfaces and command-line interfaces.

2.1.3.3 Types of Decision Support Systems

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

4. **Data-driven DSS**

A data-driven DSS is a computer program that makes decisions based on data from internal databases or external databases. Typically, a data-driven DSS uses data mining techniques to discern trends and patterns, enabling it to predict future events. Businesses often use data-driven DSS to help make decisions about inventory, sales and other business processes. Some are used to help make decisions in the public sector, such as predicting the likelihood of future criminal behaviour.

5. **Model-driven DSS**

Built on an underlying decision model, model-driven decision support systems are customized according to a predefined set of user requirements to help analyse different scenarios that meet these requirements. For example, a model-driven DSS may assist with scheduling or developing financial statements.

6. **Communication-driven and Group DSS**

A communication-driven and group decision support system uses a variety of communication tools -- such as email, instant messaging or voice chat -- to allow more than one person to work on the same task. The goal behind this type of DSS is to increase collaboration between the users and the system and to improve the overall efficiency and effectiveness of the system.

7. **Knowledge-driven DSS**

In this type of decision support system, the data that drives the system resides in a knowledge base that is continuously updated and maintained by a knowledge management system. A knowledge-driven DSS provides information to users that is consistent with a company's business processes and knowledge.

8. **Document-driven DSS**

A document-driven DSS is a type of information management system that uses documents to retrieve data. Document-driven DSS enable users to search webpages or databases, or find specific search terms. Examples of documents accessed by a document-driven DSS include policies and procedures, meeting minutes and corporate records.

2.1.4 Introduction to Prioritization

2.1.4.1 What is Meant by Priority Setting?

Priority setting is a shared and multisectoral responsibility that relies on participatory and inclusive stakeholder engagement, including both people who will be affected by decision-making and people who can influence the implementation of the selected priorities during the priority-setting process.

2.1.4.2 Why is Prioritization Important?

To assist in selecting a car to purchase, we make an assumption that you will be using an evaluation condition of say 1. five-year life-cycle cost, 2. horsepower, and 3. safety. The life cycle cost (in Naira, for instance) comprises of purchase price of the car, taxes applicable, licenses cost, interest on loan, insurance premium, fueling, and maintenance costs. Let's assume that you streamlined the field to a maximum of three cars as follows: 1. Best car on five-year life-cycle cost, 2. best car on horsepower, 3. best car on safety. Which among the cars would you be buying? Your choice would obviously depend on which of the conditions or criterion are most preferred to you. In order to assist you make this important decision, it is pertinent to have a process of prioritization. This article describes such a process. Development of this prioritization process was stimulated by

a need to prioritize requirements, but the resulting prioritization process is not limited to requirements. It can also be used to derive weights of importance for tradeoff studies and to prioritize customer needs, capabilities, risks, activities, and functions. First, we will discuss some of the reasons that requirements should be prioritized. Then, we will discuss prioritization of other items and, finally, we will present the prioritization process.

2.1.5 The Internet of Things (IoT)

2.1.5.1 History of IoT

Most sites that attempt to explain the history of the web of Things want to offer you the entire story of how the web itself – and every one the technologies concerning it – came into being. However, as long as it's pretty darn obvious that you simply don't get the web of Things without first having a worldwide network to attach those things, let's skip this part and start with what you're really curious about – the history of IoT.

The term Internet of Things is 16 years old. The concept of connected devices dates back to 1832. When the first electromagnetic telegraph was designed, allowing direct communication between two machines through the transfer of electrical signals. However, the true Internet of Things history began with the invention of the Internet in the late 1960s. Back then, the thought was often called "embedded internet" or "pervasive computing". The phrase was at a time used as the title of some presentations for a new sensor project that was being worked on and it stuck from there[26].

"Suddenly, tales of the Prancing Pony [the first computer-controlled vending machine] at Stanford and realized that we didn't need to put up with this was brought to my memory, that we had the technology," Nichols later recalled. Soon, Nichols and a couple of friends had developed a system to attach to the machine via the APRANET – a precursor to today's internet – which enabled them to remotely check the status of the machine (i.e., see if there was drink available, and if it had been cold) before making the trip. Many say that this slot machine was the primary the primary true IoT-enabled device.

2.1.5.2 How IoT Works

The possibilities of the Internet of Things in all industries are practically endless – and indeed, the technology has so much more potential than just the smart fridge. But how does the Internet of Things work, and what are the fundamental components of a functioning IoT system?

Well, the first thing you need is sensors and devices with the ability to collect, store, transmit and receive data. Next is connectivity – the data that's collected needs to be communicated with other machines, and the internet is the primary vehicle through which this usually and most readily achieved. Normally, IoT sensors and devices will communicate with applications and services that are running in the cloud – and if this isn't achieved via the public internet, then it will be through some sort of private network, depending on the cloud model[26].

Data processing is the next step. Once the collected data has been passed from the device to the cloud, installed software can begin its analysis. To give you a simple example, data passed from the smart air conditioning unit in your home will be analysed to check that temperature readings are within an acceptable range. With Industrial Internet of Things (IoT) systems and applications, data processing is where the real IoT value and benefits lie, as the number of devices transmitting data can be huge, providing vital, real-time insights into the state of the

2.1.5.6 Technical Challenges of IoT

Outline requirements: Information requirements in developing countries differs from those in advanced countries. So IoT systems for developing countries generally have different design requirements and technological frameworks. As reported by the World economic Forum's report "Internet of Things Guidelines for Sustainability", the full potential of IoT acting as a catalyst to sustainable development is achieved when sustainability is integrated at the design phase of the IoT initiatives It further states thus "Address infrastructure solutions first to enable business models and facilitate scale"[26].

- **Inadequate Research:** In 2013, only 7 publications were published in peer-reviewed journals for every 1 million people in African Least Developed Countries. However, in the member countries of the Organisation for Economic Co-operation and Development, about 1,100 scientific and technical journal articles were published for every 1 million people[27]. Health is a key area in which innovations in mobile services have had important development impacts. In Malawi, Airtel 321 provides information on maternal and child nutrition via mobile phone in the local language. In Tanzania, an SMS-based application has been developed that makes the birth registration process more efficient, cost-effective and accessible for parents. In October 2016, Zipline, a combination high-tech start-up drone manufacturer, logistics service provider and public health-care system consultant, began using drones to deliver medical supplies to remote health clinics in Rwanda. Zipline's partnership with the Government of Rwanda has dramatically reduced the time it takes to deliver essential medical supplies. The Secretary-General's Strategy on New Technologies puts forward this message in a set of principles that give us the necessary framework to proceed with our efforts and ensure that the benefits of new technologies are put to use for equitable and sustainable development. We must avoid a head-long rush for the latest and greatest, which could result in marginalization and leave the poorest countries behind [28].

- **Simple and Cost-effective Technology:** As resources are lacking, simpler and cost-effective solutions may prove more suitable in a developing country context; the current trend is to deploy a dedicated infrastructure for IoT data, using Low Power Wide Area Network (LPWAN) technologies, in addition to the ones already existing for voice and human oriented Internet[29]. Although LPWANs are rather stable from the technical point of view, on the commercial side, strong contrasts are arising between hardware and service providers[30]. The alternative is to use established technologies, like Wi-Fi or 3G. From the technical point of view, they have very little in common, but both exhibit the basic capability to send or receive small pieces of data, being powered only when needed. In the first sub-stream, Walid Balid and his team investigates traffic and road surface control using a compact device that embeds a number of sensors, including a GPS receiver and an accelerometer[31]. The paper does not mention experimental results or implementation details to produce the device. Its cost is estimated of $30, and the study comes from the USA.
- **Lack of Modern Infrastructure:** Stable and reliable power supply systems are more limited in developing countries. The same happens with the availability of data centres [32].
- **Connectivity:** The International Telecommunication Union (ITU) estimated in 2016 that approximately seven billion persons, the 95% of the global population, live in an area that is covered by a mobile network. According to a Groupe Speciale Mobile Association (GSMA) report, 63% of Africans had access to improved water supply and 32% to electricity in 2014, compared to 82 % who had access to GSM coverage. In rural Africa, GSM/GPRS and 3G/4G are very costly for IoT devices[33]. Instead, short-range technologies like IEEE 802.15.4 can be used by administering multi-hop routing. Transmitted-receivers (wireless communications devices) consume an enormous amount

of power in a radio node, and as long-distance transmission needs immense power multi-hop routing could be a more energy efficient option than single-hop routing[34].

- **Internet Connectivity:** Internet connectivity is a prime issue for enabling IoT. Internet penetration in developing countries is increasing. In most developing countries, mobile broadband is more affordable than fixed broadband services. Figure 2 shows the growth of mobile broadband subscriptions during the period from 2012 to 2017. In industrialized countries, 94% of young people aged 15–24 use the Internet compared with 67% in developing countries and only 30% in Least Developed Countries (LDCs). However, overall figures reveal that of the 830 million young people who are online worldwide, 320 million (39%) live in China and India[35].
- **Power Supply:** As things move around and they are not connected to a power supply, their smartness needs to be powered from a self-sufficient energy source. On the other hand, Reliable power supply is a big challenge for enabling IoT in most of the developing countries, being solar and wind the effective solutions[36].
- **Lacking Local IoT Expertise:** In developing countries, one main challenge is lack of technically knowledgeable personnel due to IoT systems requiring regular maintenance, updates and function testing[37].

The prospect also brings a whole bunch of challenges. In developing countries, the administrative and financial systems run by mostly without any integrated and automated system. The level of technology usage is low, and the investment on research and development is very little. In the following sections, we focus on various IoT challenges in detail in respect to developing countries.

2.2 Review of Related Works

This section discusses research works done by other researchers that are closely related to this thesis work. The ultimate goal is to have a deep understanding of tools and techniques used by other researchers who have carried out works that bears similarities in methods, tools, etc. but with identifiable gaps that can be filled by this thesis work.

2.2.1 Decision Support System for Prioritizing Internet of Things Challenges Using Analytic Hierarchy Process (AHP) Method[38].

This is a Multi-criteria decision support system designed as a support system that is targeted at aiding company's decision stakeholders in prioritizing challenges of adoption and utilization Internet of things technologies with a view to ranking them in order at making decision on the selection of the head of the warehouse with the best assessment from several parties[38].

The system Analytic Hierarchy Process (AHP algorithm to prioritizes main and sub challenges of IoT based on their characteristic influence in affecting rapid adoption and utilization of IoT technologies. The results are expected to aid institutions to channel limited resources on most influential challenges of IoT. From the AHP algorithm will produce something that is very helpful for those in need[38].

However, the deficiencies observed in the system can be grouped into two as follows:

1. **Based on the Multi-criteria Analysis Technique Used:** While Analytic Hierarchy Process (AHP) algorithm has been widely used in multicriteria decision support systems globally, However, AHP has known drawbacks in its ccharacteristic inability to sufficiently and precisely capture the right judgments of the decision-maker(s)[39].
2. **Based on the Structure of the Decision Support System (DSS):** As discussed in section 2.1.3.20 of the literature review in this thesis report, DSS are supposed to be composed of three basic components namely: Knowledge base, Software system and User interface. DSS are supposed to be real world systems. However, the work of seem to have ended on paper as there does not seem to have any user interface for

navigation and data input/output. This makes it impractical and unusable, hance not fit to be called decision support system.

3. **Based on Specific Problem Area:** Both the research considered above and this thesis work employ multi-criteria decision-making algorithm in as the base technique for prioritization/Selection of the best alternative items. However, while the specific problem area addresses in the research above is in the selection of head of warehouse, this research work focuses on prioritization of challenges on adoption and utilization of Internet of things technology.

2.2.2 A Fuzzy Analytic Network Process (FANP) Approach for Prioritizing Internet of Things Challenges[40]

The research applies an integrated approach using fuzzy analytic network process (FANP) was to identify the most important IoT technology development challenges in Iran and prioritize them based on their characteristic influence in affecting rapid adoption and prioritization of challenges of IoT in Iran. The implemented approach took into account that technological factors, privacy and security issues, business related factors, legal and regulatory challenges, and cultural elements are the main factors which have an impact on IoT technology development. Besides, it was also taken into consideration that several correlations among the aforementioned classes exist.

The results indicate that “technological” and “privacy and security” challenges are the most significant factors which affect IoT. Furthermore, “business model”, “architecture and design” and “education and training” were ranked as the most considerable sub-factors respectively

FANP is an effective and widely used multi-criteria decision analysis approach adopted by most researchers globally.

However, the gap here is that the paper did not cover development of a real-world system with well-defined user interface for use by decision makers. A good decision support system should have a user interface for input/output and navigation purposes.

2.2.3 IoT Solutions in Farming

The most common IoT systems in agriculture are briefly described in this section along with some of its core features.

2.3 Summary of Gaps in Literature Reviewed

Our motivation for proposing an improved method and tool arose from the limitations of existing techniques as enumerated below:

1. **Scalability:** Techniques like AHP used in some of the research work discussed in section 2.2 above suffer from scalability problems because, requirements are compared based on possible pairs causing $n\ (n - 1)/2$ comparisons[40]. For example, when the number of requirements is doubled in a list, other techniques will only require double the effort or time for prioritization while AHP, pairwise com- parisons and bubble sort techniques will require four times the effort or time. This is poor in terms of scalability.
2. **Error Proneness:** Internet of Things have a network of numerous challenges and sub challenges[43]. Prioritization of these complex IoT challenges by a group of decision makers who are mostly uncertain about alternatives to choose at certain times would require more advanced decision comparison matrices like fuzzy triangular decision comparison matrices. The fuzzy triangular decision comparison matrix works more effective than the traditional decision matrix in Analytic Hierarchy Process in removing uncertainties emanating from the choices of the decision makers. The application of Analytical Hierarchy Process (AHP) used by Valentino is therefore

prone to errors and thus the generation of unreliable prioritization results. In such instances, the results do not reflect the true ranking of IoT challenges from stakeholder's point of view or assessment after the ranking process. Therefore, robust algorithms such as the ones in Fuzzy AHP are required to generate reliable prioritization results[41].

3. **Lack of Fully Implemented Support Tools:** From the literature, it was observed that most existing prioritization techniques have not been really implemented for real-life scenarios probably because of the complexities associated with prioritizations and the time required for generating prioritized requirements. Therefore, there is need to implement algorithms that will improve or support IoT challenges prioritization at commercial or industrial level. Before these algorithms can work efficiently, the methods for capturing IoT challenges in an unambiguous way must be well thought of since the output of prioritization processes depend on the inputs.

Endnotes

1. G. Terry, H. Weihrick, H. Koontz & L.Allen, *Handbook on Decision Making*, 2018.

2. GoogleDir, *15 Main Characteristics of Decision Making (With Examples),* **Googlesir**, 2022, https://www.googlesir.com/characteristics-of-decision-making/.

3. B. Jeff, *The 9 Characteristics of a Good Decision,* 2022, https://www.entrepreneur.com/article/250175.

4. K. Sean , *Importance of Building Commitment & Trust in Strategic Decision-Making* , **Study.Com**, 2022, https://study.com/academy/lesson/importance-of-building-commitment-trust-in-strategic-decision-making.html.

5. C. Craig, *Choosing Among Alternatives | Ag Decision Maker*, **IOWA State University**, 2007, https://www.extension.iastate.edu/agdm/wholefarm/html/c5-152.html.

6. Change Factory, *The Power of Positive Decision-Making*, **Change factory**, 2022, https://www.changefactory.com.au/our-thinking/articles/the-power-of-positive-decision-making/.

7. Course Hero, *2 Pervasiveness of Decision Making the Decision Is Made in All Managerial*, **Course Hero**, 2022, https://www.coursehero.com/file/p4rppqi/2-Pervasiveness-of-decision-making-the-decision-is-made-in-all-managerial/.

8. G. Da Silva e. Souza & E. Gomes, *A Performance Measure to Support Decision-Making in Agricultural Research Centers in Brazil,* **Procedia Computer Science 55**, no. Itqm (2015): 405–14, https://doi.org/10.1016/j.procs.2015.07.094.

9. Prime Care Technologies, *Data-Driven Decisions – an Art and a Science*, **Prime Care Technologies**, 2022, https://www.primecaretech.com/news/data-driven-decisions-an-art-and-a-science.

10. Slide to Doc, *Planning and Decision Making Definition and Importance Of*, **Slide to Doc**, 2022, https://slidetodoc.com/planning-and-decision-making-definition-and-importance-of/.

11. Wikipedia, *Decision Rule*, **Wikipedia**, 2022, https://en.wikipedia.org/wiki/Decision_rule.

12. A. Emidio, *10 Reasons Why Decision Making Is Important In Management*, 2022, https://www.analyticsfordecisions.com/decision-making-is-important-in/.

13. Harappa Learning Private Limited, *What Is Decision Making: Definition, Importance & Meaning of Decision Making,* **Harappa Education**, 2022, https://harappa.education/harappa-diaries/what-is-decision-making/.

14. IEduNote, *Programmed Decision and Non-Programmed Decision Explained*, **IEduNote**, 2022, https://www.iedunote.com/programmed-decision-non-programmed-decision.

15. A. Tanuja, *Types of Decisions: Programmed and Non-Programmed*, **Business Management Ideas**, 2022, https://www.businessmanagementideas.com/decision-making/types-of-decisions-programmed-and-non-programmed/4831.

16. Indeed, *What Is a Multiple Criteria Decision Analysis? (With Example)*, **Indeed.Com**," 2022, https://www.indeed.com/career-advice/career-development/multiple-criteria.

17. A. Pearman, J. Dodgson, L. Phillips & M. Spackman, *Multi-Criteria Analysis : A Manual,* **Appraisal**, vol. 11, 2009, https://doi.org/10.1002/mcda.399.

18. IGI Global, *What Is Analytical Network Process (ANP),* **IGI Global**, 2015, https://www.igi-global.com/dictionary/analytical-network-process-anp/43223.

19. D. Goepel, *Comparison of Judgment Scales of the Analytical Hierarchy Process - A New Approach,* **International Journal of Information Technology and Decision Making 18**, no. 2 (March 1, 2019): 445–63, https://doi.org/10.1142/S0219622019500044.

20. A. Meenakshi, *Fuzzy Matrix: Theory and Applications*, **Google Books**, 2021, https://books.google.com.ng/books?hl=en&lr=&id=4aacDwAAQBAJ&oi=fnd&pg=PA1&dq=fuzzy+theory&ots=XdAfqFSYaF&sig=sXDhYD8cL1DTZveqy2FslNj-26g&redir_esc=y#v=onepage&q=fuzzy theory&f=false.

21. J. Liu, H. Chen, P. Xie, P. Zhang, T. Li & Z. Yuan, *Attribute reduction methods in fuzzy rough set theory: An overview, comparative experiments, and new directions*, **Applied Soft Computing**, 2021: 107353, https://doi.org/10.1016/j.asoc.2021.107353

22. A. Salo & P. Hämäläinen, *Multicriteria Decision Analysis in Group Decision Processes*, 2010, 269–83, https://doi.org/10.1007/978-90-481-9097-3_16.

23. G. Odu, *Weighting Methods for Multi-Criteria Decision Making Technique*, **Journal of Applied Sciences and Environmental Management 23**, no. 8 (September 11, 2019): 1449–57, https://doi.org/10.4314/jasem.v23i8.7.

24. D. Marco, *Multi-criteria analysis*, **Advances in Transport Policy and Planning**, vol. 6, 2020: 165-224, http://dx.doi.org/10.1016/bs.atpp.2020.07.001.

25. TechTarget Contributor, *What Is a Decision Support System (DSS)*, **TechTarget Contributor**, 2022, https://www.techtarget.com/searchcio/definition/decision-support-system.

26. S. Jade, *History of the Internet of Things (IoT)*, **IT Blog**, 2021, https://www.itonlinelearning.com/blog-history-iot/.

27. United Nations, *Closing the Technology Gap in Least Developed Countries,* **United Nations**, 2021, https://www.un.org/en/chronicle/article/closing-technology-gap-least-developed-countries.

28. F. Daniel, *Unpacking the UN Secretary-General's Strategy on New Technologies,* **IPI Global Observatory**, 2021, https://theglobalobservatory.org/2018/09/unpacking-secretary-generals-strategy-new-technologies/.

29. Lirima, *(English) IoT4D – Internet of Things for Developing Countries*, **LIRIMA**, 2021, https://lirima.inria.fr/fr/focus-on-a-joint-project-team-iot4d/.

30. A. Ciuffoletti, *Low-Cost IoT: A Holistic Approach*, **Journal of Sensor and Actuator Networks 7**, no. 2, 2018, https://doi.org/10.3390/jsan7020019.

31. W. Balid & H. Refai, *On the Development of Self-Powered Iot Sensor for Real-Time Traffic Monitoring in Smart Cities*, **In Proceedings of IEEE Sensors**, vol. 2017-December (Institute of Electrical and Electronics Engineers Inc., 2017), 1–3, https://doi.org/10.1109/ICSENS.2017.8234157.

32. J. Sattelberger & T. Scherf, *Internet of Things-Hype or Hope for Developing Countries?*, June 24, 2016, moz-extension://1660c496-045a-4211-85b3-d2879d15cc70/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fwww.kfw-entwicklungsbank.de%2FPDF%2FDownload-Center%2FPDF-Dokumente-Development-Research%2FInternet-of-Things-%25E2%2580%2593-hype-or-hope-for-developing-countries.pdf.

33. K. Opala & M. Nique *The SynergieS beTween Mobile, Energy and WaTer AcceSS: Africa*, 2014, http://www.gsma.com/mobilefordevelopment/new-report-on-sizing-the-opportunity-of-mobile-to-support-energy-water-access.

34. H. Han, H. Wu, S. Sun & X. Wang, *Research on Artificial Intelligence Enhancing Internet of Things Security: A Survey,* **in IEEE Access**, vol. 8, 2020, pp. 153826-153848, doi: 10.1109/ACCESS.2020.3018170.

35. B. Lee, D. Jeong, I. Hong, J. Lee, S. Park & Z. Zhou, *IoT-Based Smart Garbage System for Efficient Food Waste Management*, **Scientific World Journal** 2014, https://doi.org/10.1155/2014/646953.

36. C. El-Bayeh & K. Alzaareer, *Steps toward Smart Energy Self-Sufficient Buildings*, **IEEE Smart Grid**, 2021, https://smartgrid.ieee.org/newsletters/april-2020/steps-toward-smart-energy-self-sufficient-buildings.

37. A. Singh, A. Tripathi, K. Singh, N. Firoz, P. Choudhary & P. Vashist, *Internet of Things: From Hype to Reality*, **in An Industrial IoT Approach for Pharmaceutical Industry Growth, Elsevier 2020**, 191–230, https://doi.org/10.1016/b978-0-12-821326-1.00007-3.

38. A. Putra & N. Dewi, *ECONOMIC-Looking at the Implication and Solutions in the Time of Pandemic through Social, Economic, Educational, Health, and Legal Points of View and Perspectives Decision Support System for Head of Warehouse Selection Recommendation Using Analytic Hierar*, **The International Conference of Universitas Pekalongan** 2021, 2021, 43–50.

39. P. Achimugu, A. Selamat, & R. Ibrahim, *ReproTizer: A Fully Implemented Software Requirements Prioritization Tool*, **Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)** 9655, 2016: 80–105, https://doi.org/10.1007/978-3-662-49619-0_5.

40. B. Regnell, J. Karlsson & C. Wohlin, *An Evaluation of Methods for Prioritizing Software Requirements*, **Information and Software Technology** 39, no. 14–15, 1998: 939–47, https://doi.org/10.1016/s0950-5849(97)00053-0.

41. F. Lelli, *Interoperability of the Time of Industry 4.0 and the Internet of Things*, **Future Internet**, MDPI AG, February 3, 2019, https://doi.org/10.3390/fi11020036.

42. D. Rousseau, *Making evidence-based organizational decisions in an uncertain world*, **Organ Dyn,** 2018, https://doi.org/10.1016/j.orgdyn.2018.05.001

43. A. Mohammadzadeh, A. Mohammadian, B. Mahbanooei, S. Ghafoori, R. Ghasemi & R. Mohammadkazemi, *A Fuzzy Analytic Network Process (FANP) Approach for Prioritizing Internet of Things Challenges in Iran*, **Technology in Society**, 53, 2018, 124–34, https://doi.org/10.1016/j.techsoc.2018.01.007.

Chapter Three

Methodology

3.1 Research Approach

The research approach in this thesis work falls under experimental research. 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.

3.2 Requirements Specification

3.2.1 Software Process Model

In the course of this thesis work, prototype process model is adopted[1]. This takes advantage of the following.

- ✓ Errors can be detected much earlier as the sample users test the systems and provide feedbacks.
- ✓ Missing functionality can be identified easily
- ✓ Project can be carried out within the time bound thesis timelines.
- ✓ Quick implementation of, incomplete, but functional, application.

3.2.2 Stages in The Software Prototype Model

Figure 3.1 below shows the steps carried out in the prototyping model adopted in the development of the MCDSS in this thesis work.

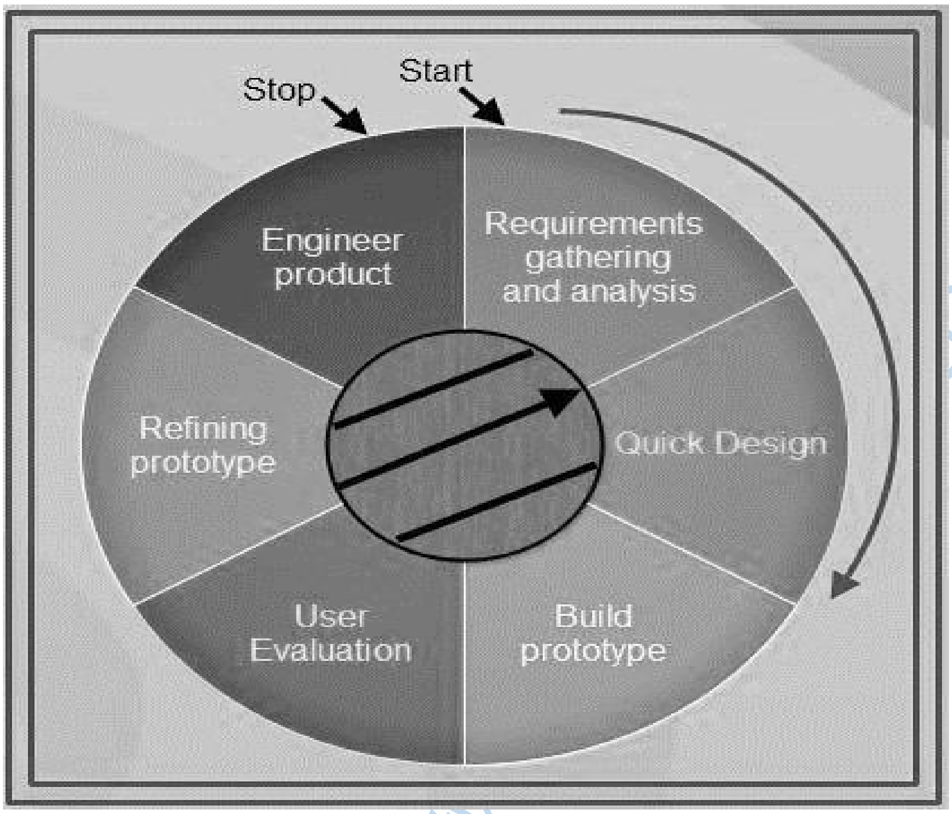

Figure 3.1 Software Prototyping Model Sorce: [7].

1. **Requirements Analysis Stage:** based on the expected research on the expected behavior of the MCDSS and the expected input and output of the system, rough assumptions were formulated on the user interface design, the database design, etc.

2. **Quick Design Stage:** At this stage, preliminary design or quick design for the system is created. It is not a detailed design though but it includes the important aspects of the system. This gives a clear idea of what the finished prototype is expected to be like. This quick design helps in developing the prototype.

3. **Prototype Building Stage:** At this stage**,** system design document obtained from stage 2 above is used to develop the initial prototype. This initial prototype represents the working model of the required system.

4. **User Evaluation:** Next, at this stage the prototype MCDSS system will be presented to group of randomly selected users who have basic knowledge of challenges of adoption of internet of thing. The purpose of this is to enable them to recognize the strengths and weaknesses of the MCDSS regarding the things be added or removed. Comments and suggestions are also to be collected from the users which in turn would be used to enhance the system.

5. **Prototype Refine State:** After the sample users evaluate the prototype and comments and suggestions are obtained, the comments are used to refine the system. That is, a new version of the prototype is developed with the additional information provided by the user. The improved prototype is evaluated just like the previous prototype version. This process continues improvement is maintained until all the comments and suggestions contributed by the users are exhausted.

6. **System Engineering Stage:** Once the suggestions and comments are completely exhausted and the system is significantly improved. It is then evaluated thoroughly. Code base is re-factored to minimize the lines of codes.

3.2.3 Benefits of the Existing Systems Based on Related Literature

1. The works of researchers analyzed above are beneficial as they Provides algorithms, other tools and data that can be used as basis for prioritizing challenges of adoption and utilization of IoT Technology.
2. Reviewed research works could be beneficial in best Student selection recommendation. Also, the Decision support system contributed are vital tools for

thesis session pass recommendation. They aid in exposing decision makers to the world of organised and scientific decision processes[12].

3. The overall benefits are that they help:

- Improve decision quality.
- Reduced cost.
- Decision time saving.
- They contribute to improved communication.
- They contribute to improved customer satisfaction.

3.2.4 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.

3.2.5 Requirement Analysis of the MCDSS

Requirement analysis is the process of determining the services the proposed MCD support system provides for the users and the constraint under which it must operate. It also describes the features the system must possess so as to satisfy users' experience. Requirement analysis is divided into two which are functional requirements and non-functional requirements.

3.2.5.1 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:

3.2.5.2 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.

3.2.5.3 Add Project Page

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

- The MCDSS must be able to validate user inputs for corresponding fields
- Mandatory data fields such as Project name, Organization Name, etc. must be provided before a project is created.

- The system should be able to allow addition of stakeholder(s) while creating a project.

- The system should have record duplication control mechanism by utilizing unique record id.

3.2.5.4 Projects List Page

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

- Displays all the projects that are entered in the system.
- Displays the list of columns such as Project ID, Project Name, User Name, Assigned

Status, Date of the project information and many more.

3.2.5.5 Add User Page

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

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

3.2.5.6 All Users

This screen displays all created users in the system regardless of their roles in the system.

- The system should be able to allow an admin user to change other users' access level
- Edit feature should be able to allows the admin to change any other field regarding to other users.
- Delete feature should allow admin user to delete other users from the system

3.2.5.7 Add/Modify IoT Challenges Page

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

- System must be able to add new IoT challenges/Sub challenges to the system apart from the default challenges adopted.
- The system should be able to validate the user inputs for corresponding mandatory fields

3.2.5.8 IoT Challenges List Page

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

- System should be able to allow the system administrator carry out edit/delete action
- The Edit functionality allows administrator to modify the IoT challenges related information
- Delete function should allow the system administrator to delete the IoT challenges from the system.

3.2.5.9 Decision Data Input Page

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

3.2.5.10 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.

3.2.5.11 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

3.2.6 Software Development Tools Used

3.2.6.1 Integrated Development Environment (IDE) Used

The IDE used for development of the MCDSS is Microsoft's Visual Studio 2022. visual studio 2022 a popular, higher authority software that is used by a majority of companies all over the world. It is a top dot NET tool that is well-known by engineers for planning and creating portable applications as well as web applications using Asp.Net. Visual studio also deals with large-scale programming advancements. The following are some of the outstanding features of visual studio 2022.

- It uses what-you-see-is-what-you-get (WYSIWYG) interface architecture, thereby focusing on drag-and-drop visual events;
- It emphasizes Projects & Solutions.
- It has an auto-completion of typed code, a debugger, database integration, server setup and configurations.
- It features bug tracking, source control as well as deployment tools for many different app types
- It is best for .NET developers

- It works great for developing cross platform operating systems applications like OS, Android, and Windows
- It supports a variety of programming languages. E.g. C#, Visual Basic, C++, TypeScript, F#, JavaScript, Python, etc.

3.2.6.2 Programming Language Used

The programming language was designed by Anders Hejlsberg of Microsoft. It was released in the year 2000. In November 2021, Microsoft released version 10 of C#. It was released alongside .NET 6 for Linux, Windows and macOS, as well as the latest version of C# (Visual Studio 2022) Visual studio 2022 is the first 64-bit version of Visual Studio. The .NET release that cones with it also supports Apple Arm64 Silicon as well as Windows Arm64.

According to Tiobe's rankings, C sharp is at the moment the fifth most popular programming.

3.2.6.3 Framework Used

ASP.NET MVC Framework was developed by Microsoft as a is a software development platform for building as well as running Windows applications. It consists of programming languages, developer tools, as well as libraries for building web and desktop applications. It is also used to build games, websites and web services.

3.3 System Design

3.3.1 Unified Modelling Language (UML) Diagrams

3.3.1.1 Use Case Diagram of the Multi-criteria Decision Support System (MCDSS)

Use Case diagrams represents the functionality of the system from the user's point of view. In the Unified Modelling Language, use case diagrams are used to show the functionality that the system will provide and to show which user will communicate with the system in some way to use that functionality. The use case diagram of the is shown in Figure 3.2

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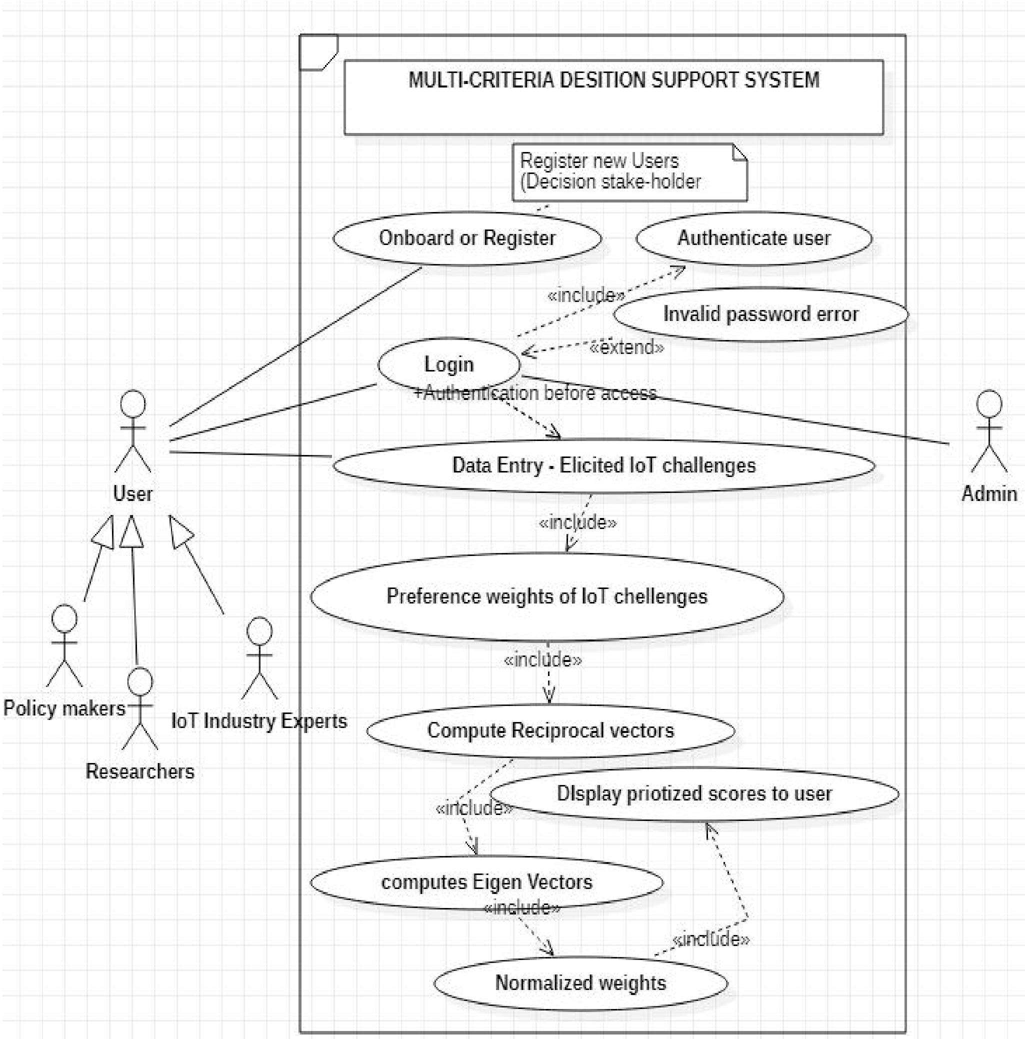


Figure 3.2 Use Case Diagram for the MCDSS
Source: Research Design, 2023

3.3.1.2 Context Level Diagram of the Multi-criteria Decision Support System (MCDSS)

In the Context Level, the whole system is shown as a single process and no data stores are shown. Inputs to the overall system are shown together with data sources (as External entities).

Outputs from the overall system are shown together with their destination (as External entities). The diagram is shown in Figure 3.3

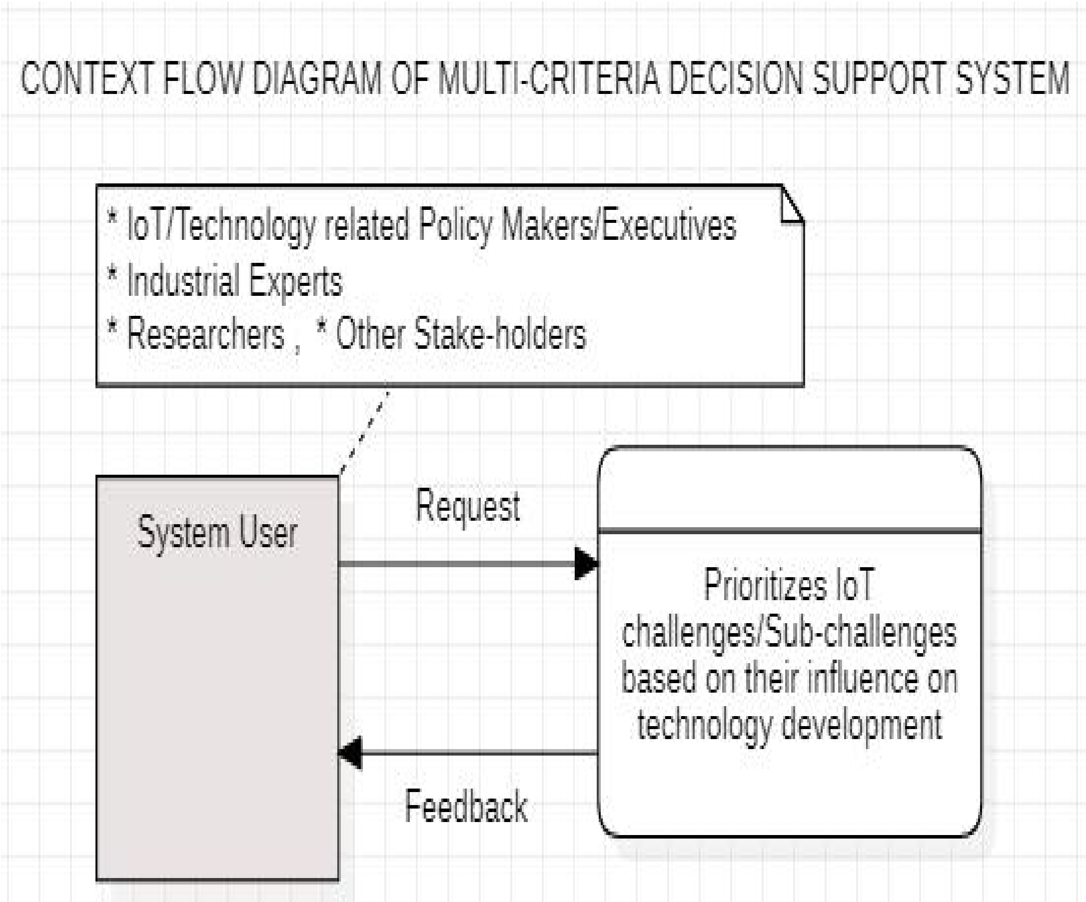


Figure 3.3 Context Level Data Flow Diagram of the MCDSS
Source: Research Design, 2023

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

According to Valacich and his research team, A Data Flow Diagram (DFD) is a graphic that illustrates the movement of data between external entities and the processes and data stores within a system.

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

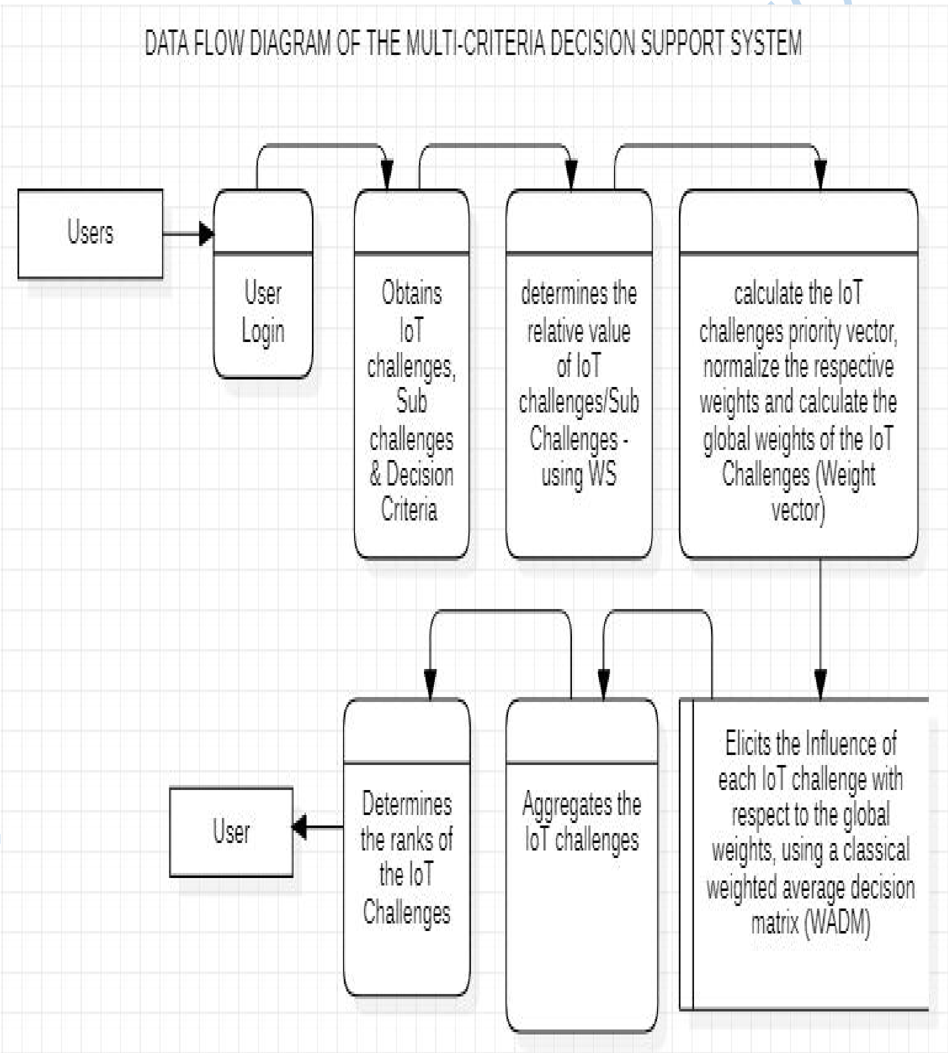


Figure 3.4 Data Flow Diagram of MCDSS Source: Research Design, 2023

3.3.1.4 Entity Relationship Diagram

Entity-Relationship (ER) diagram is used to represent the information structure of the system. This is shown in Figure 3.5 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.

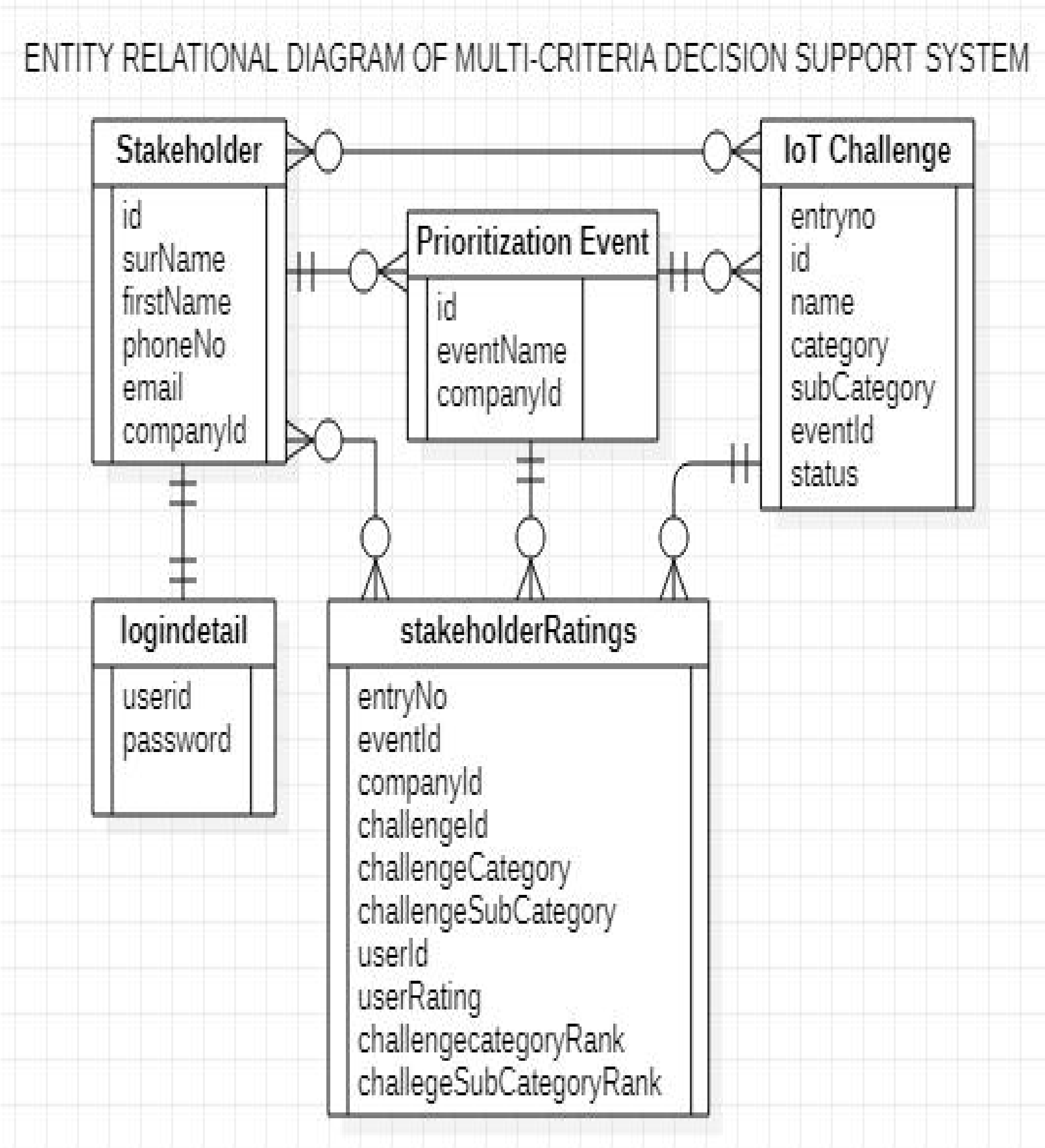


Figure 3.5 Entity Relational Diagram of MCDSS Source: Research Design, 2023

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

The architecture of the MCDSS as shown in Figure 3.6 explains the major interactions among the various sub units of the MCDSS. The system adopts ASP.NET MVC Architecture.

The Model-View-Controller (MVC) architectural pattern in software engineering has been in existence for a long time. The architecture is supported in ASP.NET framework of Microsoft's visual studio integrated development environment (IDE).

MVC represents Model, View, and Controller. MVC groups a software application into three main components - Model, View, and Controller.

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.

View: View in MVC is the interface which the system user interacts with. It displays model data to the system user. It also enables the user to insert, modify or delete data. 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.

Controller: The controller is the engine room of the system. It handles all system user request. Typically, the user raises an HTTP request through the view, which will be handled by the controller. The controller processes the request and returns the appropriate view as a response.

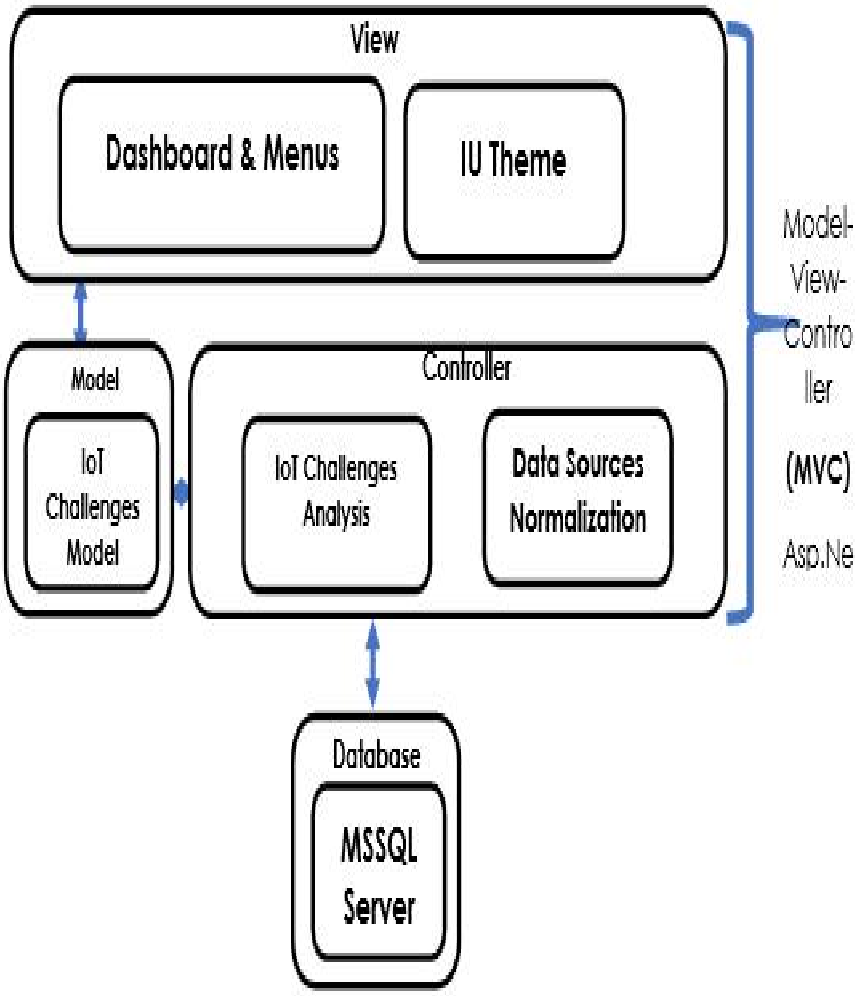


Figure 3.6 Architecture of the MCDSS Source: Research Design, 2023

3.3.1.6 Flowchart of the Multi-criteria Decision Process Based on Fuzzy Analytic Hierarchy Process (FAHP) Technique

In order to simplify the fuzzy AHP process of prioritizing challenges of IoT from a practical and feasible viewpoint, the fuzzy AHP based on fuzzy interval arithmetic that uses triangular fuzzy numbers plus confidence index α has been proposed. This adopts interval mean approach to determine the weights for evaluative elements. The flow chart representing the process is shown in figure 3.7 below. The flow chart has been divided into five phases:

i. Planning,

ii. Fuzzification,

iii. Fuzzy operations,

iv. Defuzzification and

v. Normalization

vi. Result presentation.

From the analytic outcome of this integrated model, a relative importance ranking for each pairwise prioritization hierarchy is obtained. In order to model this type of uncertainty in ways that are preferable by humans, the fuzzy sets its possible to incorporated the fuzzy sets with the pair wise comparison as an extension of analytic hierarchy process (AHP). Also, since most decision-making tasks are commonly known to be fuzzy and vague, the fuzzy AHP approach is used to allow a more accurate outcome of the decision-making process. A major importance of fuzzy set theory is its ability of representing vague data.

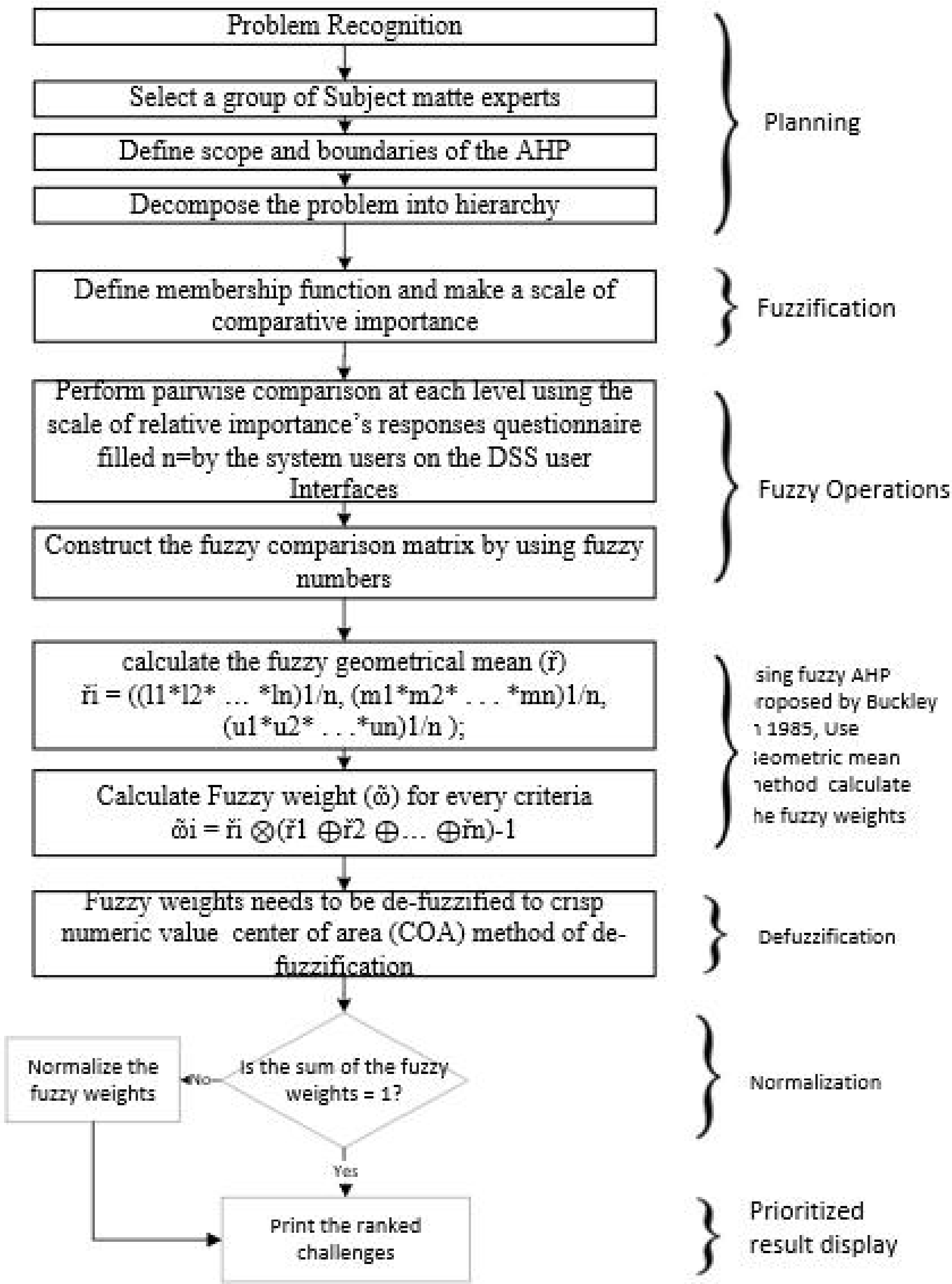


Figure 3.7 Flowchart of the Proposed Multi-Criteria Decision Process Based on Fuzzy Analytic Hierarchy Process (FAHP) Technique Source: Research Design, 2023

3.3.2 The Multi-criteria Decision Support System (MCDSS)

In order to get a perspective of what the MCDSS's applicability, this Project will sketch out the different components of the system and also demonstrate how the system can be used as a tool to assist decision making in solving inherent challenges of IoT in adoption and utilization of IoT technologies.

The MCDSS proposed in this thesis work is a web-based application that can be used as a pairwise comparison support tool by group of users in government organisations, business entities, scholars, researchers, IoT industry experts, etc who are desirous of ranking or prioritizing categories of challenges they have that that has affected their adoption and/or development of technologies of Internet of things(IoT). The proposed system uses an effective and efficient scientific decision-making technique known as Fuzzy Analytic Hierarchy Process to prioritize main and sub-challenges of IoT based on the user(s) perceived influence of these challenges on adoption of IoT technologies in their respective institutions. The use of the proposed system is expected to assist in:

- Improve decision quality;
- Giving direction on most influential challenges to solve within limited resources – thereby reducing cost; saving decision time;
- Improved communication among decision making stake-holders.
- Improved customer satisfaction when the bottle-necks in challenges reduction have been eliminated.

The processes involved in using the decision support system (DSS) by the users who have been fully registered and validated through the user interface can be summarised five distinct steps;

Step 1 – Create Project;

In this stage, a new IoT prioritization project or task name is created. The name by default is named Goal. The user can modify this to any project or task name of interest. The users at this stage are admin users. The admin users are responsible for adding other users. The added users are at this stage sent email notifications inviting them to participate in the decision of IoT challenges prioritization. The nominated users follow the email links sent to them to enrol into the project created.

Step 2 – Create Hierarchy Structure;

The hierarchical chart stage is used to define the IoT main challenges and sub-challenges in the form of hierarchical charts. Figure 3.1 below shows sample IoT challenges hierarchy that can be created by the proposed DSS admin user. As shown in the figure, three challenges have been created each with their respective sub challenges. These would form part of the input to the fourth stage in the process. However, to prepare grounds for easy creation of the challenges Hierarchy, the system user is presented with default with the IoT challenges hierarchy adopted from the base project used in this thesis[7]. The user however, should be able to modify these hierarchy of challenges to suit the flexibility of their peculiar IoT adoption challenges.

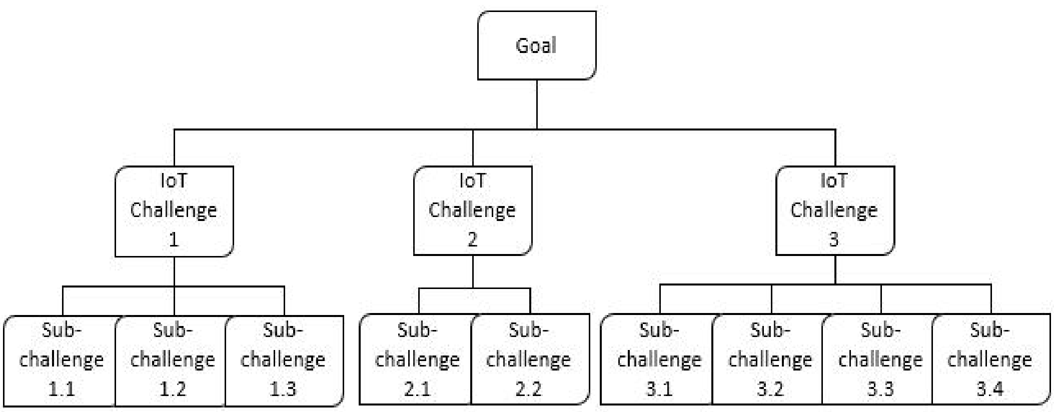


Figure 3.8 Sample IoT Challenges Hierarchy Source: Research Design, 2023

Step 3 – Select/Modify Fuzzy AHP Pairwise Comparison Scale (Triangular Comparison Scale);

The third stage the DSS system takes in the process of prioritizing the challenges of IoT is to select a standard fuzzy AHP pairwise comparison scale for use in the challenges weights determination. For the sake of simplicity of use of the DSS application by the user, the system by default adopts a standard five (5) level fuzzy AHP pairwise comparison scale as shown in the figure below; This stage is skipped from the user interface, however, the DSS system uses the scale in a linguistic form on the user interface to allow the user make choices of among alternative IoT challenges.

Table 3.1 Triangular Fuzzy Conversion Scale

Linguistic Scale	**Crisp Value**	**Triangular Fuzzy Scale**	**Triangular Fuzzy**

			Reciprocal
Equally Influential IoT challenge	1	(1, 1, 1)	(-1, -1, 1)
	2	(1/2,2,4)	(-4,-2,-1/2)
slightly more influential IoT challenge	3	(1, 3, 5)	(-5, -3, -1)
	4	(2,4,6)	(-6,-4,-2)
Moderately more influential IoT challenge	5	(3, 5, 7)	(-7, -5, -3)
	6	(4,6,8)	(-8,-6,-4)
More influential IoT challenge	7	(5, 7, 9)	(-9, -7, -5)
	8	(6,8,8)	(-8,-8,-6)
Extremely more influential IoT challenge	9	(7, 9, 9)	(-9, -9, -7)

Source: [8].

Step 4 – Enter/provide Decision Input Data/Make Decision Choices;

This is the stage where each of the onboarded decision making stake holder makes pairwise comparison choices among the various IoT challenges and sub challenges. The DSS present to the user pairwise comparison questions in the form of comparative questionnaire questions that uses the linguistic languages in table 3.1.10 in the form of questions on each of the competing IoT challenges alternatives. Appendix I shows sample pairwise questionnaire that was formulated using the IoT challenges adopted from the base project used in this thesis[7].

Step 5 – Print Results;

The DSS takes in the input data in step 4 above and processes it to output the IoT challenges in a ranking order with their relative weights that represents the influence they have in affecting the adoption and development of IoT technologies.

3.3.3 Problems With Existing Systems Based on Related Literature

Our motivation for proposing methods and tools used in this thesis work arose from the limitations of existing techniques that were garnered from related literature as enumerated in section 2.3 in chapter two.

3.3.4 Fuzzy Analytic Hierarchy Process (FAHP) Multicriteria Decision Making Analysis Process Design

3.3.4.1 Process of Fuzzy Analytical Hierarchy

Although the Analytic Hierarchy Process (AHP) is simple and widely used, its approach is known to have certain drawbacks. AHP's evaluations are dependent upon decision makers' or experts' opinion, their expertise levels as well as competences in the subject area of interest. However, the preferences of the experts or decision makers may be biased as a result of their personal convictions, even when their ideas are professional in nature. In this case, AHP often fails to translate and/or reflect the imprecision and/or fuzziness in the understanding of human since is only known to represent values as crisp values, The use of an analysis tool that can handle uncertainties may be of high advantage because of the use of ambiguity of the evaluation process[2].

An operations research-based theory called fuzzy set theory can be utilized to model uncertainties of linguistic judgments as well as subjective. The drawbacks of crisp values regarding to uncertainties in real-world solutions have been addressed by the use of both fuzzy sets and fuzzy logic in multi criteria decision making processes. Fuzzy set theory is used to create decision models that help companies determine their market position and raise the standard of their services[3].

In addition, the fuzzy set theory was introduced in order to take care of the uncertainties that are inherent in human judgments. The works of Bellman contributed by introducing fuzzy set theory into multicriteria decision making as an approach that is capable of effectively dealing with known imprecision, indistinctness and ambiguity related to human decision-making process. A preferential element is then calculated by aggregating all criteria weights and alternatives ratings across decision makers where elements with higher weights are considered to be the most valued [4].

3.3.4.2 Proposed Fuzzy Analytic Hierarchy Process (FAHP) Technique Design

The hierarchical structure (Figure 3.9) of the factors/Challenges and sub-factors/sub-challenges militating against adoption and/or development of IoT challenges used in this thesis work is adopted from the base project used in this thesis[7].

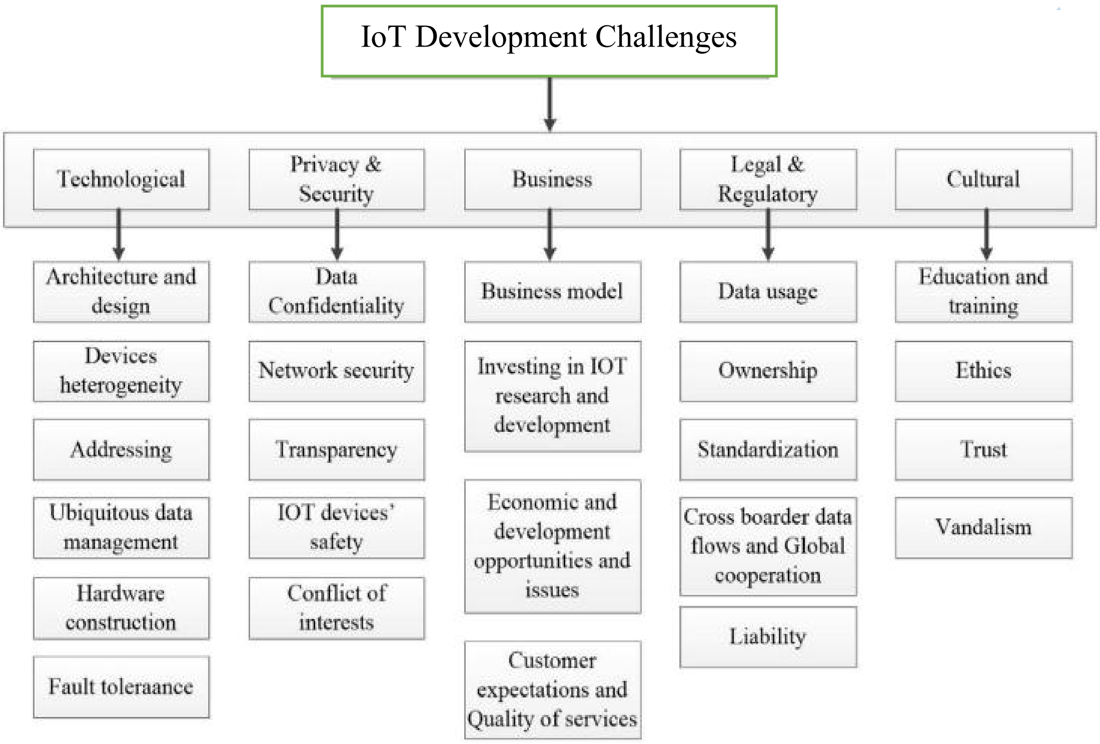


Figure 3.9. IoT Technology Development Challenges Hierarchical Structure.
Definition Source: [8].

As seen in figure 3.9, there are five main factors/challenges (Technological, Privacy and Security, Business, Legal and Regulation as well as Cultural), each of which have multiple sub-challenges.

One of the goals of this thesis is to use the hierarchical structure of factors, as a default alternative factors/sub factors affecting the adoption of IoT technologies. Users are expected to make comparisons from among these challenges using the linguistic terms in the scale of relative importance in figure 3.11. Next, the users' input would be used to form pairwise comparison matrix. Finally, the input data would be processed using Multi-criteria Decision-making technique of Fuzzy Analytic Hierarchy Process (FAHP).

Following the flowchart in figure 3.7 above, for our FAHP process, we will design our multi-criteria decision-making module of the system in the following stages:

Stage 1 - Planning

As shown in in the flowchart in figure 3.7, the planning stage usually involve:

1. Recognizing the problem,
2. Selection of group of experts or decision stake holders;
3. Definition of the scope and boundaries of Analytic Hierarchy (AHP);
4. Decomposing the problem into hierarchy;

However, by fully adopting the IoT technology development challenges hierarchical structure in figure 3.9, all the 4-planning stage have stage has already been taken care. The hierarchical structure of the IOT challenges aligns to the global standards of hierarchical structure of FAHP as enumerated below.

a. Goal is kept in the first Level. In this thesis, the goal is to prioritize factors/challenges of IoT technology development.
b. Criteria is kept in level 2 (In our case they are driven by the scale of relative importance).
c. Alternatives is kept in level 3 (These are the IoT technology adoption and development challenges/sub challenges) each of which should have their own value of criteria associated with them by way of pairwise comparison of the challenge, relative to each of the other IoT challenges. Figure 3.10 below shows a typical standard hierarchical structure of our FAHP process.

Hierarchical Structure of our Fuzzy Analytic Hierarchy Process for Prioritizing Challenges of IoT Development

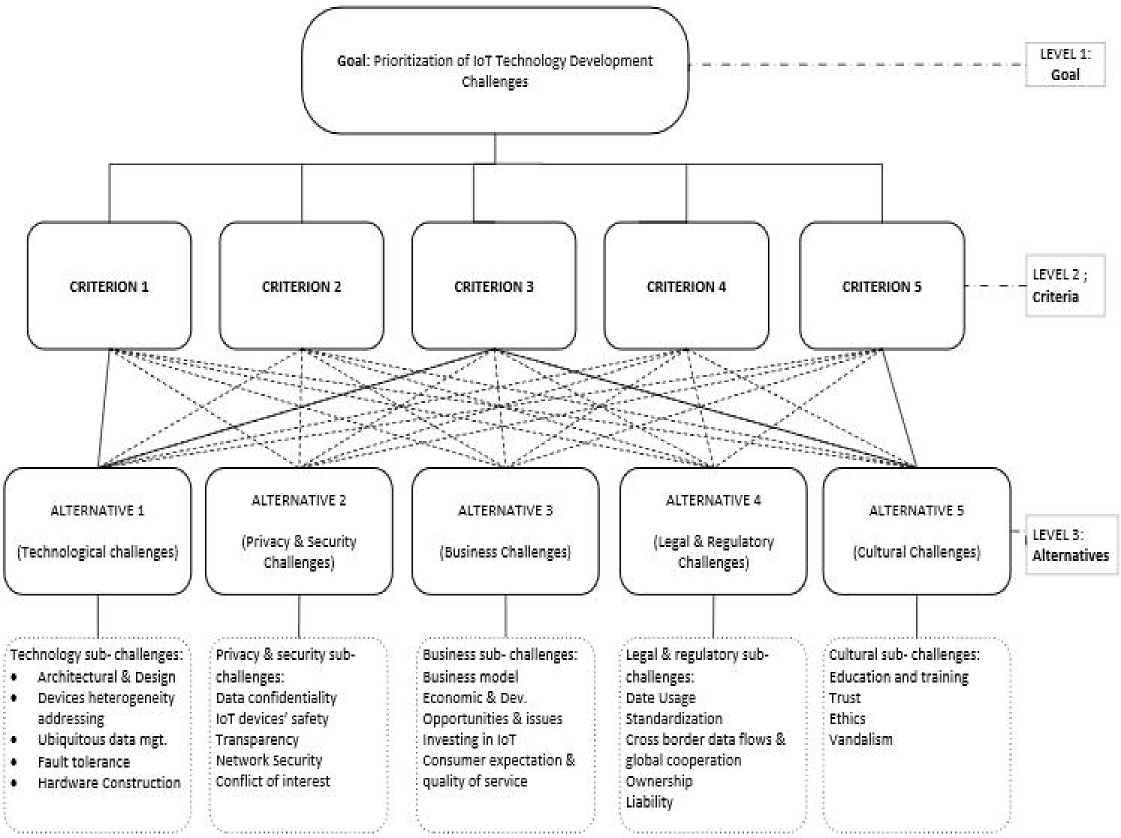


Figure 3.10: Hierarchical Structure of our Fuzzy Analytic Hierarchy Process for Prioritizing Challenges of IoT Development Source: [8].

Stage 2 - Fuzzification

Based on the flowchart in figure 3.7 for Multi-criteria Decision Process Based on Fuzzy Analytic Hierarchy Process (FAHP) Technique that we are using in this thesis work, the Fuzzification stage entails defining of membership functions as well as preparing scale of relative importance. The scale of relative importance is basically used in formulating linguistic questions for pairwise comparison of the available alternatives (the featured IoT technology development challenges) that would be answered by the nominated decision stakeholders. The answers from stakeholders are usually transformed into pairwise comparison matrix like the one in table 3.1.

Below is a highlight that describe how scale of relative importance is formed.

Fuzzy values in scale of relative importance are derived from crisp numeric values like 1,3,5,7,9. Each of the crisp numeric number correspond to a linguistic term. The linguistic terns are the English terms that a typical system user understands and uses to supply their opinions of the users into the system. These linguistic terms are usually converted to crisp numeric values that corresponds to each of the linguistic terms for computational purposes. The process of converting these linguistic terms into their respective membership function is referred to as Fuzzification.

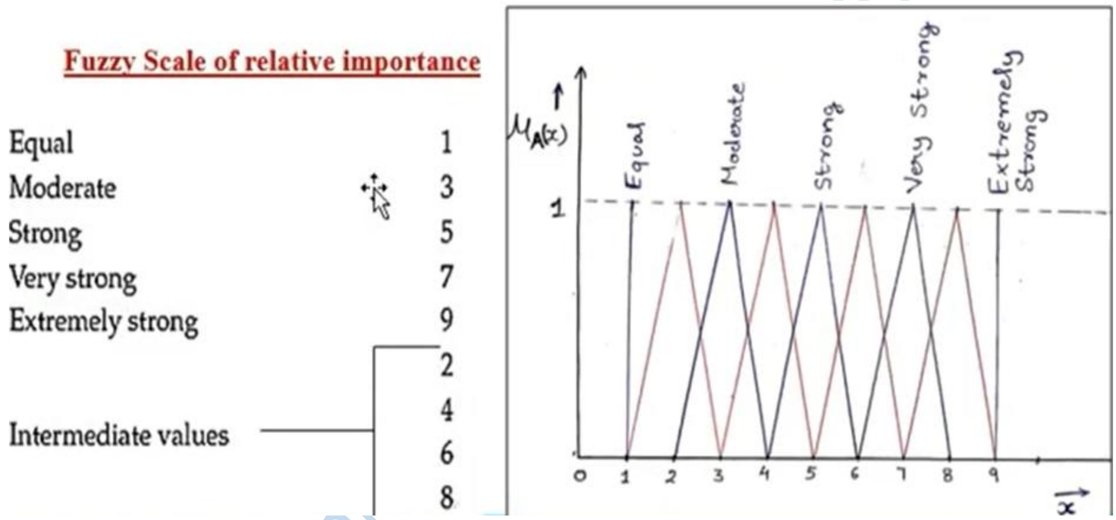


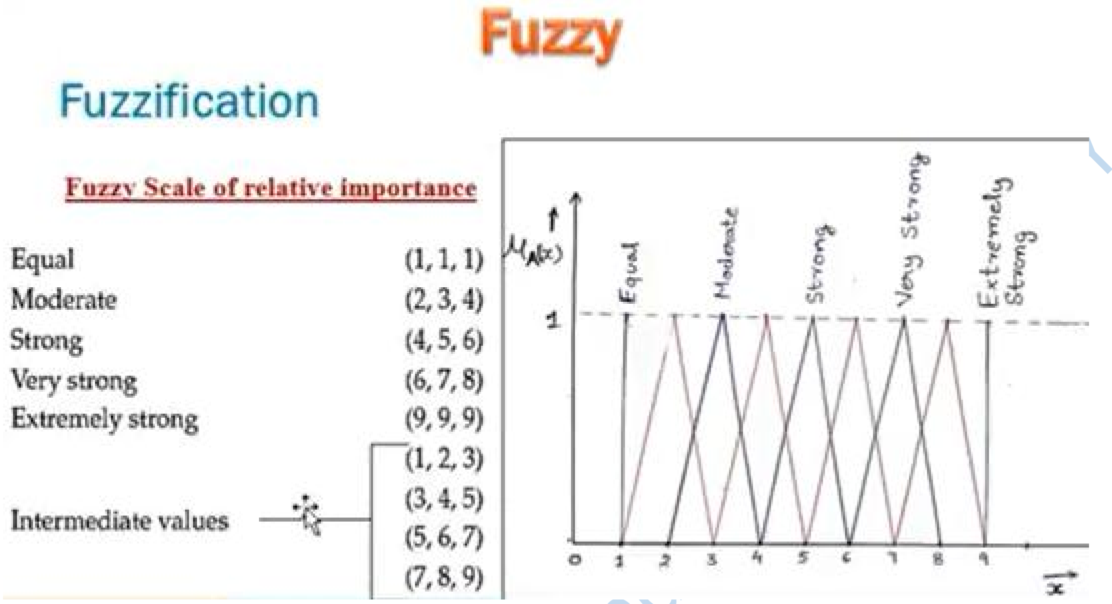
Figure 3.11 Fuzzy Scale of Relative Importance Source: [6].

The fuzzy value is generally represented using the membership function symbol (Ã) as shown in the formula below

$\mu_{\tilde{A}}(x) = \tilde{A} = (1,2,3)$

The numbers (1,2,3) together are known as fuzzy numbers. It is associated with the triangular membership function Ã. These three numbers are the lower, middle and upper ends of the fuzzy triangle on the x axis.

In the scale of relative importance in figure 3.12, each of the crisp numbers like 1,3,5,7 and 9 is replaced with fuzzy numbers. This is so because it is seen that assigning a single number to any term was not justified. For example, moderate has been assigned the value 3, but what about 2.5 or 3.5? What do you call 3.5? … Moderate or strong?



3.12 Fuzzy Scale of Relative Importance Source: [6].

To solve these issues, concept of fuzzy numbers was introduced. The intermediate membership function is shown with the help of red lines.

Since input dataset for this thesis would be adopted from the base project used in this these that is specifically targeted to IoT technology development challenges, we shall be adopting the scale of relative importance he used (Appendix II. - Fuzzy Linguistic scales for difficulty and importance table) to construct our linguistic questionnaire that would be used in the user interface of our Multi-criteria decision support system (MCDSS).

From the adopted scale of relative importance in Appendix II - Fuzzy Linguistic scales for difficulty and importance table, it can be seen that the level of influence of each of the IoT technology adoption challenges is based on two important features:

a. The perception of the system users on level of *importance* of a challenge/factor in affecting adoption of IoT technology in their respective institutions as compared to other challenges.

b. The perception of the system users on level of *difficulty* that would be involved in solving a challenge/factor that affects adoption of IoT technology in their respective institutions as compared to other respective challenges.

The above therefore implies that the pairwise linguistic questionnaires that would be constructed and imbedded in the decision support system in this thesis shall be in two categories, one should cover category of importance, while the other should cover the aspect of difficulty. Appendix I shows the questionnaires that is coopeted into the system, covering both pairwise comparative importance and difficulty of each of the adopted IoT technology adoption challenges/factors.

Stage 3 - Fuzzy Operation

In this stage, first the fuzzy scale of relative importance is used to form linguistic questions for each of the IoT technology challenges and sub challenges to be answered as input question to the DSS by the users. Figure 3.12 shows sample scale of relative importance that can be modified in the design of the MCDSS to form input questionnaires to be filled up by the system users. Appendix II (Fuzzy Linguistic scales for difficulty and importance table) shows the fuzzy scale of relative importance that was adopted and used to form linguistic questionnaire in this decision support system while Appendix I shows the drafted questionnaire that is presentable to users via the user interface of the DSS in the thesis work. The responses to be obtained from the system user are usually used to form fuzzy pairwise comparison matrix. This pairwise comparison matrix always forms the input data to decision support systems. Figure 3.22 shows a sample pairwise comparative matrix for a single user.

Table 3.1 Sample Pairwise Comparison Matrix for IoT Technology Development Main Challenges

factors	Tech	Privacy	Legal	Business	Cultural
Tech	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	(2/3,1,2)	(1,3/2,2)
Privacy	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(1,3/2,2)
Legal	(1/2,2/3,1)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(1,1,1)
Business	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)
Cultural	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)	(1,1,1)

Source: [8].

However, where there are multiple users, the geometric mean of the individual matrices would be calculated to obtain a single comparison matrix like the one in table 3.1. that would be used.

In the context of the decision Support system which is the focus of this thesis,

IoT technology adoption challenges or factors F, can stand for alternatives to be assessed based on C criteria (Figure 3.10).

Based on linguistic variables, the weights (W) of IoT challenges/factors (F) across the system users or decision stakeholders (S) with respect to all the criteria C can be computed as follows:

$F_1 = S_{11}(W_1) + S_{21}(W_2) + \ldots + S_{J1}(W_J)$

$F_2 = S_{12}(W_1) + S_{22}(W_2) + \ldots + S_{J2}(W_J)$

$F_3 = S_{13}(W_1) + S_{23}(W_2) + \ldots + S_{J2}(W_J)$

$F_4 = S_{14}(W_1) + S_{24}(W_2) + \ldots + S_{J2}(W_J)$

$$F_I = S_{1I}(W_1) + S_{2I}(W_2) + \ldots + S_{JI}(W_J) \quad (1)$$

All the system users'/stakeholders' relative preferential weights are elicited using the imbedded questionnaire (Appendix I). The valuation is done in accordance to Saaty's scale of relative importance and is given as linguistic terms used for the comparison between IoT challenges F_1, F_2, F_3 and F_4.

The input data by each of the system users based on the questionnaire are summarized by the system in one matrix table similar to the one in table 3.1, where Fi represents the IoT challenges; i ∈[1 ,…, n] stands for the number of IoT challenges, fij are results from the comparison between the IoT challenges. The relative weights of the IoT challenges obtained from the questionnaire across all decision makers or stakeholders are computed in a decision matrix table in the form shown in Equation 2.

$$D = \begin{array}{c} \\ F_1 \\ F_2 \\ \vdots \\ F_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & C_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix} \end{array} \qquad (2)$$

$$W = [\, W_1 \quad W_2 \ \ldots \ W_n]$$

After obtaining the relative weights of requirements from all the stakeholders, the next task is to apply the appropriate computation techniques to rank the main challenges and the respective sub challenges for each of the featured IoT challenges.

Stage 4 - Calculate Fuzzy Weights of Challenges and Sub-challenges

As shown in the flow chart of fuzzy analytic hierarchy process analysis technique adopted in this thesis work (figure 3.7), the next process is to use the already prepared pairwise Comparison Matrix table for IoT technology adoption and development challenges (as in table 3.1) to compute fuzzy weights of each of the IoT challenge/sub-challenge, which represents the ranked/prioritized weights.

To do this, we adopt the Buckley's geometric mean technique of fuzzy analytic hierarchy process who proposed a new approach of fuzzy analytic hierarchy process (FAHP) by using geometric mean. Geometric mean uses a unique and appropriate rule for aggregating the decision maker's preferential choices within the analytic hierarchy process (AHP) method. It has a characteristic property of maintaining the reciprocal property in the collective pairwise comparison matrix. It is straightforward and easy to adopt[5].

After obtaining the aggregated pairwise comparative matrix table in step 3 above, the following steps are used for the remaining part of the computation process.

Next is to compute the fuzzy geometric mean ($\check{r}_i$) for each IoT technology adoption challenge/factor using the equation below:

$$\check{r}_i = (\tilde{A}_1 \otimes \tilde{A}_2 \otimes \ldots \otimes \tilde{A}_n)^{1\backslash n}$$

$$= ((l_1,m_1,u_1) \otimes (l_2,m_2,u_2) \otimes \ldots \otimes (l_n,m_n,u_n))^{1/n};$$

$$\check{r}_i = ((l_1 * l_2 * \ldots * l_n)^{1/n}, (m_1 * m_2 * \ldots * m_n)^{1/n}, (u_1 * u_2 * \ldots * u_n)^{1/n}) \quad (3)$$

where l = lower, m = middle and u = upper elements of the fuzzy membership term. And n = number of competing alternatives.

Next, Next The fuzzy weight ($\tilde{\omega}$) for each IoT technology adoption challenge/factor is calculated

$$\tilde{\omega}_i = \check{r}_i \otimes (\check{r}_1 \oplus \check{r}_2 \oplus \ldots \oplus \check{r}_n)^{-1} \quad (4)$$

Stage 5 - Defuzzification of Fuzzy Weights

The fuzzy weights obtained in stage 4 are in fuzzy form, these fuzzy values need to be converted into crisp numeric values which is easier to read and interpret to non-technical users. The process of converting the fuzzy weights to crisp numeric values is known as defuzzification.

We use the center of area (COA) method of de-fuzzification[6]. This can be demonstrated in the equation below.

$$\text{COA } \tilde{\omega}i = (l_i+m_i+u_i)/3 \quad (5)$$

Stage 6 - Normalization

Next is to check for consistency by adding the resulting weights obtained in stage 5. If the result is not 1, it means the pairwise comparison is not consistent.

So, we have to normalize the weight through a process known as normalization. This is done by dividing each of the crisp numeric value weights by the sum of the weights to obtain each of the normalized weights[6].

$$\tilde{\omega}i = \tilde{\omega}i / \sum_{j=1}^{n} \tilde{\omega} \quad (6)$$

Stage 7 - Display of Prioritized Result

The result obtained in stage 6 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.

3.3.5 Database Design

As seen the system architecture for the Multi-criteria decision support system for prioritizing challenges of IoT technology adoption, the database sits on Microsoft SQL server.

Microsoft SQL Server is a relational database management system (RDBMS) that supports a wide variety of transaction processing, business intelligence and analytics applications in corporate IT environments.

In designing the database used in this thesis work, the following standard procedures for designing database as contributed by Microsoft was followed.

- **Determine the Purpose of the Database**: This helps in preparing for subsequent steps involved.

- **Obtain and Organize the Required Information:** All of the types of information that needs to be recorded in the database are gathered, such as Stakeholders names and emails, etc.
- **Categorize Information on Table Bases:** Information items were categorized into major subjects, such as Users or Challenges Institutions, etc. Each subject then becomes a table.
- **Convert Information Items to Columns:** Decision was made as to what information are needed to be stored in each table. Each information item was made as a field, and is displayed as a column in the table.
- **Choose Primary Keys:** Each table's primary key was determined. The primary key is a unique column that is used to identify each row. An example might be stakeholder ID or organization ID.
- **Set Table Relationships:** decision was made on how each data in one table is related to the data in other tables. Fields were added to tables or new tables were created to clarify the relationships, as situation demands.
- **Refine Design:** Design was analyzed for COA ῶ errors. Adjustments were made to the design, as needed.
- **Apply Normalization Rules:** Data normalization rules was applied to see if tables were structured correctly. Adjustments were made to the tables, as needed.

3.3.5.1 Table Design and Description

Some of the most basic database table design images are depicted in appendix VI.

3.4 Research Methods

The fundamental goal of this system is to design and implement a prototype system that can be used by decision makers or stakeholders in an organization to prioritise factors or challenges that affect their adoption of technologies of internet of things. It uses Fuzzy analytic hierarchy process (FAHP) technique for the prioritization of the IoT challenges. By so doing, they would be able to channel their limited resources in solving for challenges that are most important and less difficult to solve.

One of the basic motivations of this design is to be able to improve on the adopted baseline research by designing a real-world decision support prototype system (instead on designing only a multi-criterion decision-making technique)[7]. This chapter therefore seek to achieve The design part of the overall aims of this study.

Although there are many techniques for evaluating FANP, this system uses Buckley's Geometric mean method for computation of Fuzzy weights. This technique is known to be very easy to use.

Datasets from the base research used in this thesis was used as input data to the system for analysis[8].

Table 3.2 Fuzzy Linguistic Scales for Difficulty and Importance

Linguistic Scale for Difficulty	Linguistic Scale for Importance	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal
Just equal	Just equal	(1,1,1)	(1,1,1)
Equally difficult (ED)	Equally important (EI)	(1/2,1,3/2)	(2/3,1,2)
Weakly more difficult (WMD)	Weakly more important (WMI)	(1,3/2,2)	(1/2,2/3,1)
Strongly more difficult (SMD)	Strongly more important (SMI)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more difficult	Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more difficult (AMD)	Absolutely more important (AMI)	(5/2,3,7/2)	(2/7,1/3,2/5)

Source: [8].

The Fuzzy Linguistic scales for difficulty and importance in table 3.2 was used alongside with adopted IoT challenges and sub-challenges in figure 3.9 to formulate user based linguistic questionnaire for importance and difficulty of the IoT adoption challenges (Appendix I).

The questionnaires are used to present default questions that the developed system present to its users to provide their pairwise comparative preferences regarding the IoT challenges.

3.4.1 Fuzzy Analytic Hierarchy Process (FAHP) Analysis Based on Sample Dataset

As a proof of concept, we subject a dataset below (table 3.3) adopted from the base research used in this thesis to Buckley's Geometric mean method of FAHP (proposed in section 3.3.40.20) to obtain the weights of each main criteria. We shall compare the result obtained with the results obtained in the base data set[8].

Table 3.3 Sample Pairwise Comparison Matrix for IoT technology Development Main Challenges

factors	Tech	Privacy	Legal	Business	Cultural
Tech	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	(2/3,1,2)	(1,3/2,2)
Privacy	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(1,3/2,2)
Legal	(1/2,2/3,1)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(1,1,1)
Business	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)
Cultural	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)	(1,1,1)

Source: [8].

From the dataset above, it can be seen that there are five competing IoT main challenges, namely:

i. Technological challenges

ii. Privacy and security challenges

iii. Legal challenges

iv. Business challenges

v. Cultural challenges

The aim is to compute their respective weights using geometric mean method of FAHP.

The most important stages involved in the computation process include the following:

Stage 1: Compute the Fuzzy Geometric Mean ($\check{r}_i$) for Each IoT Technology Adoption challenge/factor using the equation below:

$$\check{r}_i = (\tilde{A}_1 \otimes \tilde{A}_2 \otimes \dots \otimes \tilde{A}_n)^{1\backslash n}$$

$$= ((l_1,m_1,u_1) \otimes (l_2,m_2,u_2) \otimes \dots \otimes (l_n,m_n,u_n))^{1/n};$$

$$\check{r}_i = ((l_1 * l_2 * \dots * l_n)^{1/n}, (m_1 * m_2 * \dots * m_n)^{1/n}, (u_1 * u_2 * \dots * u_n)^{1/n}) \quad (3)$$

where l = lower, m = middle and u = upper elements of the fuzzy membership term.

And n = number of competing alternatives.

Computations

ř(technology) = [(1*1/2*1*2/3*1)1/5, (1*1*3/2*1*3/2)1/5, (1*3/2*2*2*2)1/5]

= [(0.333)1/5, (2.250) 1/5, (12.000) 1/5]

= (0.803, 1.176, 1.644)

ř(Privacy) = [(2/3*1*2/3*2/3*1)1/5, (1*1*1*1*3/2)1/5, (2*1*2*2*2)1/5]

= [(0.296)1/5, (1.500) 1/5, (16.000) 1/5]

= (0.784, 1.084, 1.741)

ř(Legal) = [(1/2*1/2*1*2/3*1)1/5, (2/3*1*1*1*1)1/5, (1*3/2*1*2*1)1/5]

= [(0.167)1/5, (0.667) 1/5, (3.000) 1/5]

= (0.699, 0.922, 1.246)

ř(Business) = [(1/2*1/2*1/2*1*2/3)1/5, (1*1*1*1*1)1/5, (3/2*3/2*3/2*1*2)1/5]

= [(0.083)1/5, (1.000) 1/5, (6.750) 1/5]

= (0.608, 1.000, 1.465)

ř(Cultural) = [(1/2*1/2*1*1/2*1)1/5, (2/3*2/3*1*1*1)1/5, (1*1*1*3/2*1)1/5]

= [(0.125)1/5, (0.444) 1/5, (1.500) 1/5]

= (0.660, 0.850, 1.084)

Stage 2: Calculate the Fuzzy Weight (ῶ) for Each IoT Technology Adoption Challenge/Factor

$$\tilde{\omega}_i = \check{r}_i \otimes (\check{r}_1 \oplus \check{r}_2 \oplus \dots \oplus \check{r}_n)^{-1} \quad (4)$$

$$\tilde{\omega}_i = \check{r}_i \otimes (\check{r}_1 \oplus \check{r}_2 \oplus \dots \oplus \check{r}_n)^{-1}$$

but $(\tilde{r}1 \oplus \tilde{r}2 \oplus \ldots \oplus \tilde{r}n)\text{-}1$ = $(\tilde{r}(\text{technology}) \oplus \tilde{r}(\text{Privacy}) \oplus \tilde{r}(\text{Legal}) \oplus \tilde{r}(\text{Business}) \oplus \tilde{r}(\text{Cultural}))\text{-}1$

= $[(0.803+ 0.784+ 0.699+ 0.608+ 0.660)^{-1}, (1.176+ 1.084+ 0.922+ 1.000+ 0.850)^{-1}, (1.644+ 1.741+ 1.246+ 1.465+ 1.084)^{-1}]$.

= $[(3.554)^{-1},(5.033)^{-1},(7.180)^{-1}]$

= (0.281, 0.199, 0.139).

$\tilde{\omega}(\text{Technological})$ = $\tilde{r}(\text{Technological}) \otimes (\tilde{r}1 \oplus \tilde{r}2 \oplus \ldots \oplus \tilde{r}n)\text{-}1$

= $(0.803, 1.176, 1.644) \otimes (0.281, 0.199, 0.139)$.

= (0.226, 0.234, 0.228)

$\tilde{\omega}(\text{Privacy})$ = $\tilde{r}(\text{Privacy}) \otimes (\tilde{r}1 \oplus \tilde{r}2 \oplus \ldots \oplus \tilde{r}n)\text{-}1$

= $(0.784, 1.084, 1.741) \otimes (0.281, 0.199, 0.139)$.

= (0.220, 0.216, 0.242)

$\tilde{\omega}(\text{Legal})$ = $\tilde{r}(\text{Legal}) \otimes (\tilde{r}1 \oplus \tilde{r}2 \oplus \ldots \oplus \tilde{r}n)\text{-}1$

= $(0.699, 0.922, 1.246) \otimes (0.281, 0.199, 0.139)$.

= (0.196, 0.183, 0.173)

$\tilde{\omega}(\text{Business})$ = $\tilde{r}(\text{Business}) \otimes (\tilde{r}1 \oplus \tilde{r}2 \oplus \ldots \oplus \tilde{r}n)\text{-}1$

= $(0.608, 1.000, 1.465) \otimes (0.281, 0.199, 0.139)$.

= (0.171, 0.199, 0.204)

$\tilde{\omega}(\text{Cultural})$ = $\tilde{r}(\text{Cultural}) \otimes (\tilde{r}1 \oplus \tilde{r}2 \oplus \ldots \oplus \tilde{r}n)\text{-}1$

= $(0.660, 0.850, 1.084) \otimes (0.281, 0.199, 0.139)$.

= (0.185, 0.169, 0.151)

Stage 3: Defuzzification the Fuzzy Weights Obtained

We use the center of area (COA) method of de-fuzzification to obtain corresponding crisp weights of the computed fuzzy weights as follows

COA $\tilde{\omega}i = (l_i+m_i+u_i)/3$ (5)

$\tilde{\omega}$(Technological) = (0.226 + 0.234 + 0.228)/3

= 0.229

$\tilde{\omega}$(Privacy) = (0.220 + 0.216 + 0.242)/3

= 0.226

$\tilde{\omega}$(Legal) = (0.196 + 0.183 + 0.173)/3

= 0.184

$\tilde{\omega}$(Business) = (0.171 + 0.199 + 0.204)/3

= 0.191

$\tilde{\omega}$(Cultural) = (0.185 + 0.169 + 0.151)/3

= 0.168

Stage 4: Normalization of the Weights Obtained Using the Formular

If the sum of the computed crisp weights does not equal to 1, it means there is no consistency on the comparison matrix obtained, in this case, we normalize the output obtained via the following formula

$\tilde{\omega}i = \tilde{\omega}i/\sum_{j=1}^{n} \tilde{\omega}$ (6)

$$\sum_{j=1}^{n} \tilde{\omega} = \tilde{\omega}(\text{Technological}) + \tilde{\omega}(\text{Privacy}) + \tilde{\omega}(\text{Legal}) + \tilde{\omega}(\text{Business} + \tilde{\omega}(\text{Cultural})$$

$$= 0.229 + 0.226 + 0.184 + 0.191 + 0.168$$

= 0.999…. Since this sum is does not equal to 1, we normalize the weights by dividing each of the calculated weight by this sum to obtain their respective normalized weights.

$$\tilde{\omega}(\text{Technological}) = \tilde{\omega}(\text{Technological}) / \sum_{j=1}^{n} \tilde{\omega}$$

$$= 0.229/0.999$$

$$= 0.230$$

$$\tilde{\omega}(\text{Privacy}) = \tilde{\omega}(\text{Privacy}) / \sum_{j=1}^{n} \tilde{\omega}$$

$$= 0.226/0.999$$

$$= 0.226$$

$$\tilde{\omega}(\text{Legal}) = \tilde{\omega}(\text{Legal}) / \sum_{j=1}^{n} \tilde{\omega}$$

$$= 0.184/0.999$$

$$= 0.185$$

$$\tilde{\omega}(\text{Business}) = \tilde{\omega}(\text{Business}) / \sum_{j=1}^{n} \tilde{\omega}$$

$$= 0.191/0.999$$

$$= 0.191$$

$$\tilde{\omega}(\text{Cultural}) = \tilde{\omega}(\text{Cultural}) / \sum_{j=1}^{n} \tilde{\omega}$$

= 0.168/0.999

= 0.169

Stage 5: Display Prioritized Result

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.

The results obtained from the computations can be summarized in the following table

Table 3.4 Computed Result Using Geometric Mean Method

IoT Main Challenge	**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

Source: Research Design, 2023

Stage 6: Compare the Result with that of the Base Research Result

Table 3.5 Compared Result With that of the Base Research Result

IoT Main Challenge	Calculated Weight	Weight from Baseline Dataset	Weight Variance	Current Rank	Rank in 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

Source: Research Design, 2023

3.4.2 Global Weights of Sub-challenges

After computing the weights of all main challenges and local weights of each of the sub-challenges of IoT technology adoption and development. The sub challenges can be ranked globally on the bases on their local weights and the weights of the main challenges to which they belong as shown below:

$$\tilde{\omega}(\text{Global - sub challenge}) = \tilde{\omega}(\text{Main challenge}) \times \tilde{\omega}(\text{Local - sub challenge});$$

3.5 Results Dissemination and Procedure

The results obtained from test and evaluation od the prototype system would be disseminated through all or some of the following channels:

- Professional conferences;
- published in popular scholarly journals;
- newsletters;
- etc

3.6 Target Audience

The target audience for this thesis is not limited to, but include:

- research participants/respondents (Experts in IoT);
- interest groups and enthusiast in IoT.
- Other scholars who study similar topics.
- Nigeria policymakers regarding IoT and SDGs
- Organizations and business owners that work and/or benefit from IoT technologies.

- etc.

Endnotes

1. Tutorials Teacher, *ASP.NET MVC Architecture*, 2019 https://www.tutorialsteacher.com/mvc/mvc-architecture.

2. H. Deng, *Multicriteria Analysis with Fuzzy Pairwise Comparison*, **International Journal of Approximate Reasoning 21**, no. 3, 1999: 215–31, https://doi.org/10.1016/S0888-613X(99)00025-0.

3. F. Ren, L. Wu, M. Xu, N. Sun & X. Zhang, *Changes in Soil Microbial Biomass with Manure Application in Cropping Systems: A Meta-Analysis*, **Soil and Tillage Research 194**, no. April (2019): 104291, https://doi.org/10.1016/j.still.2019.06.008.

4. R. E. Bellman & L. Zadeh, *Decision-Making in a Fuzzy Environment.* **Management Science 17**(4):B-141-B-164. https:// doi.org/10.1287/mnsc.17.4.B141

5. H. Zhou, M. Jia, Y. Feng & Y. Liu, *Evaluation System for Automatic Fare Gate Capacity Based on Delphi and Improved FAHP*, **Proceedings of 2017 IEEE 6th Data Driven Control and Learning Systems Conference**, DDCLS 2017, 2017, 754–59, https://doi.org/10.1109/DDCLS.2017.8068168.

6. M. Mathew, *Fuzzy Analytic Hierarchy Process (FAHP) - Using Geometric Mean*, **YouTube**, 2019, https://www.youtube.com/watch?v=5k3Wz1AfVWs.

7. A. Mohammadzadeh, A. Mohammadian, B. Mahbanooei, S. Ghafoori, R. Ghasemi & R. Mohammadkazemi, *A Fuzzy Analytic Network Process (FANP) Approach for Prioritizing Internet of Things Challenges in Iran*, **Technology in Society**, 53, 2018, 124–34, https://doi.org/10.1016/j.techsoc.2018.01.007.

8. T. Dinesh, *Prototyping Model in Software Engineering*, **Computer Notes**, 2022, https://ecomputernotes.com/software-engineering/explain-prototyping-model

Chapter Four

Implementation and Evaluation

4.1 Implementation

Having established a framework on which the multi-criteria decision support system (MCDSS) for prioritizing challenges of IoT technology adoption and development will be built, this chapter describes how the framework described in Chapter 3 was built and tested.

In this Chapter, the choice of components put together to arrive at a working prototype would be talked about; the minimum hardware and software requirements for the MCDSS to function would also be discussed. Screenshots of different modules showing inputs and corresponding outputs that were being used to test the system are shown.

Usability test of the prototype system was also carried out the feedback obtained from the randomly selected system users was summarised and documented accordingly.

The chapter also describes and analyses output results obtained from the adopted input dataset as compared with the result from base research used in this thesis.

4.1.1 Software Deployment

4.1.1.1 Deployment Diagram of The Multi-criteria Decision Support System

A deployment diagram visualizes the distribution of components in the application and involves modelling the hardware configuration with the software that the operation of multi-criteria decision support system (MCDSS) is dependent on. Figure 4.1 shows the deployment diagram of the multi-criteria decision support system (MCDSS) while Table 4.1 explains the elements in the figure.

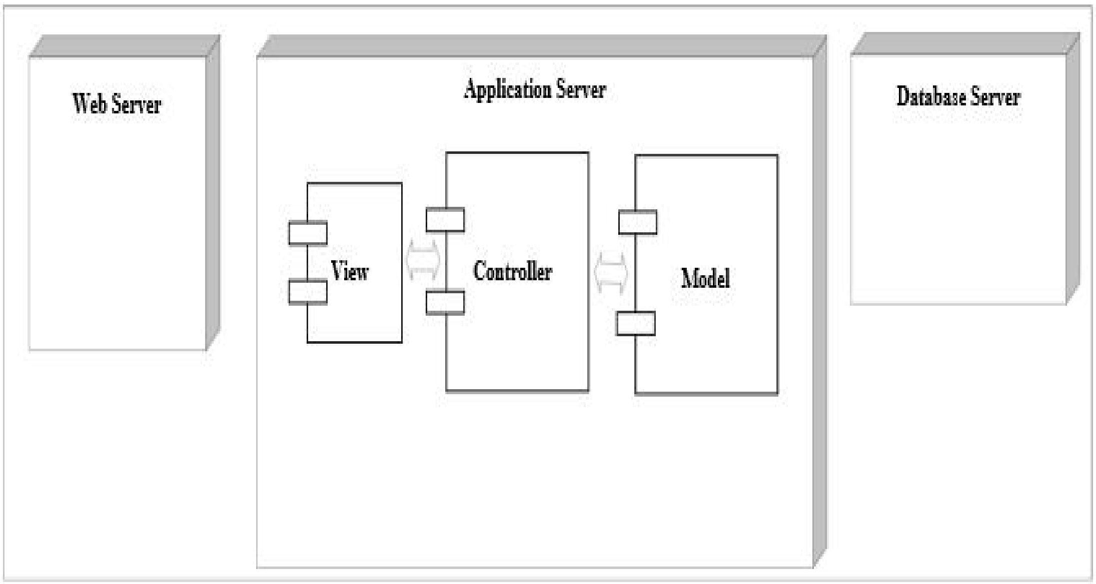


Figure 4.1 Deployment Diagram of MCDSS Source: Research Design, 2023

4.1.1.2 Components of The Multi-criteria Decision Support System

As indicated in figure 4.1 above, the components of the MCDSS have been partitioned on the lines of the Model View Controller (MVC) architecture.

The Model-View-Controller (MVC) architectural pattern separates the MCDSS into three major groups of components, namely: Models, Views, & Controllers. This pattern is concerned with separation of concerns.

In addition, the MCDSS is designed to interact with a database to store and retrieve the data manipulated by the application. The following are therefore the list of the main components involved in the deployment of the MCDSS.

Below are highlights on each of the main components deployed.

- **View**

Views are basically designed to present content to the system users through the user interface. Razor view engines are used by view to embed Microsoft's .NET code in HTML markup. By default, logic within view was kept as minimal as possible, and all logic within views were made to relate to contents being presented. For all needs to perform a great deal of logic in view files in order to display data from a complex model, ViewModel, or view template were used to simplify the view.

- **Controller**

Controllers are the MCDSS components that handle all user interactions. They work with the system model, and they are ultimately responsible for selecting a view to render. In an all MVC applications, the view's responsibility is only to display information. In the MVC pattern, the controller is usually the initial entry point into the software application. It is responsible for selecting the model types to work with the view to render.

- **Model**

The Model in the MVC application stands for the state of the application as well as business logics and/or operations that needs to be carried out by it. All business logics are encapsulated within the model, and any execution logic for persisting the software state. Then views are strongly typed, ViewModel are used which are typically designed to contain the data to display on that view.

- **Database Access**

A database in Microsoft SQL Server is comprises of tables that stores a set of structured data. A typical table contains collection of rows. The rows are also known as records or tuples, while columns are referred to as attributes. Each of the column in a table is designed to store a certain type of information or data, for example, dates, names, dollar amounts, and numbers.

4.1.1.3 Deployment Environment of The Multi-criteria Decision Support System

The deployment environment for the MCDSS was determined. A good deployment environment is usually well partitioned to ensure that the application components have proper resources in their execution environment. Therefore, the nodes of our deployment environment are as follows:

- Web Server—This node represents the Web server. It receives user requests and send responses from the application. Back to the user.
- 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.
- Database 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.

4.1.1.4 Deployment of The Multi-criteria Decision Support System on Web Server

Deployment was the next step after successful development of the prototype MCDSS. A windows server with Internet Information System (IIS) manager installed was used to publish the web application.

Prerequisites

Prerequisites that were taken care of before publishing the web application on the web server:

- Microsoft Web Deploy & IIS Server were Enabled/Installed;

Appendix I shows stages taken to publish the MCDSS

4.1.2 Some Basic Pages of The System

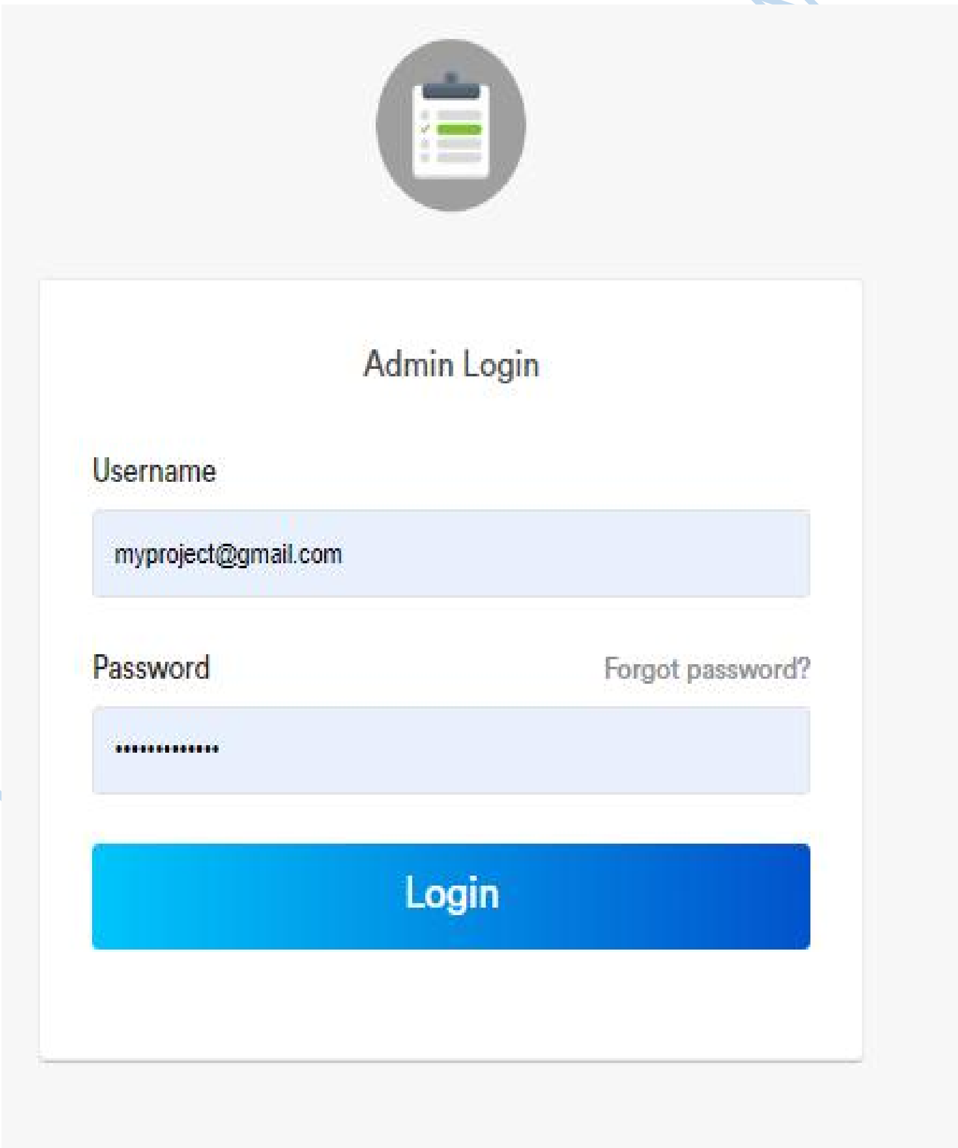


Figure 4.2 Login Page Source: Research Design, 2023

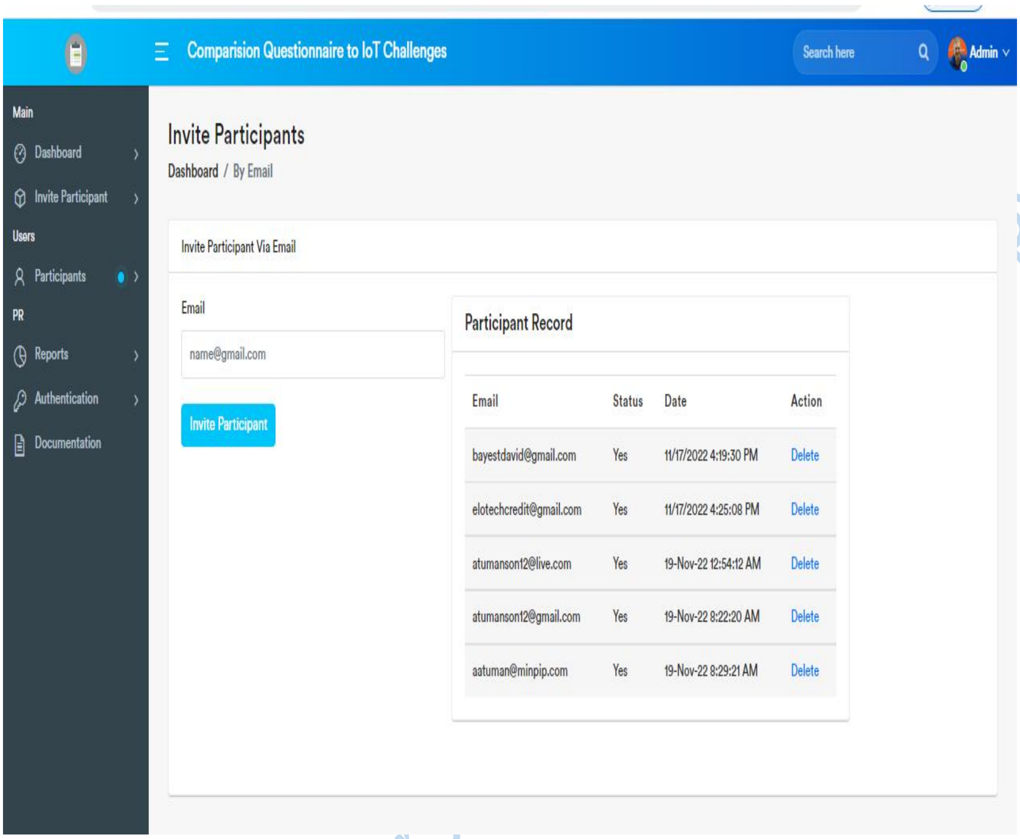


Figure 4.3 Landing and navigation page Source: Research Design, 2023

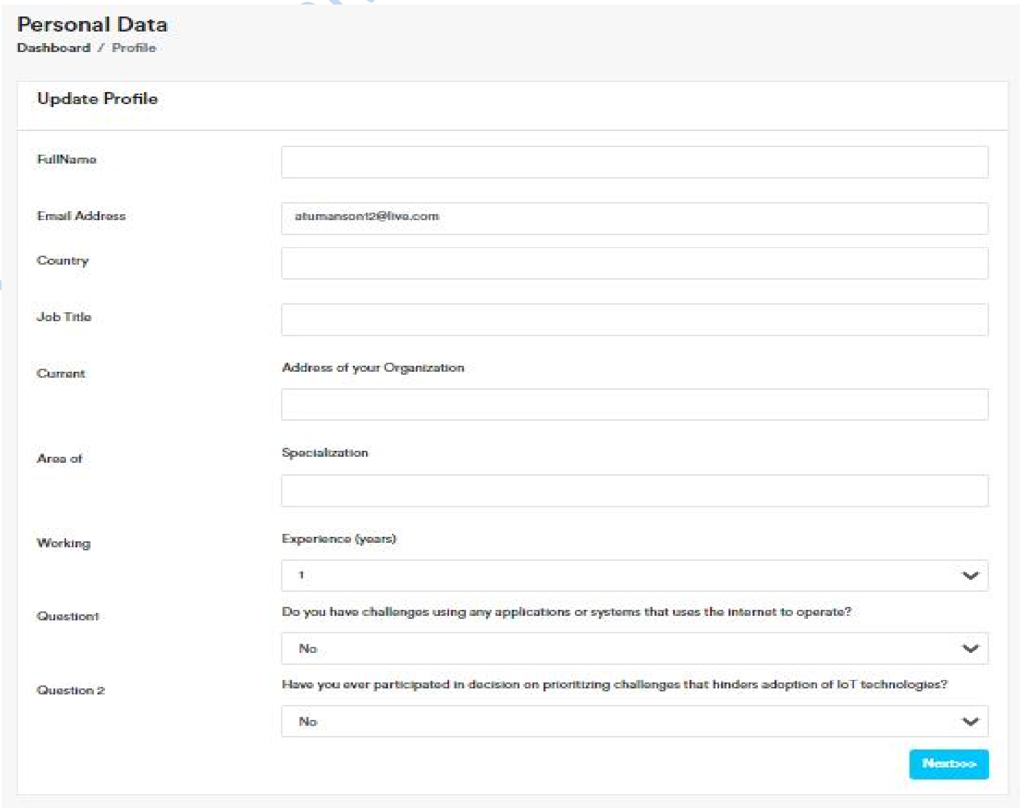


Figure 4.4 User profile Update Page Source: Research Design, 2023

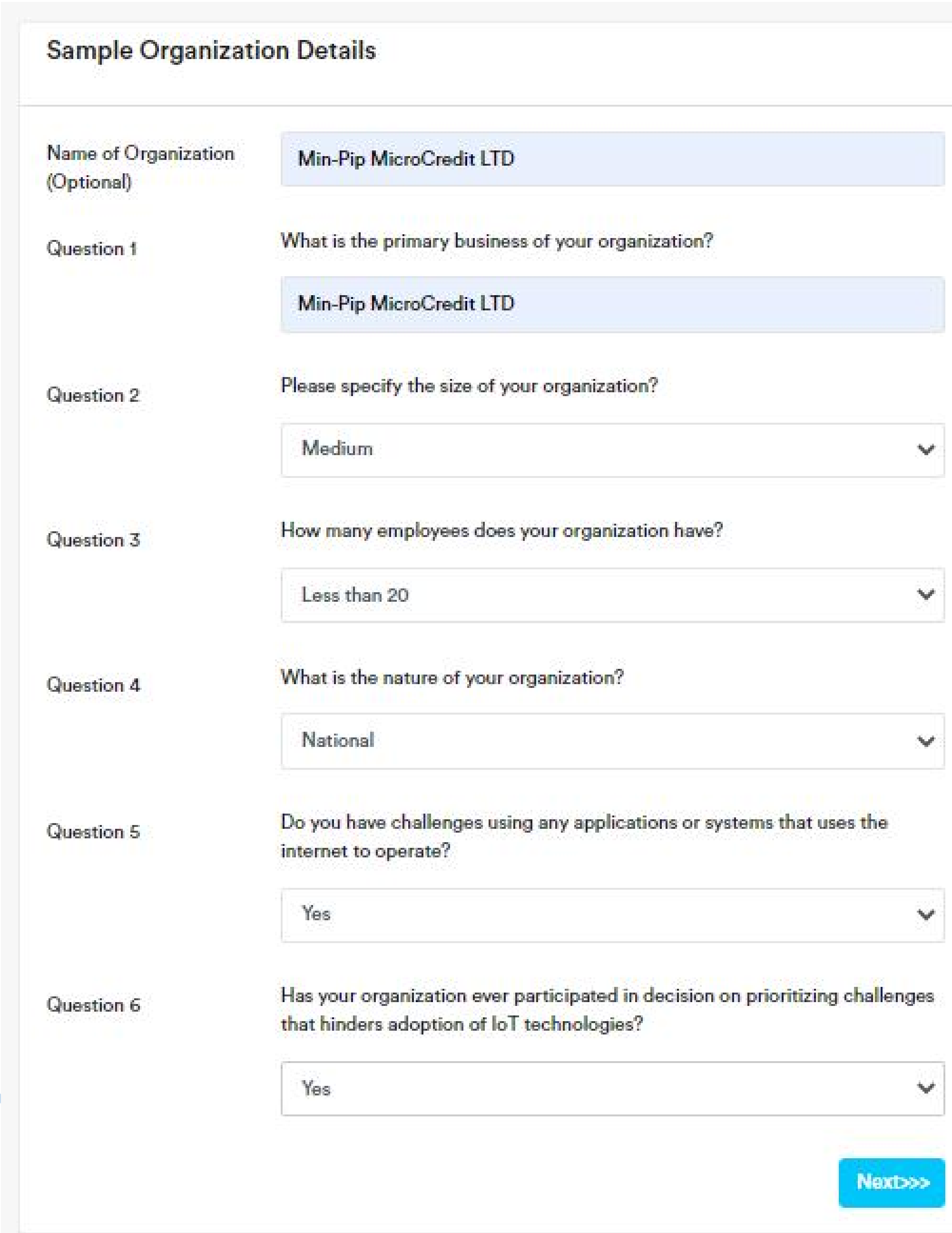


Figure 4.5 Organisation Update Page Source: Research Design, 2023

4.1.3 System Usability Test and User Feedback

The purpose of the usability test is to understand from the test system users through the feedback from them on how usable the prototype system is and how easy it is to use the MCDSS.

The test users are expected to consciously take note of their experiences on all the tasks they carry out on the prototype MCDSS.

Some of the most important tasks on the system for which usability feedback is important include the following:

- Admin user account creation
- First and subsequent user login
- User profile creation, update and delete
- Organization creation, update and delete
- Invitation of decision stakeholders by organization admin via email
- The email reception experience and email content
- The decision stakeholder invitation link and experiences regarding it
- The stakeholder profile update experiences
- Stakeholder experiences on the questionnaires content
- Admin experiences on the nature and layout of the result obtained from the system

The system usability test also enables us to gain a deeper understanding of their test users' needs and frustrations as they use the application whether they are using their computer browsers, or their mobile phones browsers. The usability tests are important in discovering inherent flaws as well as areas of confusion in the MCDSS.

The developed prototypes system was subjected to system usability test. The test users were asked at the end of each pairwise questionnaire session to follow the System usability test online link to fill in their feedback regarding their experiences on the MCDSS.

4.1.3.1 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.

4.1.3.2 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.

4.1.3.3 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.

The test result obtained from Microsoft forms is shown in Appendix V.

4.1.4 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.

4.1.4.1 Prioritization Result for Main IoT Challenges

The following categories of dataset adopted from the baseline dataset was used as input to the system[2].

6. Pairwise comparison matrix table of the main challenges of IoT technology adoption and development challenges as used in the baseline dataset[2].
7. Pairwise comparison matrix table of the sub challenges for each of the main challenges of IoT technology adoption and development challenges as used in the baseline dataset (Appendix V).

The dataset was used as input data into the MCDSS in this thesis work.

The aim of this work is to develop a real-world decision support system that can be used for prioritizing challenges of IoT technology adoption faced by institutions, government agencies, researchers, etc.

The MCDSS in this thesis work Uses fuzzy analytic hierarchy process (Geometric mean approach – adopted from Buckley's 1985 Geometric mean technique of fuzzy analytic hierarchy process analysis method) to compute the fuzzy weights of the IoT technology development adoption challenges/sub-challenges.

The output result obtained from the system is expected to be similar to the result obtained in the baseline research, since the same sets of input dataset were used in both his analysis works and the input into the interfaces of the decision support system developed in this thesis work[2].

Table 4.1 below 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].

Table 4.1 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

Source: Research Design, 2023

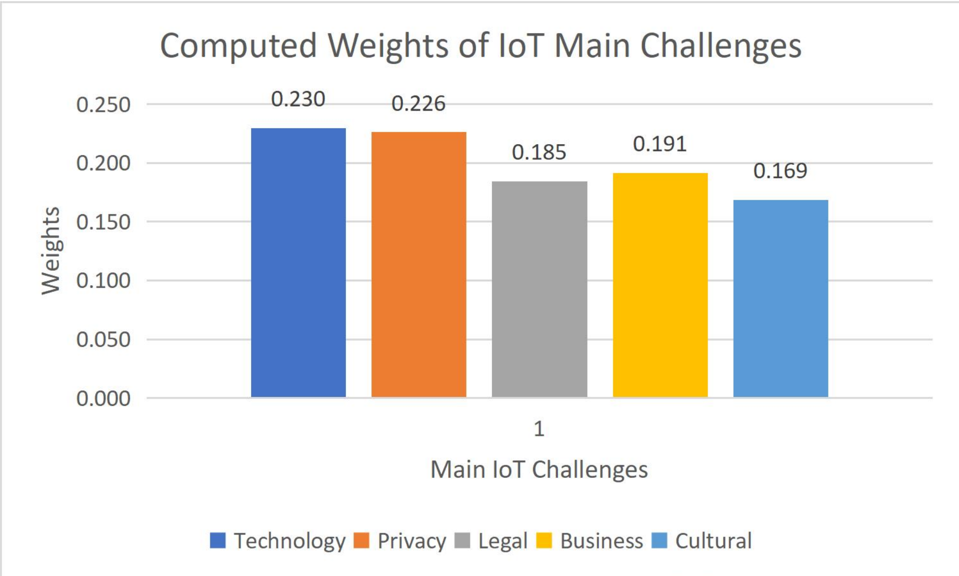


Figure 4.6 Chart of Weights of Main Challenges of IoT Technology Adoption and Development Source: Research Design, 2023

Table 4.1 shows weights of the IoT technology adoption challenges as well as the raking for each of the challenges. Also figure 4.6 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 4.2 and figure 4.7 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 4.2 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

Source: Research Design, 2023

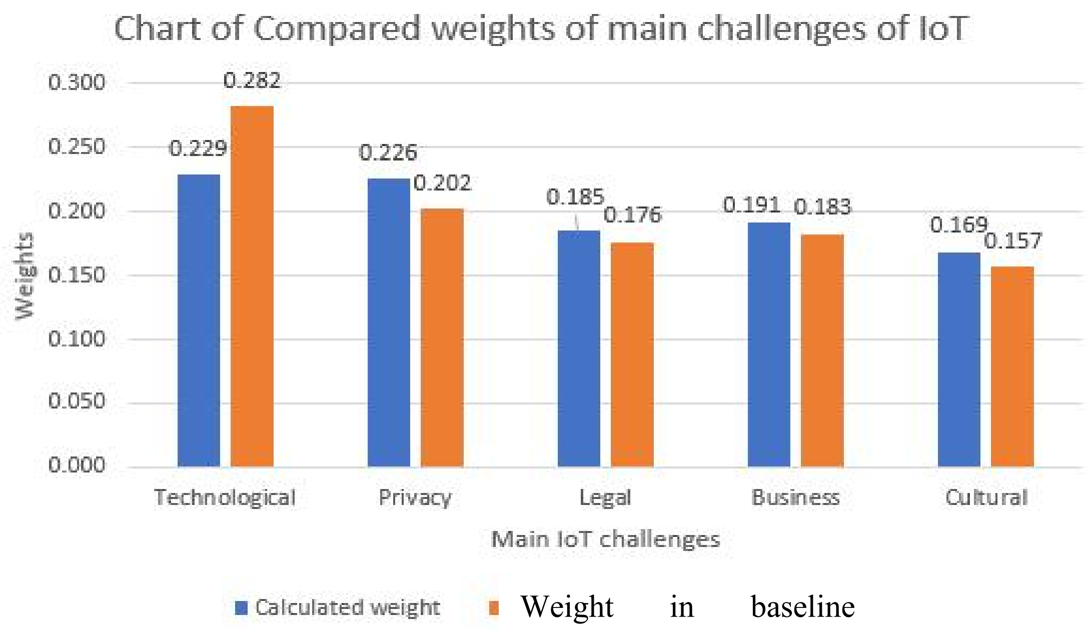


Figure 4.7 Chart of Compared Weights of Main Challenges of IoT Technology Adoption and Development Source: Research Design, 2023

Table 4.3 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 4.4 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 4.3 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

Source: Research Design, 2023

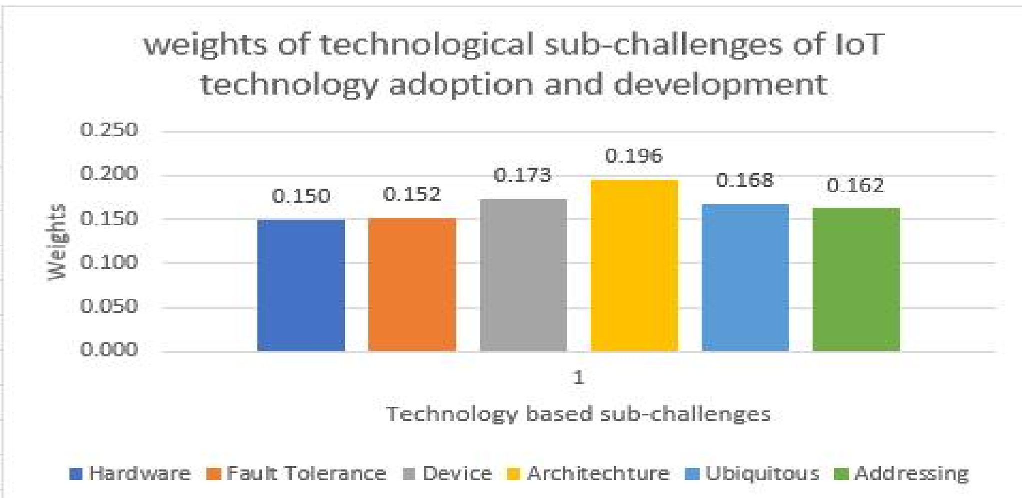


Figure 4.8 Chart of Weights of Technological Sub-challenges of IoT

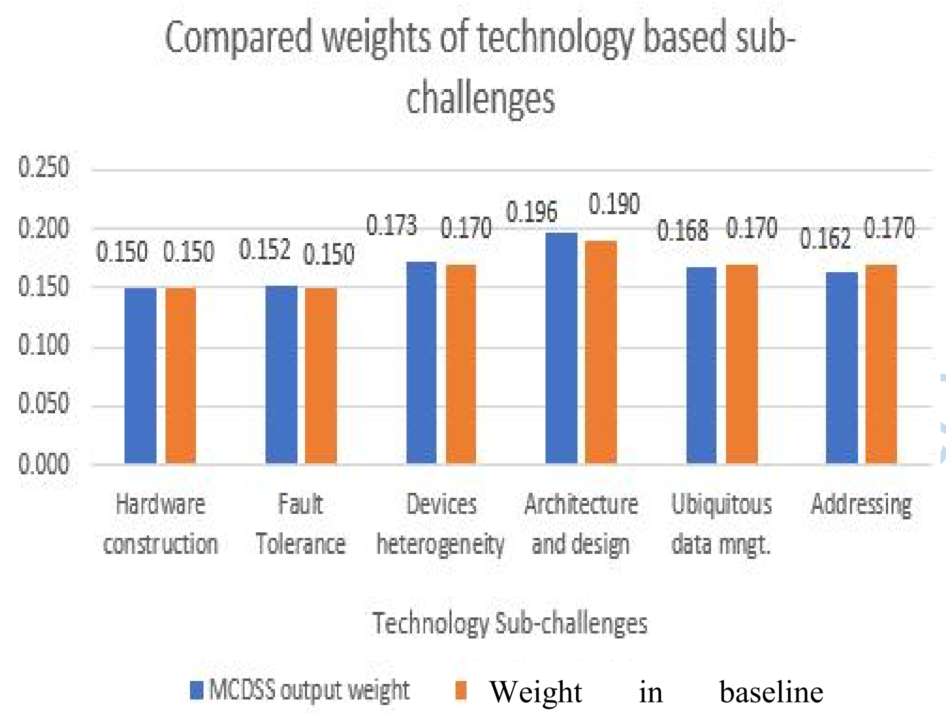


Figure 4.9 Compared Weights of Technology Based Sub-challenges
Source: Research Design, 2023

Table 4.4 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

Source: Research Design, 2023

Table 4.5 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 4.6 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 4.5 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
Transparency	0.172, 0.199, 0.205	0.192	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

Source: Research Design, 2023

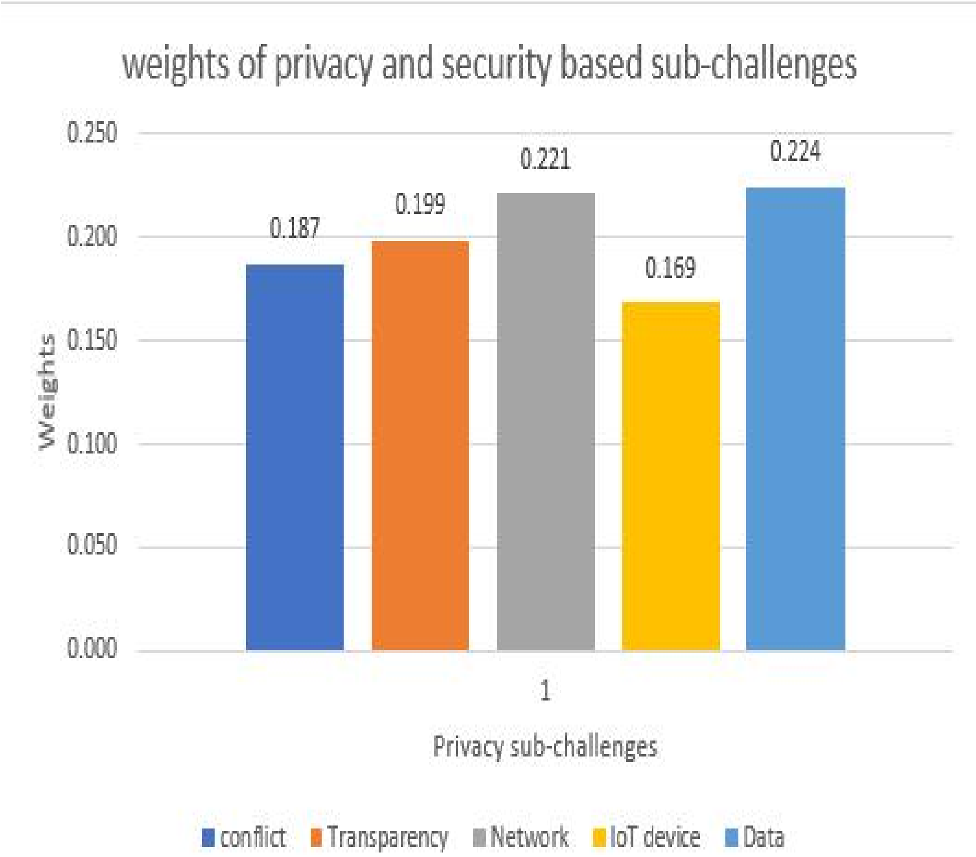


Figure 4.10 Chart of Weights of Privacy and Security Based Sub-challenges Source: Research Design, 2023

Table 4.6 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
IoT devices' safety	0.176	0.180	-0.006	5	4
Data confidentiality	0.222	0.240	0.005	1	1

Source: Research Design, 2023

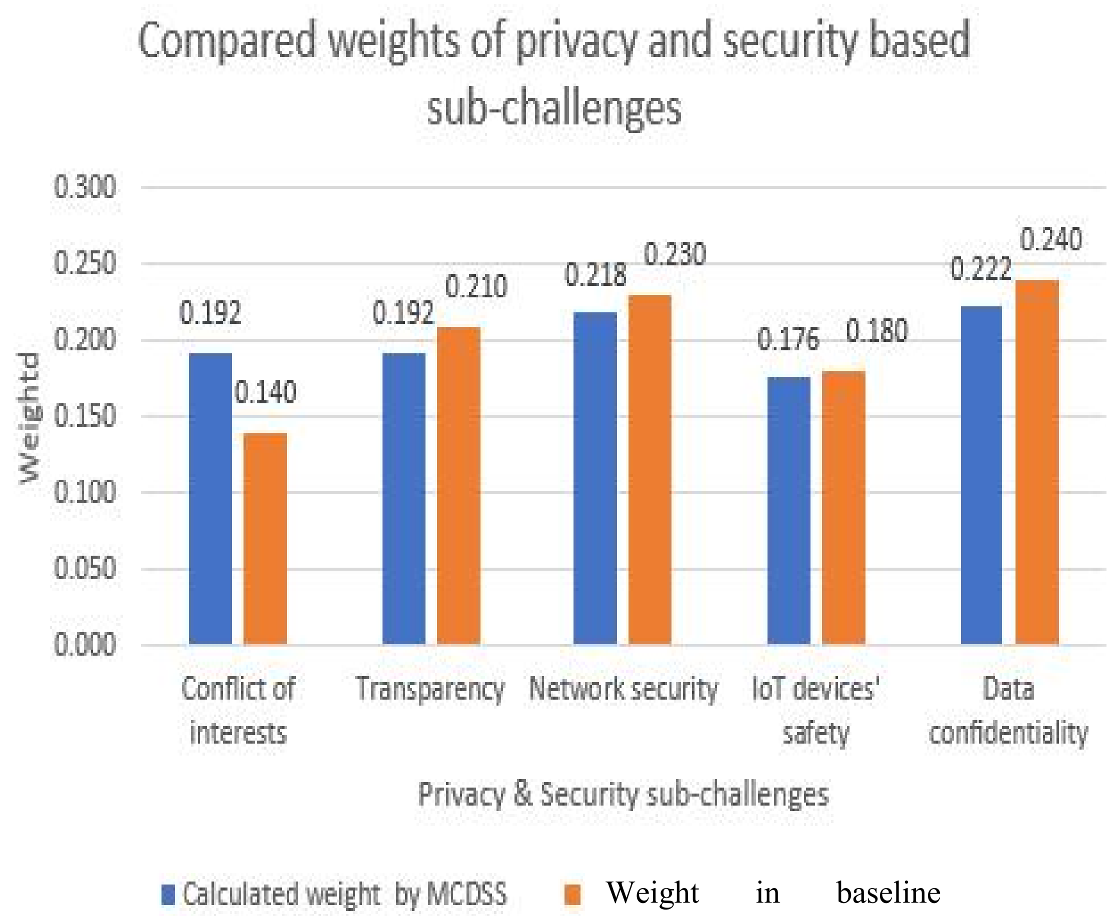


Figure 4.11 Chart of Compared Weights of Privacy and Security Based sub-Challenges Source: Research Design, 2023

Table 4.7 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 4.8 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 4.7 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

Source: Research Design, 2023

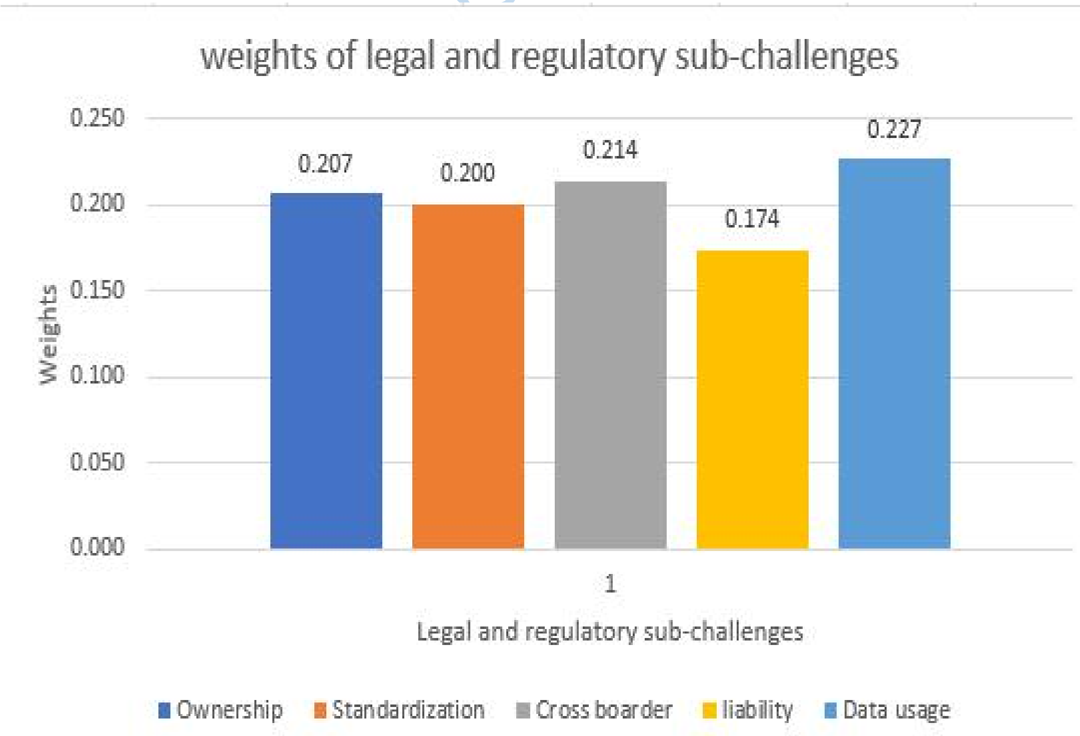


Figure 4.12 Chart of Weights of Legal and Regulatory Sub-challenges. Source: Research Design, 2023

Table 4.8 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

Source: Research Design, 2023

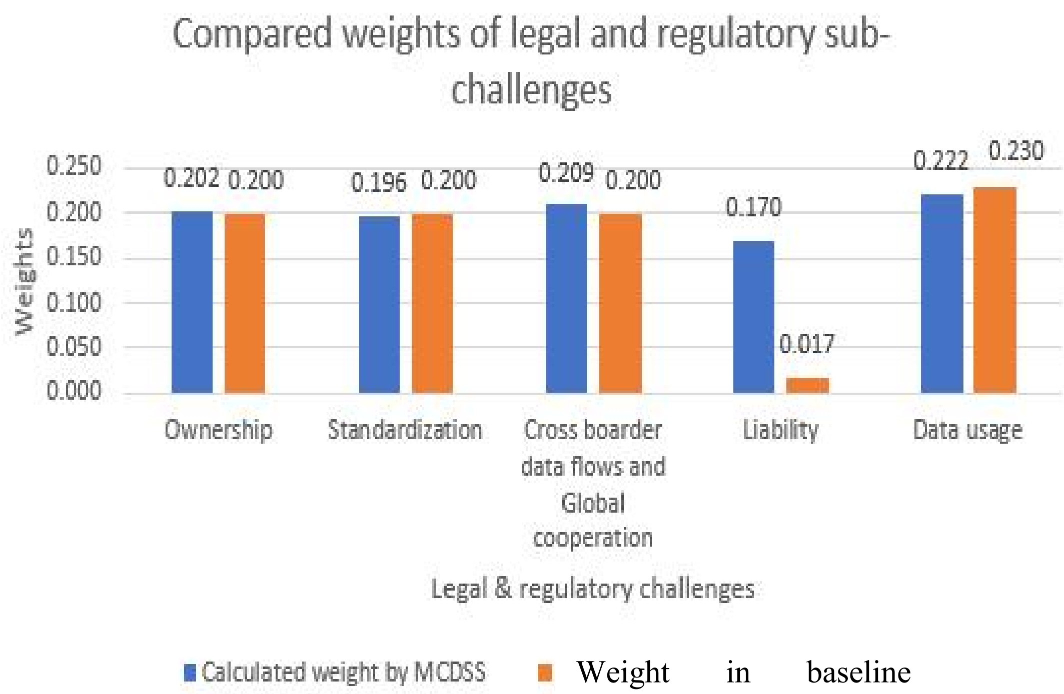


Figure 4.13 Chart of Compared Weights of Legal and Regulatory Sub-challenges Source: Research Design, 2023

Table 4.9 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 4.9 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

Source: Research Design, 2023

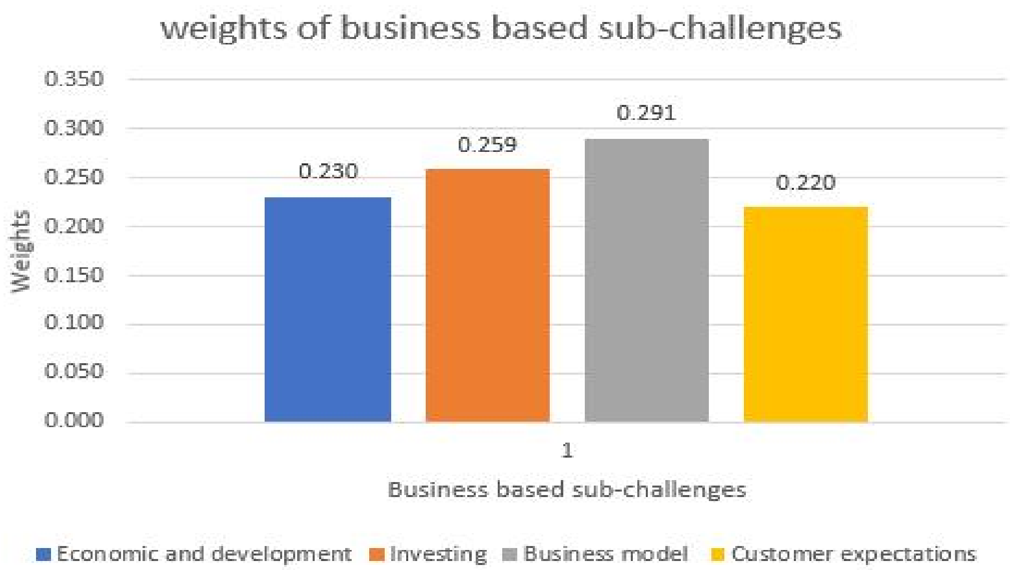


Figure 4.14 Chart of Weights of Business Based Sub-challenges
Source: Research Design, 2023

Table 4.10 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

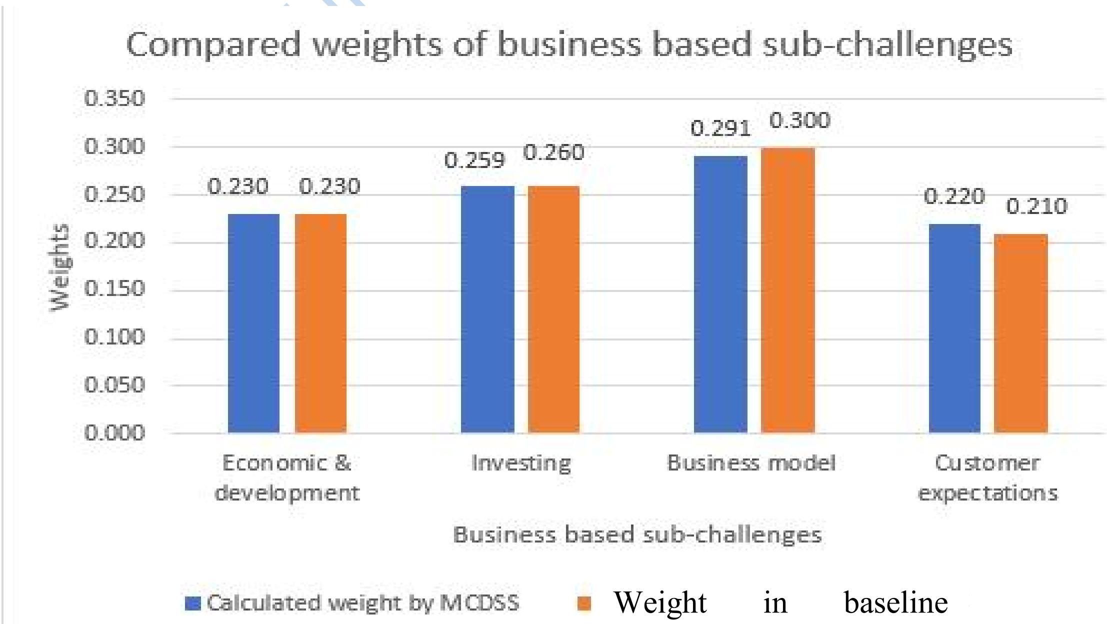


Figure 4.15 Chart of Compared Weights of Business-based Sub-challenges
Source: Research Design, 2023

Table 4.11 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 4.11 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

Source: Research Design, 2023

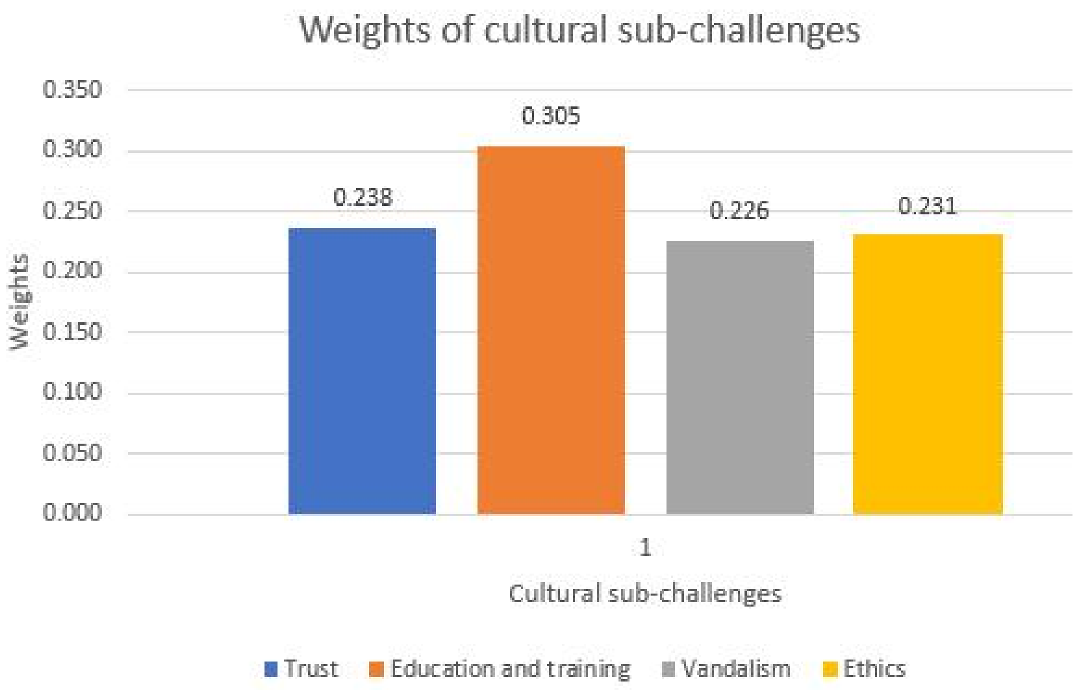


Figure 4.16 Chart of Weights of Cultural Sub-challenges Source: Research Design, 2023

Table 4.12 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

Source: Research Design, 2023

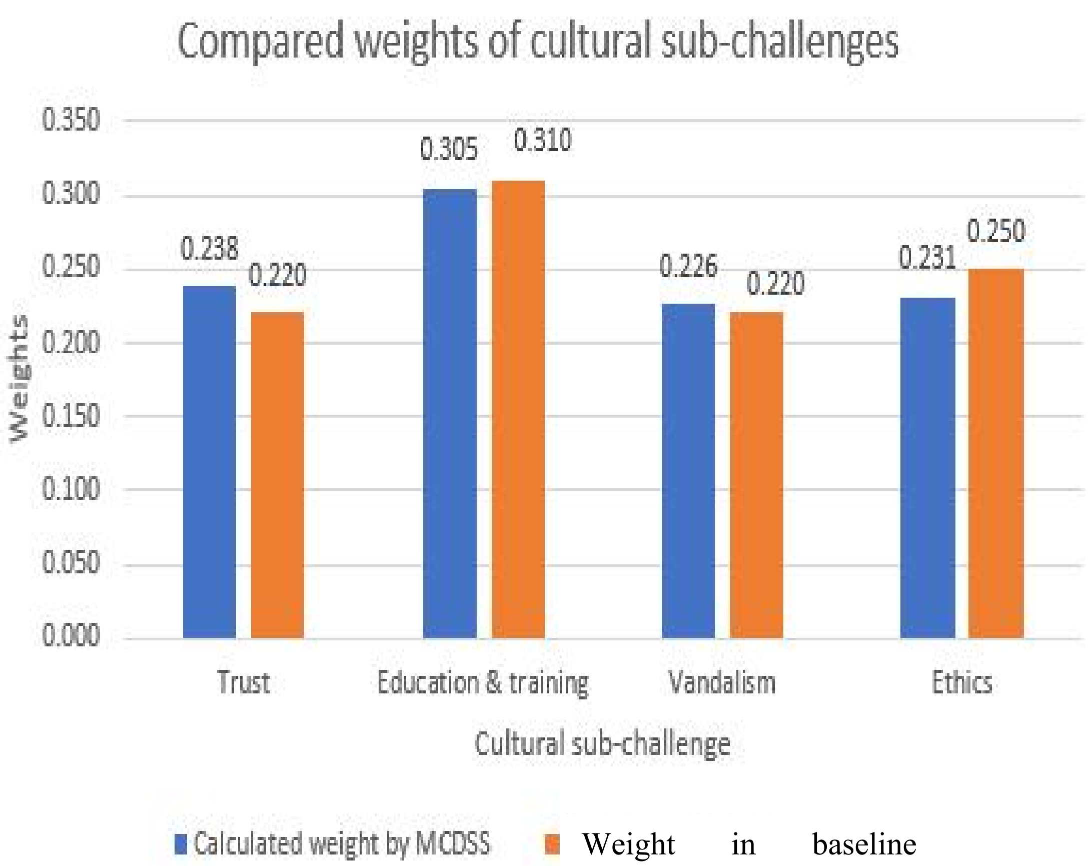


Figure 4.17 Chart of Compared Weights of Cultural Sub-challenges Source: Research Design, 2023

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

Table 4.13 Global Weights and Ranks for IoT Challenges and Sub-challenges

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

Source: Research Design, 2023

4.2 Evaluation (Discussion of Results)

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

4.2.1 System Usability Test

In testing for the system usability, targeted user experience tests questions were formed. Microsoft forms online survey tool was used to design and despatch the user feedback questionnaire to target users in who interacted with the prototype MCDSS system[7].

Appendix II shows summary of feedback downloaded from the Microsoft website.

4.2.2 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.

4.2.2.1 Analysis of Main IoT Challenges

Table 4.1 shows weights of the IoT technology adoption challenges as well as the raking for each of the challenges. Also figure 4.6 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 4.2 and figure 4.7) 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 4.2 and figure 4.7 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.

4.2.2.2 Analysis of Technological – Sub-challenges

Analysis of technological sub-challenges of IoT (table 4.3 and figure 4.8) 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 4.4 and figure 4.9) 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.

4.2.2.3 Analysis of Privacy and Security – Sub-challenges

For Privacy and security sub-challenges of IoT (table 4.5 and figure 4.10) 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 4.6 and figure 4.11) 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%.

4.2.2.4 Analysis of Legal and Regulatory – Sub-challenges

Table 4.7 and figure 4.12 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 4.8 and figure 4.13) 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%.

4.2.2.5 Analysis of Business – Sub-challenges

Table 4.9 and figure 4.14 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 4.10 and figure 4.15) 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%.

4.2.2.6 Analysis of Cultural – Sub-challenges

Table 4.11 and figure 4.16 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 (Table 4.12 and figure 4.17) 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%.

Endnotes

1. M. Rhodes, *Creating a Survey Solution with Forms, Power Automate, SharePoint, and Power BI*, *Creating Business Applications with Microsoft 365*, 2022, 63–70, https://doi.org/10.1007/978-1-4842-8823-8_5.

2. A. Mohammadzadeh, A. Mohammadian, B. Mahbanooei, S. Ghafoori, R. Ghasemi & R. Mohammadkazemi, *A Fuzzy Analytic Network Process (FANP) Approach for Prioritizing Internet of Things Challenges in Iran*, **Technology in Society**, 53, 2018, 124–34, https://doi.org/10.1016/j.techsoc.2018.01.007.

Chapter Five

Conclusion

5.1 Summary of Findings

The main objective of this thesis work is to design and develop a real-world prototype system that can be used as a support tool to prioritize or rank the numerous challenges and sub challenges of IoT technology adoption and development faced by governmental and non-governmental organizations.

The decision to prioritize challenges becomes handy particularly when the challenges are numerous, but the available human and non-human resources to use in solving these challenges at a time are limited in supply. In such situation, challenges that are most important to solve, yes less difficult to solve are expected to be accorded higher priority over their competing alternatives.

Unfortunately, this kind decision making in institutions with multiple criteria to be considered by multiple decision stake holders require advanced methods and tools. Research has shown that real-world decision support tools for this specific support type is seemingly limited in supply, hence the proposed Multi-criteria decision support tool for prioritizing challenges of internet of things (IoT) adoption and development.

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

- System usability test
- Output data accuracy test

In testing for the system usability, targeted user experience tests questions were formed. Microsoft forms online survey tool was used to design and despatch the user feedback questionnaire to target users in who interacted with the prototype Multi criteria decision support system (MCDSS). Appendix II shows summary of feedback downloaded from the Microsoft website.

In testing for output data accuracy, 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.

5.2 Conclusion

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

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

- 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.
- 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.
- 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.
- 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-challege of business (0.220) is the least influential/prioritized.
- 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.

5.3 Recommendations

- The prototype system designed and developed in this thesis work is limited to prioritizing only challenges IoT technology adoption and development. More work can be done using the same technique to make it dynamic enough to be applicable to other areas where items need to be ranked.

5.4 Contribution to Knowledge

This thesis aims to contribute to the embodiment of knowledge by meeting up with the limitations of IoT based challenges prioritization approaches garnered in the literature.

Tools, Multicriteria decision making analysis method used, development procedures adopted among others that are used to arrive at a real-world, User-friendly decision support system in this thesis work would add to the existing embodiment of knowledge.

This thesis work would form the bases for more improved research on IoT challenges prioritization decision support tools.

5.5 Suggested Area of 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. Its application to areas other than IoT technology adoption and utilization challenges is currently nearly impossible.

In the light of the above, it is hereby suggested that 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.

Bibliography

Book

Dodgson J., Pearman A., Phillips L. & Spackman M., *Multi-Criteria Analysis: A Manual*, *Appraisal*, vol. 11, 2009, https://doi.org/10.1002/mcda.399.

Ebook

Achimugu P., Ibrahim R. & Selamat A., *ReproTizer: A Fully Implemented Software Requirements Prioritization Tool*, Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 9655 2016: 80–105, https://doi.org/10.1007/978-3-662-49619-0_5.

Aryanfar Y., García-Alcaraz J., García-Alcaraz P., Haj-Assad M., Mohtaram S., Realyvásquez-Vargas A., *Multicriteria Decision Making Methods—A Review and Case of Study. In: Zapata-Cortes, J.A., Sánchez-Ramírez, C., Alor-Hernández, G., García-Alcaraz, J.L. (eds) Handbook on Decision Making. Intelligent Systems Reference Library*, vol 226. Springer, Cham, 2023, https://doi.org/10.1007/978-3-031-08246-7_10

Meenakshi A., *Fuzzy Matrix: Theory and Applications*, Google Books, 2019, https://books.google.com.ng/books?hl=en&lr=&id=4aacDwAAQBAJ&oi=fnd&pg=PA1&dq=fuzzy+theory&ots=XdAfqFSYaF&sig=sXDhYD8cL1DTZveqy2FslNj-26g&redir_esc=y#v=onepage&q=fuzzy theory&f=false.

Conference Proceeding

Balid W. & Refai H., *On the Development of Self-Powered Iot Sensor for Real-Time Traffic Monitoring in Smart Cities*, Proceedings of IEEE Sensors, vol. 2017-December (Institute of Electrical and Electronics Engineers Inc., 2017), 1–3, https://doi.org/10.1109/ICSENS.2017.8234157.

Dewi N. & Putra A., *ECONOMIC-Looking at the Implication and Solutions in the Time of Pandemic through Social, Economic, Educational, Health, and Legal Points of View and Perspectives Decision Support System for Head of Warehouse Selection Recommendation Using Analytic Hierar*, The International Conference of Universitas Pekalongan 2021, 2021, 43–50.

Feng Y., Jia M., Liu Y. & Zhou H., *Evaluation System for Automatic Fare Gate Capacity Based on Delphi and Improved FAHP*, Proceedings of 2017 IEEE 6th Data Driven Control and Learning Systems Conference, DDCLS 2017, 2017, 754–59, https://doi.org/10.1109/DDCLS.2017.8068168.

Journals

Abdullah, F.M., Al-Ahmari, A.M. & Anwar, S. *A Hybrid Fuzzy Multi-Criteria Decision-Making Model for Evaluating the Influence of Industry 4.0 Technologies on Manufacturing Strategies.* **Machines**, 11(2), 2023, p.310. doi:https://doi.org/10.3390/machines11020310.

Adnan M., Akpakwu G., Gerhard P., Hancke & Silva B., *A Survey on 5G Networks for the Internet of Things: Communication Technologies and Challenges,* **IEEE Access Institute of Electrical and Electronics Engineers Inc.,** December 2, 2017, https://doi.org/10.1109/ACCESS.2017.2779844.

Agrawal R., Jamwal A., Kumar V. & Sharma M., *Review on Multi-Criteria Decision Analysis in Sustainable Manufacturing Decision Making*, 14, no. 3, 2020, 202–25, https://doi.org/10.1080/19397038.2020.1866708.

Aikhuele, D.O., Nwosu, H.U. & Ighravwe, D.E. *Data-driven model for the evaluation of the reliability of sensors and actuators used in IoT system architecture*. **Journal of Reliable Intelligent Environments**, 2022 doi:https://doi.org/10.1007/s40860-022-00179-0.

Ahmadi H.B., Lo H.-W., Gupta H., Kusi-Sarpong S. & Liou J.J.H. An integrated model for selecting suppliers on the basis of sustainability innovation. **Journal of Cleaner Production**, 277, 2020, p.123261. doi:https://doi.org/10.1016/j.jclepro.2020.123261

Aji N., Arman S., Dona K., Priatno & Wibisono, *Decision Support System For The Best Student Selection Recommendation Using Ahp (Analytic Hierarchy Process) Method*, **International Journal of Educational Research & Social Sciences**, ISSN: 2774-5406, 2021, 1210–17.

Akhound, N., Adabi, S., Rezaee, A. & Rahmani, A.M. *Clustering of mobile IoT nodes with support for scheduling of time-sensitive applications in fog and cloud layers*. **Cluster Computing.** 2022, doi:https://doi.org/10.1007/s10586-022-03579-2.

Albayrak, Ö. & Erkayman, B. *A Multi-criteria Analysis for Critical Success Factors Through Industry 4.0.* **International Journal of Fuzzy Systems**, 2023, doi:https://doi.org/10.1007/s40815-023-01464-7.

Ali M., Amrozi Y. & Usman I., "*History of Decision-Making: Development and Its Applications*," **Journal of Physics: Conference Series 1573**, no. 1, 2020, https://doi.org/10.1088/1742-6596/1573/1/012010.

Alojaiman, B. *A Multi-Criteria Decision-Making Process for the Selection of an Efficient and Reliable IoT Application* **Processes**, 11(5), p.1313. 2023 doi:https://doi.org/10.3390/pr11051313.

Alzaareer K., & El-Bayeh C., *Steps toward Smart Energy Self-Sufficient Buildings*, **IEEE Smart Grid**, 2020, https://smartgrid.ieee.org/newsletters/april-2020/steps-toward-smart-energy-self-sufficient-buildings.

Asadi, S., Nilashi, M., Iranmanesh, M., Hyun, S.S. & Rezvani, A. *Effect of internet of things on manufacturing performance: A hybrid multi-criteria decision-making and neuro-fuzzy approach. Technovation*, 2021, p.102426, doi:https://doi.org/10.1016/j.technovation.2021.102426.

Beers P., Boshuizen H., Gijselaers W. & Kirschner P., *Common Ground, Complex Problems and Decision Making*, **Group Decision and Negotiation 15**, no. 6 2006, 529–56, https://doi.org/10.1007/s10726-006-9030-1.

Bellman R. & Zadeh L., *Decision-Making in a Fuzzy Environment.* **Management Science 17(4),** 1970, p.B-141-B-164. https:// doi.org/10.1287/mnsc.17.4.B141

Chakraborty, B. & Das, S. *Introducing a New Supply Chain Management Concept by Hybridizing TOPSIS, IoT and Cloud Computing.* **Journal of The Institution of Engineers (India): Series C**., 2020 doi:https://doi.org/10.1007/s40032-020-00619-x.

Chana I., Hadi Y. Lahmer M., Rhattoy A. & Rhazali Y., *A Model Transformation in Model Driven Architecture from Business Model to Web Model*, **IAENG International Journal of Computer Science 45**, no. 1, 2018: 104–17.

Choudhary P., Firoz N., Singh A., Singh K., Tripathi A. &Vashist P., *Internet of Things: From Hype to Reality*, **Industrial IoT Approach for Pharmaceutical Industry Growth**, Elsevier 2020, 191–230, https://doi.org/10.1016/b978-0-12-821326-1.00007-3.

Ciuffoletti A., *Low-Cost IoT: A Holistic Approach*, **Journal of Sensor and Actuator Networks 7**, no. 2, 2018, https://doi.org/10.3390/jsan7020019.

Da Silva e. Souza G. & Gomes E., *A Performance Measure to Support Decision-Making in Agricultural Research Centers in Brazil,* **Procedia Computer Science 55**, no. Itqm 2015, 405–14, https://doi.org/10.1016/j.procs.2015.07.094.

Deng H., *Multicriteria Analysis with Fuzzy Pairwise Comparison*, **International Journal of Approximate Reasoning 21**, no. 3, 1999, 215–31, https://doi.org/10.1016/S0888-613X(99)00025-0.

Dursun D., A*n Overview of the Human Decision-Making Process | Introduction to Business Analytics and Decision-Making,* **InformIT**, 2019, https://www.informit.com/articles/article.aspx?p=2992600&seqNum=2.

Everistus Z. & Emmanuel U., *Issues and Challenges in Security and Privacy of Internet of Things (IOT) Automation View Project Access Control System View Project Issues and Challenges in Security and Privacy of Internet of Things (IOT)*, **International Journal of Latest Technology in Engineering**, vol. VII, 2018, www.ijltemas.in.

Ghafoori S, Ghasemi R., Mahbanooei B., Mohammadian A., Mohammadzadeh A., & Mohammadkazemi R., *A Fuzzy Analytic Network Process (FANP) Approach for Prioritizing Internet of Things Challenges in Iran*, **Technology in Society**, 53, 2018, 124–34, https://doi.org/10.1016/j.techsoc.2018.01.007.

Goel, G. & Tiwari, R. *Resource Scheduling Techniques for Optimal Quality of Service in Fog Computing Environment: A Review* **Wireless Personal Communications**. 2023, doi:https://doi.org/10.1007/s11277-023-10421-4.

Haghparast, M.B., Berehlia, S., Akbari, M. & Sayadi, A. *Developing and evaluating a proposed health security framework in IoT using fuzzy analytic network process method.* **Journal of Ambient Intelligence and Humanized Computing,** 12(2), 2020, pp.3121–3138. doi:https://doi.org/10.1007/s12652-020-02472-3.

Hämäläinen P. & Salo A., *Multicriteria Decision Analysis in Group Decision* **Processes**, **MDPI** 2010, 269–83, https://doi.org/10.1007/978-90-481-9097-3_16.

Hoda, S.A. & Mondal, A.C.. *Studies on Multi-Criteria Decision-Making-Based Healthcare Systems Using the Machine Learning*. **Journal of Artificial Intelligence and Technology,** 3(2), 2023, pp.53–59. doi:https://doi.org/10.37965/jait.2023.0167.

Honest P., "*Reflections on the Implications of the Fourth Industrial Revolution (Fir) on Taxation*," **Financ.Dev**, vol. 1, August 18, 2020, www.ngowitv.co.tz.

Hong I., Jeong D., Lee B., Lee J., Park S. & Zhou Z., *IoT-Based Smart Garbage System for Efficient Food Waste Management***,** **Scientific World Journal** 2014, https://doi.org/10.1155/2014/646953.

Jain C. & Kacprzyk J., *Handbook on Decision Making: Techniques and Applications*, **ed. Intelligent Systems Reference Library**, Volume 1, vol. 1999 (Springer-Verlag Berlin Heidelberg, 2006), https://doi.org/DOI 10.1007/978-3-642-13639-9 Intelligent.

Karlsson J., Regnell B. & Wohlin C., *An Evaluation of Methods for Prioritizing Software Requirements*, **Information and Software Technology 39**, no. 14–15, 1998: 939–47, https://doi.org/10.1016/s0950-5849(97)00053-0.

Kiran D., "I*nternet of Things - an Overview,* **ScienceDirect Topics***,* 2021, https://www.sciencedirect.com/topics/engineering/internet-of-things.

Lelli F., *Interoperability of the Time of Industry 4.0 and the Internet of Things*, **Future Internet** MDPI AG, February 3, 2019, https://doi.org/10.3390/fi11020036.

Li K., Zhou T. & Liu B. *Internet-based intelligent and sustainable manufacturing: developments and challenges*. **The International Journal of Advanced Manufacturing Technology**, 108(5-6), 2020, pp.1767–1791. doi:https://doi.org/10.1007/s00170-020-05445-0.

Maksimovic M., "*Greening the Future: Green Internet of Things (G-IoT) as a Key Technological Enabler of Sustainable Development,*" 2018, pp283–313, https://doi.org/10.1007/978-3-319-60435-0_12.

Mogadem M., Li, Y. & Meheretie, D. *A survey on internet of energy security: related fields, challenges, threats and emerging technologies*. **Cluster Computing** 2021, doi:https://doi.org/10.1007/s10586-021-03423-z.

Mohammadian M., Sedighi M., & Serkani M. *Selection of Internet of things (IOT) applications in education industry using the Best-Worst Multi-Criteria Decision-Making Method*. **Technology of Education Journal (TEJ)**, 16(2), 2022. pp.363–386. doi:https://doi.org/10.22061/tej.2022.7414.2533.

Odu G., *Weighting Methods for Multi-Criteria Decision Making Technique*, **Journal of Applied Sciences and Environmental Management 23**, no. 8, 2019: 1449–57, https://doi.org/10.4314/jasem.v23i8.7

Olorundare A., Olorundare J. & Sayyadi S., *Internet of Things Prospect in Nigeria: Challenges and Solutions,* **IEEE 3rd International Conference on Electro-**

Technology for National Development, NIGERCON 2017, vol. 2018-January 736–45, https://doi.org/10.1109/NIGERCON.2017.8281942.

Pant S., Garg, P., Kumar, A., Ram M., Kumar, A., Hitesh Kumar Sharma & Yury K. *AHP-based multi-criteria decision-making approach for monitoring health management practices in smart healthcare system*. **International Journal of Systems Assurance Engineering and Management**. 2023, doi:https://doi.org/10.1007/s13198-023-01904-5.

Rao P.M. & Deebak B.D. *Security and privacy issues in smart cities/industries: technologies, applications, and challenges.* **Journal of Ambient Intelligence and Humanized Computing**. 2022 doi:https://doi.org/10.1007/s12652-022-03707-1.

Rhodes M., *Creating a Survey Solution with Forms, Power Automate, SharePoint, and Power BI*, **Creating Business Applications with Microsoft 365**, 2022, 63–70, https://doi.org/10.1007/978-1-4842-8823-8_5.

Sattarian M., Rezazadeh J., Farahbakhsh R. & Bagheri A., *Indoor navigation systems based on data mining techniques in internet of things: a survey.* **Wireless Networks**, 25(3), 2018, pp.1385–1402. doi:https://doi.org/10.1007/s11276-018-1766-4.

Soltani M., Behrang B., Faramarz H. & Beheshti, Z. *FSCN: a novel forwarding method based on Shannon entropy and COPRAS decision process in named data networking.* **The Journal of Supercomputing**. 2023, doi:https://doi.org/10.1007/s11227-023-05265-5.

Sun N., Ren F., Wu L., Xu M. & Zhang X., *Changes in Soil Microbial Biomass with Manure Application in Cropping Systems: A Meta-Analysis*, **Soil and Tillage Research 194**, no. April 2019: 104291, https://doi.org/10.1016/j.still.2019.06.008

World Econimic Forum, *Internet of Things Guidelines for Sustainability,* **IoT for Sustainable Development Project**, 2018, http://wef.ch/IoT4D.

Zeng S. *Ranking of Internet of Things (IOT) Applications in Dairy Cattle Industry Productivity*: A Multi Criteria Decision Making Approach and Thematic Analysis. **Pakistan Journal of Zoology**. 2022. doi:https://doi.org/10.17582/journal.pjz/20220521050533.

Zhao B., Wang H., Huang Z. & Sun Q. *Location mapping for constructing biomass power plant using multi-criteria decision-making method*. **Sustainable Energy Technologies and Assessments, 49,** 2022 p.101707. doi:https://doi.org/10.1016/j.seta.2021.101707.

Magazine Article

Craig C., *Choosing Among Alternatives - Ag Decision Maker*, **IOWA State University**, 2007, https://www.extension.iastate.edu/agdm/wholefarm/html/c5-152.html.

International Telecommunication Union, *ICT Facts and Figures 2017*, 2017, moz-extension://1660c496-045a-4211-85b3-d2879d15cc70/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fwww.itu.int%2Fen%2Fitu-D%2FStatistics%2FDocuments%2Ffacts%2FICTFactsFigures2017.pdf.

Nique M. & Opala K., *The SynergieS beTween Mobile, Energy and WaTer AcceSS: Africa*, 2014, http://www.gsma.com/mobilefordevelopment/new-report-on-sizing-the-opportunity-of-mobile-to-support-energy-water-access.

Electronic Sources (Internet)

Change Factory, *The Power of Positive Decision-Making - Change Factory*, Change Factory, 2014, https://www.changefactory.com.au/our-thinking/articles/the-power-of-positive-decision-making/.

Donald W., *Industry 4.0 and IoT are Key Elements of the Digital Revolution*, 2020, https://www.bearingpoint.com/en/our-success/insights/industry-4-0-and-iot-insight/

IEduNote, *Programmed Decision and Non-Programmed Decision Explained*, 2017, https://www.iedunote.com/programmed-decision-non-programmed-decision.

Emidio A., *10 Reasons Why Decision Making Is Important In Management*, 2020, https://www.analyticsfordecisions.com/decision-making-is-important-in/.

Forti D., *Unpacking the UN Secretary-General's Strategy on New Technologies,* IPI Global Observatory, 2018, https://theglobalobservatory.org/2018/09/unpacking-secretary-generals-strategy-new-technologies/.

Jeff B., *The 9 Characteristics of a Good Decision,* 2015, https://www.entrepreneur.com/article/250175.

GoogleDir, *15 Main Characteristics of Decision Making (With Examples),* Googlesir, 2018, https://www.googlesir.com/characteristics-of-decision-making/.

IGI Global, *What Is Analytical Network Process (ANP),* IGI Global, 2015, https://www.igi-global.com/dictionary/analytical-network-process-anp/43223.

Indeed, *What Is a Multiple Criteria Decision Analysis? (With Example)*, Indeed.Com," 2023, https://www.indeed.com/career-advice/career-development/multiple-criteria.

Harappa Learning Private Limited, *What Is Decision Making: Definition, Importance & Meaning of Decision Making,* Harappa Education, 2020, https://harappa.education/harappa-diaries/what-is-decision-making/.

Jade S., *History of the Internet of Things (IoT)*, IT Blog, 2020, https://www.itonlinelearning.com/blog-history-iot/.

Lirima, *(English) IoT4D – Internet of Things for Developing Countries*, LIRIMA, 2016, https://lirima.inria.fr/fr/focus-on-a-joint-project-team-iot4d/.

McKinsey Global Institute, *"The Internet Of Things: Mapping The Value Beyond The Hype,"* 2015, www.mckinsey.com/mgi.

Mathew M., *Fuzzy Analytic Hierarchy Process (FAHP) - Using Geometric Mean*, YouTube, 2019, https://www.youtube.com/watch?v=5k3Wz1AfVWs.

Nations Online, *Countries of the Third World* - Nations Online Project, 2007, Nationsonline.org. https://www.nationsonline.org/oneworld/third_world.htm.

Prime Care Technologies, *Data-Driven Decisions – an Art and a Science*, Prime Care Technologies, 2016, https://www.primecaretech.com/news/data-driven-decisions-an-art-and-a-science.

Scherf T. & Sattelberger J., *Internet of Things-Hype or Hope for Developing Countries?*, June 24, 2016, moz-extension://1660c496-045a-4211-85b3-d2879d15cc70/enhanced-reader.html?openApp&pdf=https%3A%2F%2Fwww.kfw-

Tanuja A., *Types of Decisions: Programmed and Non-Programmed*, Business Management Ideas, 2016, https://www.businessmanagementideas.com/decision-making/types-of-decisions-programmed-and-non-programmed/4831.

Tutorials Teacher, *ASP.NET MVC Architecture*, 2019, https://www.tutorialsteacher.com/mvc/mvc-architecture.

United Nations, *Closing the Technology Gap in Least Developed Countries,* United Nations, 2018, https://www.un.org/en/chronicle/article/closing-technology-gap-least-developed-countries.

United Nations, *The 17 Goals | Sustainable Development*, Department of Economic and Social Affairs, 2015, https://sdgs.un.org/goals.

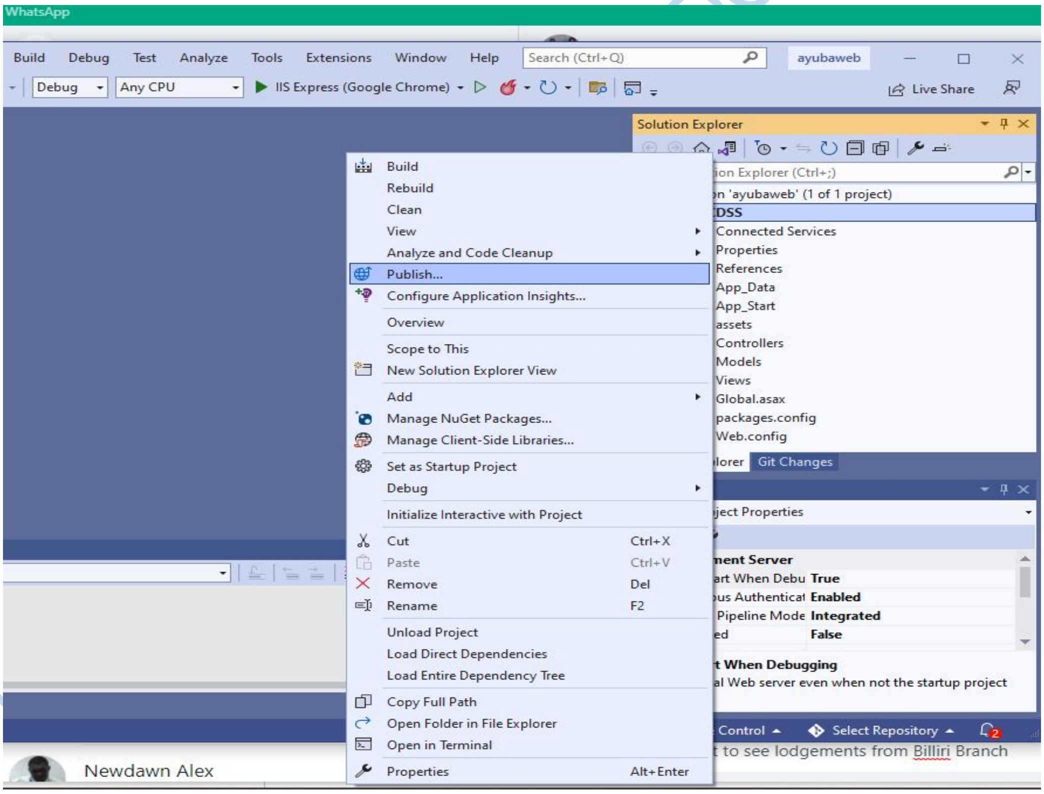
Wikipedia, *Decision Rule*, Wikipedia, 2020, https://en.wikipedia.org/wiki/Decision_rule.

Appendices

Deployment i

Step 1

Right-click on your ASP.NET MVC5 application inside Visual Studio and then click "Publish".

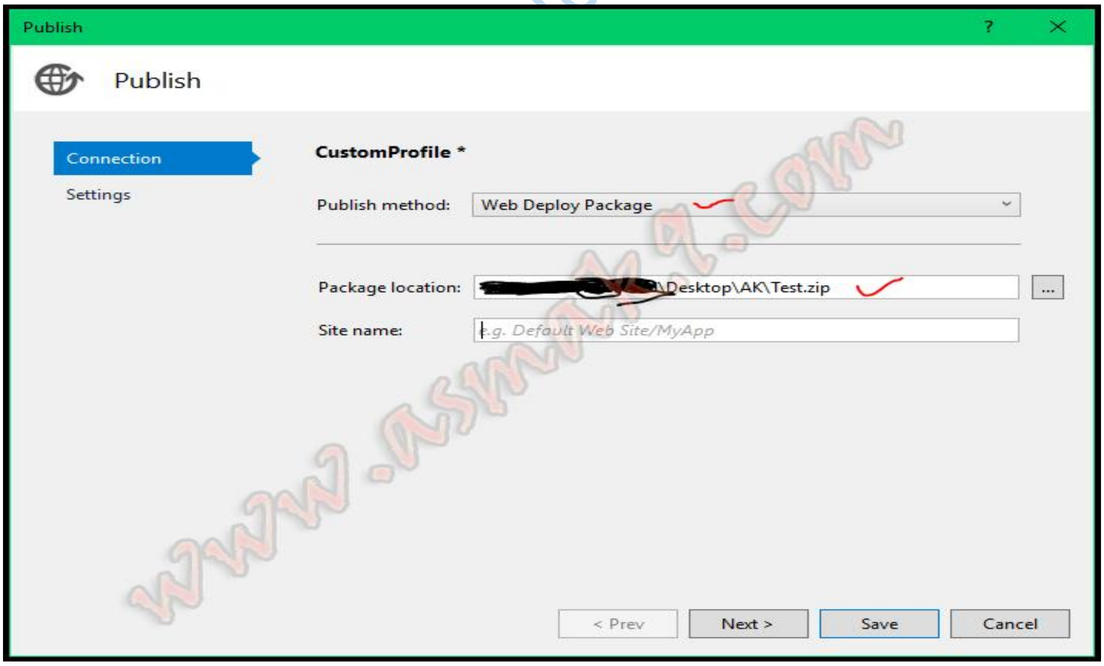


Step 2

Now, the "IIS" option was selected from the left menu and click "Create Profile" button was pressed.

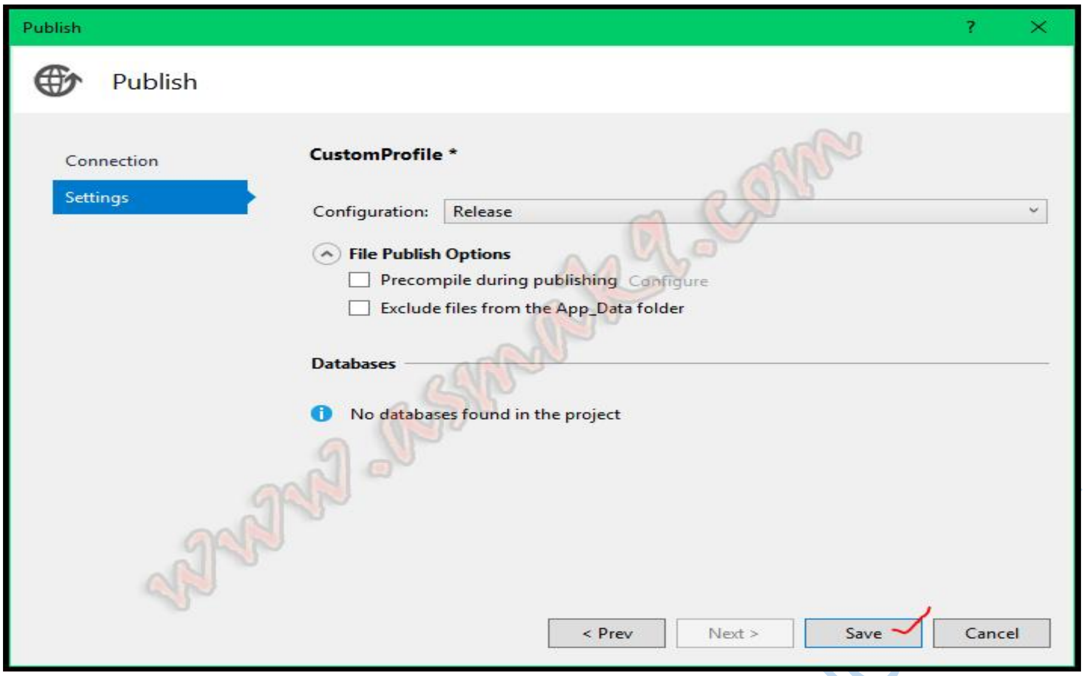
Step 3

The publish method was changed to "Web Deploy Package" and the MCDSS package location was provided, then the "Next" button was cliecked.



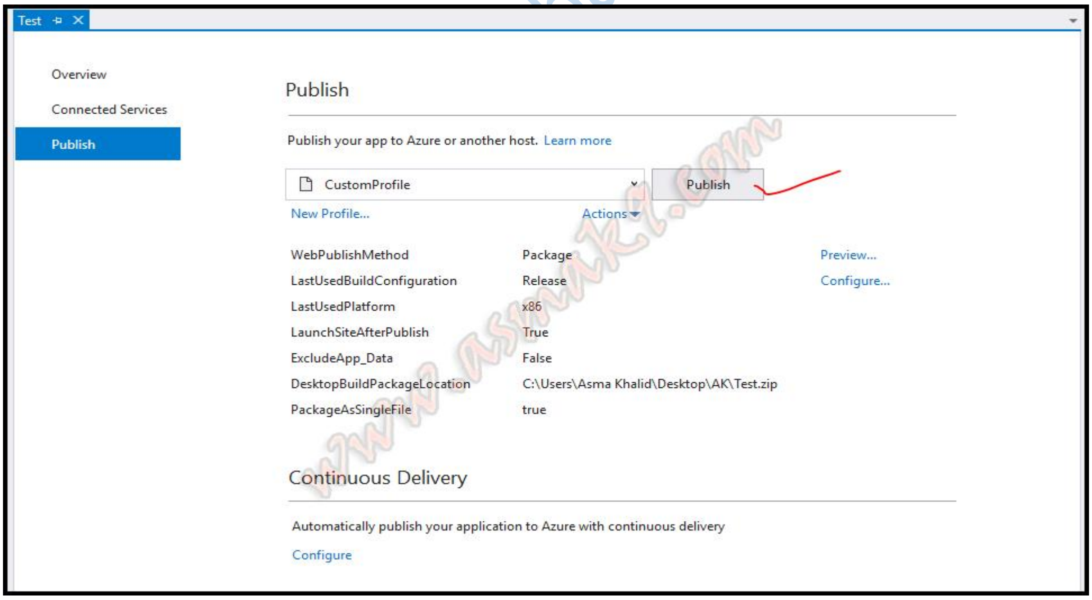
Step 4

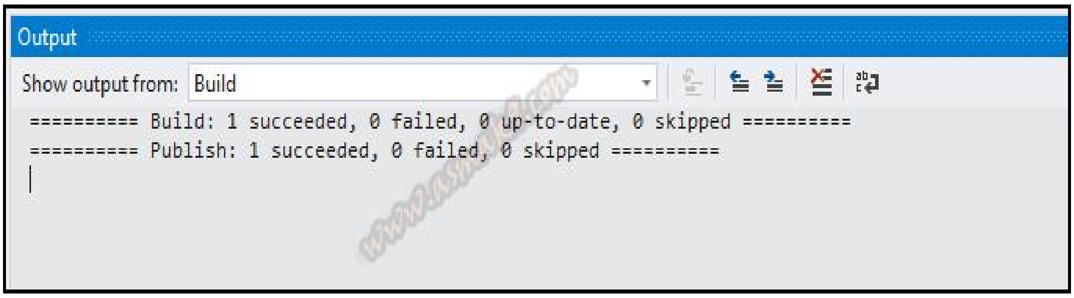
The "Save" button was clicked on the next screen.



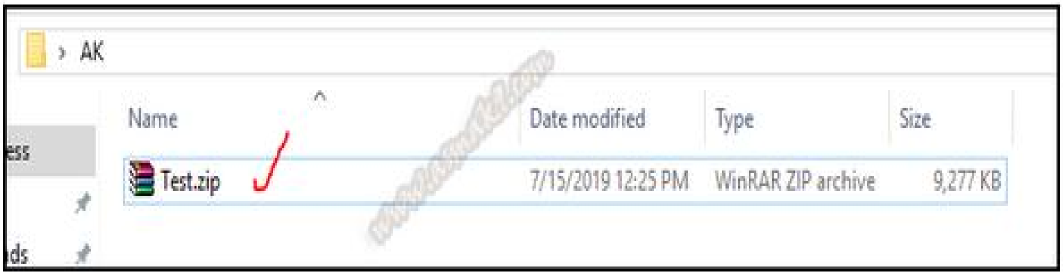
Step 5

Next, the "Publish" button was pressed on the publish screen.



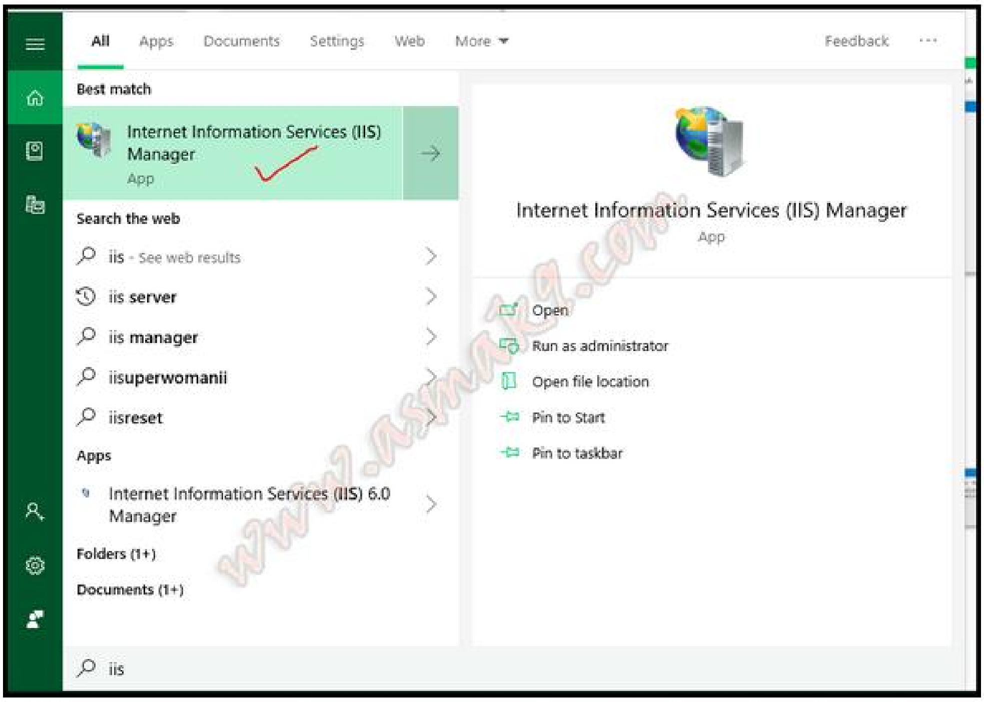


At this stage the web application deployment package got stored as ".zip" file on the target location.



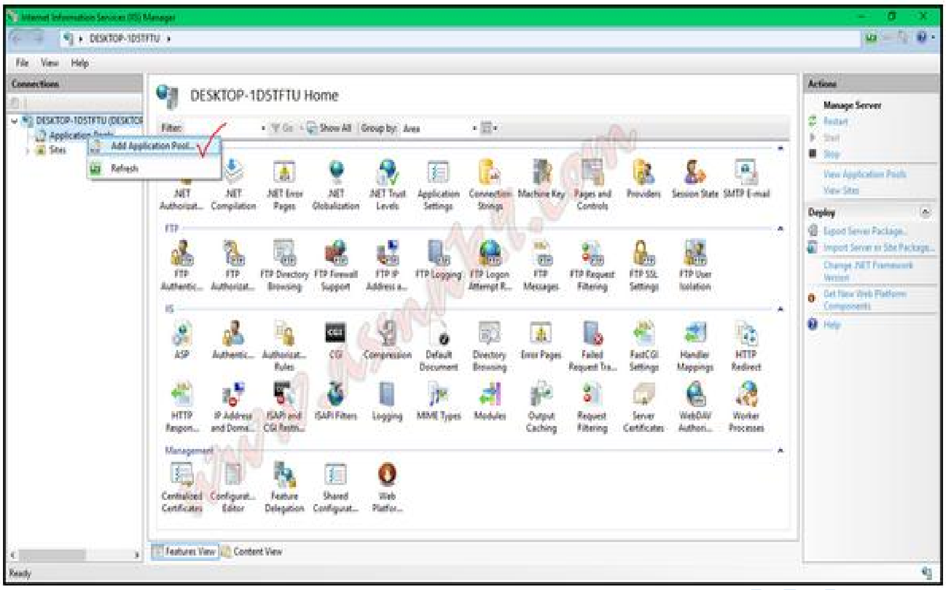
Step 6

"Internet Information Services (IIS) Manager" was run on the web server computer.



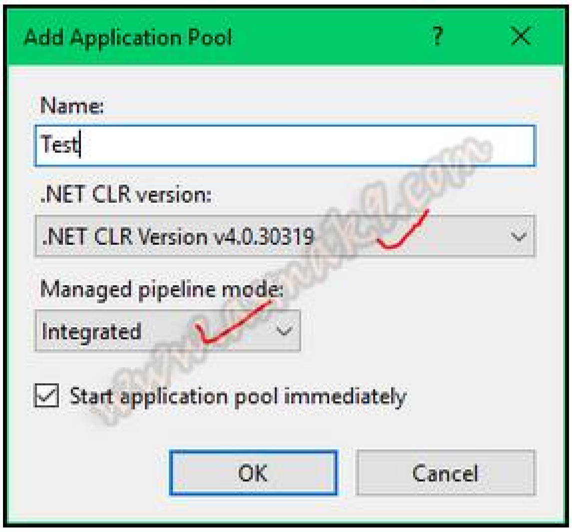
Step 7

The "Application Pool" was right-clicked and then "Add Application Pool" was selected.



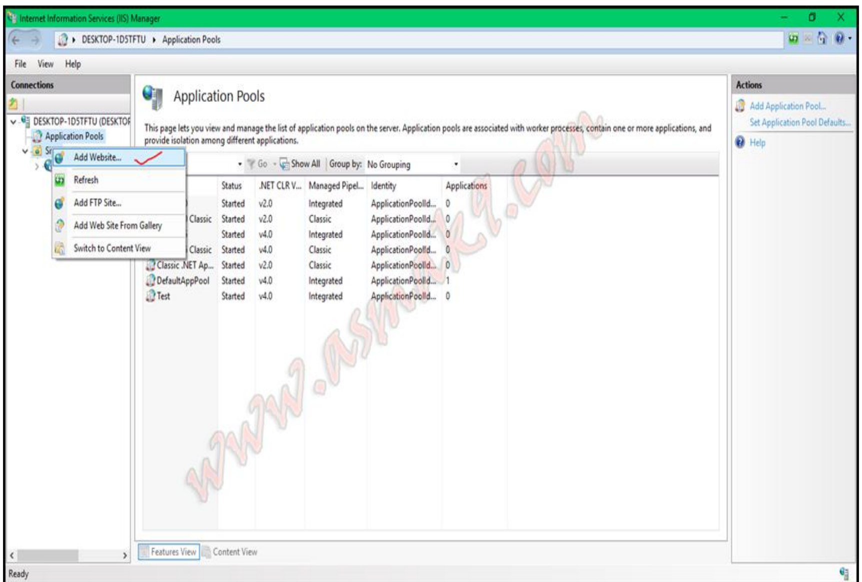
Step 8

The application pool name was provided and the settings were made as shown below, and then the "OK" button was clicked.



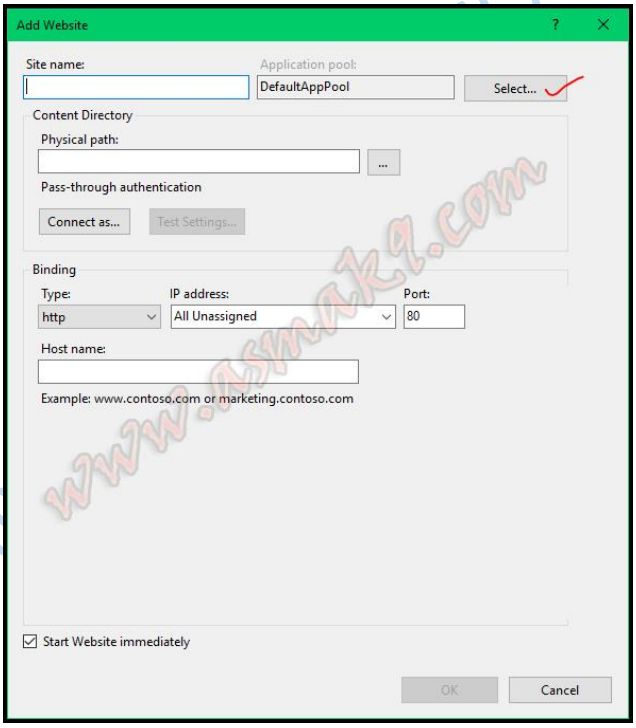
Step 9

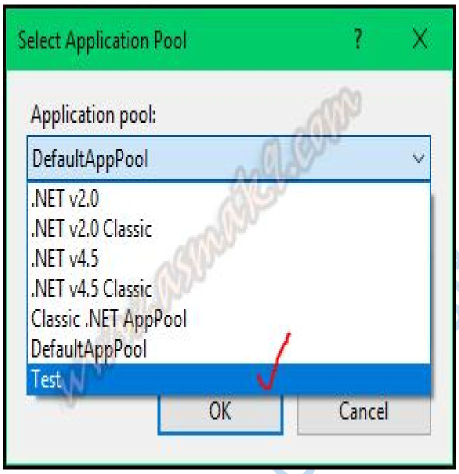
Next, on "Sites", "Add Website" was clicked



Step 10

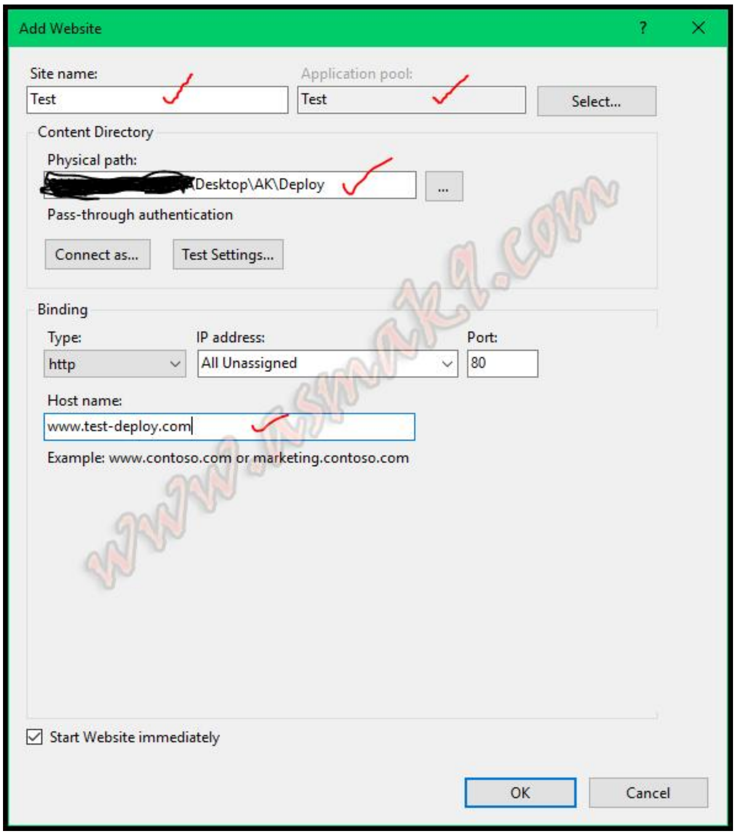
On "Add Website" window, the initially created application pool was selected;



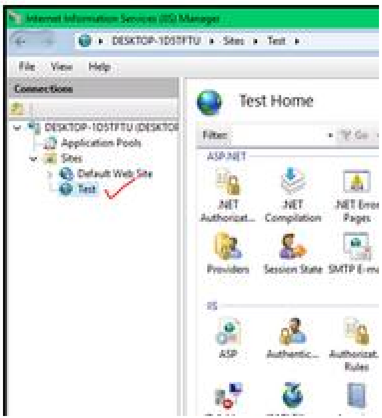


Step 11

Configuration settings were provided on "Add Website" screen;



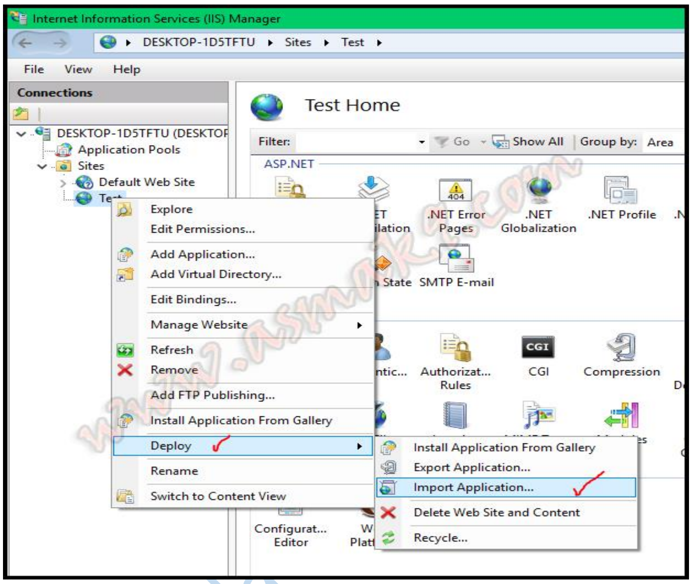
An empty website is now created on the server as shown



below:

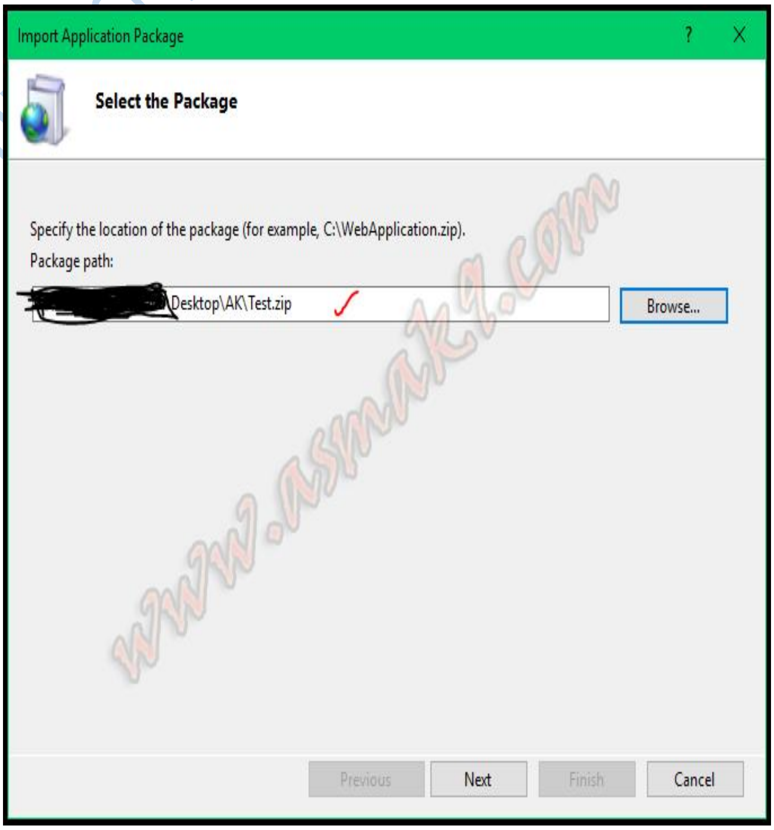
Step 12

On the "Test" site "Deploy->Import Application" was selected:



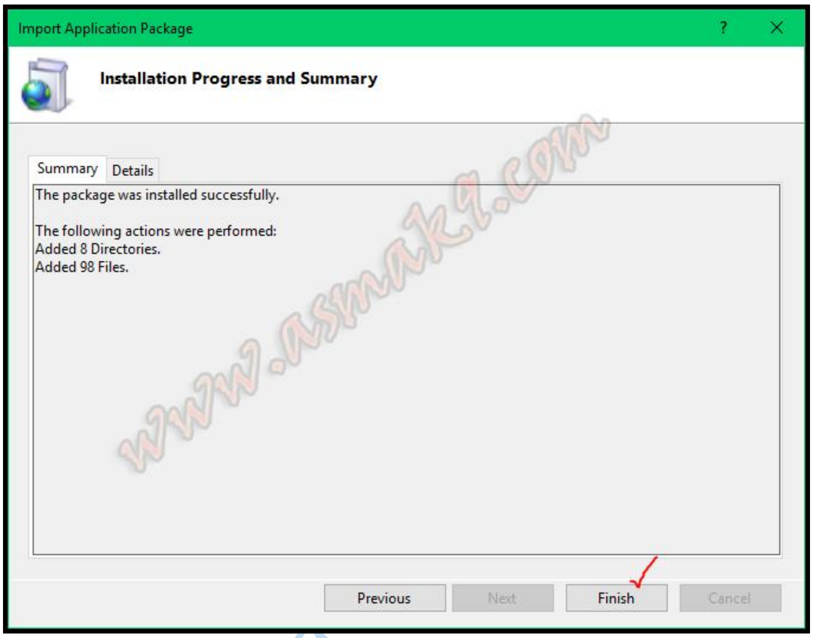
Step 13

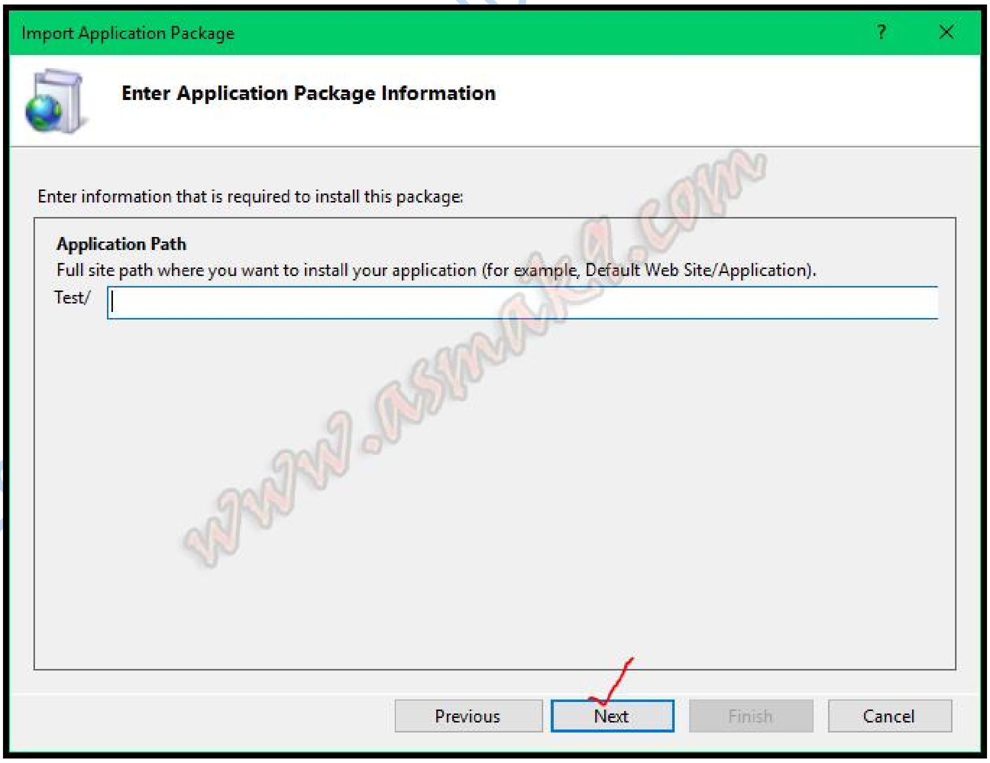
On the "Select Package" screen, the location path of the published ".zip" web application file and was provided.



Step 16

On clicking a finish button, the web application was created:





Appendix ii - System Usability Feedback Summary

Multi-criteria Decision support System (MCDSS) - System Usability Feedback Form

5	03:55	Active
Responses	Average time to complete	Status

1. Email Address

5
Responses

Latest Responses
"dpeter@gmail.com"
"alexnasiru88@gmail.com"
"jloni@gmail.com"

2. Your Organisation

5
Responses

Latest Responses
"Elotech IT Solutions"
"Elotech IT Solutions"
"Elotech IT Solutions"

3. Whats your job title in your organization

5
Responses

Latest Responses
"Technical Consultant"
"Software Developer"
"Database Administrator"

4. Briefly describe the main services/products that your organization offer

5

Responses

Latest Responses

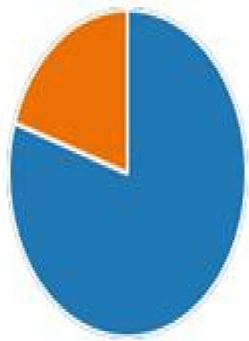
"Software design"

"IT Solutions"

"IT solutions Development"

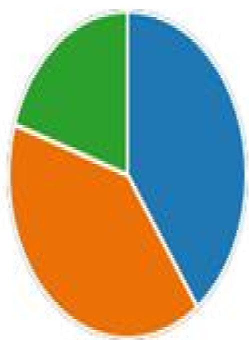
5. Gender

Male	4
Female	1



6. How old are you?

18-24	2
35-44	2
45-54	1
55-65	0
Above 65	0



7. What's your highest level of education?

PhD	0
Master	0
PGD	2
Bachelor	1
HND	1
ND	1

8. What is the size of your organization?

1 - 10 Employees	1
11 - 50 Employees	4
51 - 200 Employees	0
201 - 500 Employees	0
Above 500 Employees	0

9. How would you describe this product to someone

Poor	0
Fair	0
Good	0
Very good	2
Exceptional	2
Excellent	1

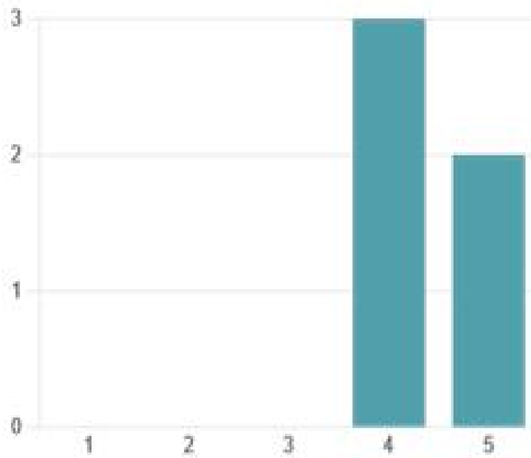
10. What was your favorite aspect of the product?

User account creation	0
User profile creation, update an...	0
Organization creation, update a...	0
Invitation of decision stakehold...	1
The decision stakeholder invitati...	0
The stakeholder profile update ...	0
Stakeholder experiences on the ...	1
Admin experiences on the natur...	0
All of the above	3

11. How satisfied are you with the available workflows?

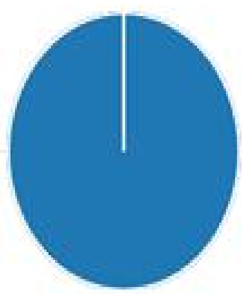
4.40

Average Rating

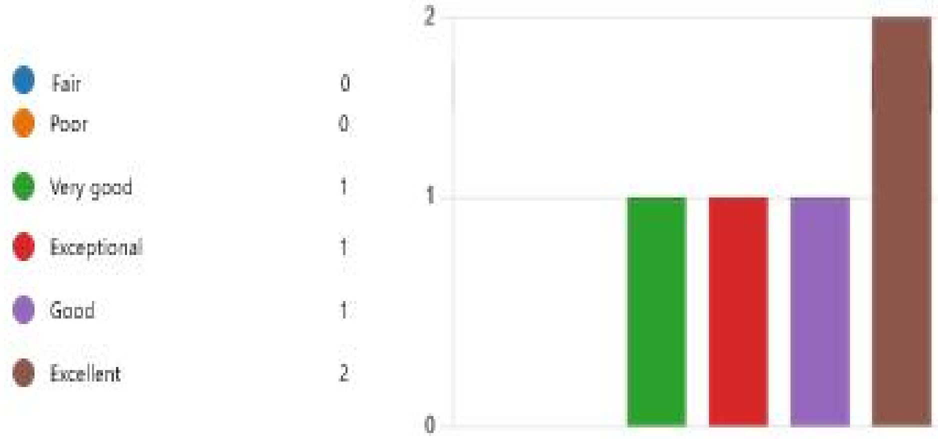


12. Do you like the interface? Is it easy to use?

Yes	5
No	0
Maybe	0



13. What do you think about how information and features are laid out?



14. If you could change one thing about the website or app, what would it be?

15. What one thing are you most excited about with the website or app? Why?

5

Responses

Latest Responses

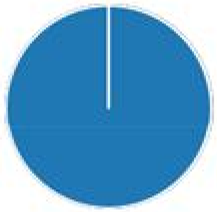
"It is easy to use"

"The output result"

"Its user friendly"

16. Would you recommend this product to a friend or colleague

- Yes 5
- No 0
- Maybe 0



17. Kindly list items that was not displaying properly

4
Responses

Latest Responses
"Non"
"None"

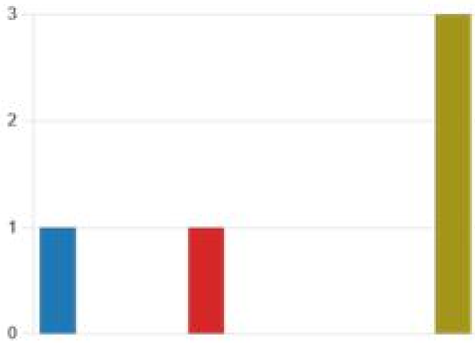
18. Kindly list errors observed during the process of the questionnaire completion

4
Responses

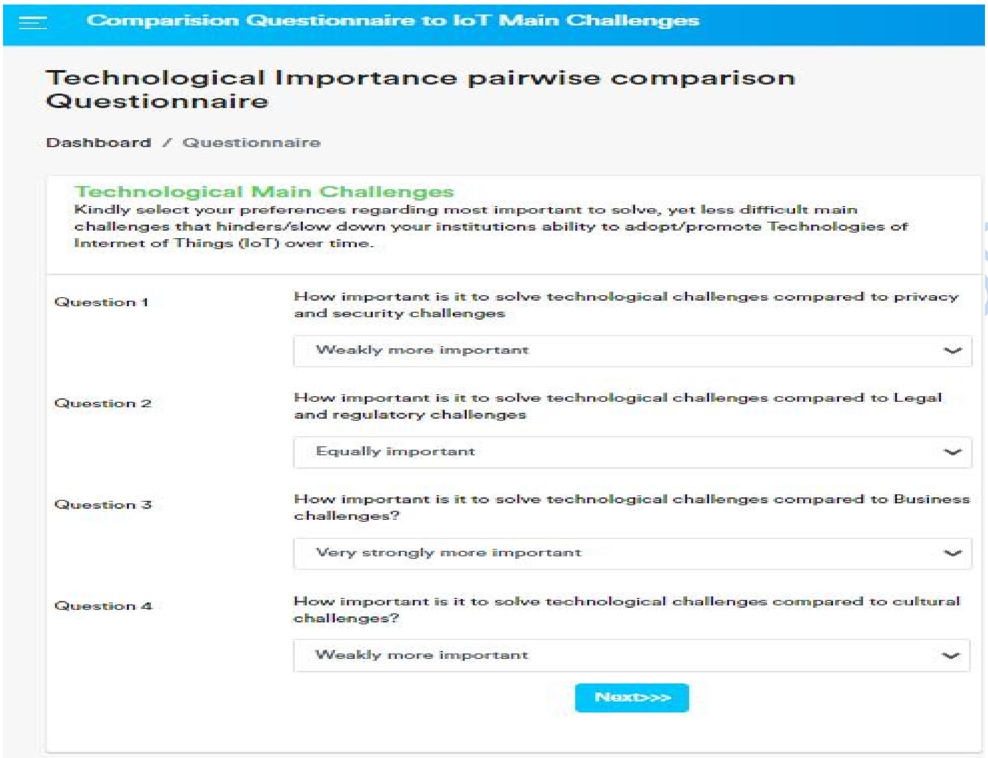
Latest Responses
"Non"
"None"

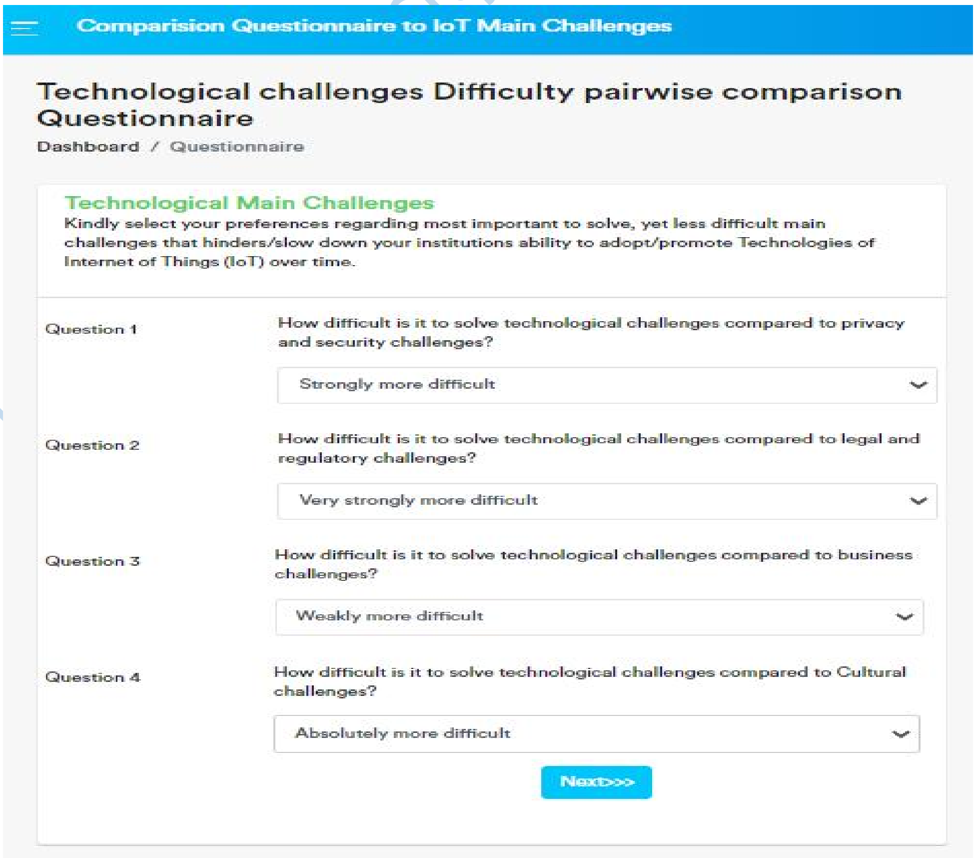
19. Which function did not work properly

- User account creation 1
- User profile creation, update an... 0
- Organization creation, update a... 0
- Invitation of decision stakehold... 1
- The decision stakeholder invitati... 0
- The stakeholder profile update ... 0
- Stakeholder experiences on the ... 0
- Admin experiences on the natur... 0
- None 3



Appendix iii : - Some Questionnaire User Interfaces on Challenges and Sub-Challenges of IoT Technology Adoption





Comparision Questionnaire to IoT Main Challenges

Privacy & Sec. Importance pairwise comparison Questionnaire

Dashboard / Questionnaire

Privacy & Security Main Challenges

Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How important is it to solve Privacy and security challenges compared to technological challenges?

Strongly more important

Question 2

How important is it to solve Privacy and security challenges compared to legal and regulatory challenges?

Equally important

Question 3

How important is it to solve Privacy and security challenges compared to business challenges?

Very strongly more important

Question 4

How important is it to solve Privacy and security challenges compared to Cultural challenges?

Just Equal

Next>>>

Comparision Questionnaire to IoT Main Challenges

Privacy & Security Difficulty pairwise comparison Questionnaire

Dashboard / Questionnaire

Privacy & Security Main Challenges

Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How difficult is it to solve Privacy and security challenges compared to technological challenges?

Equally difficult

Question 2

How difficult is it to solve Privacy and security challenges compared to legal and regulatory challenges?

Strongly more difficult

Question 3

How difficult is it to solve Privacy and security challenges compared to business challenges?

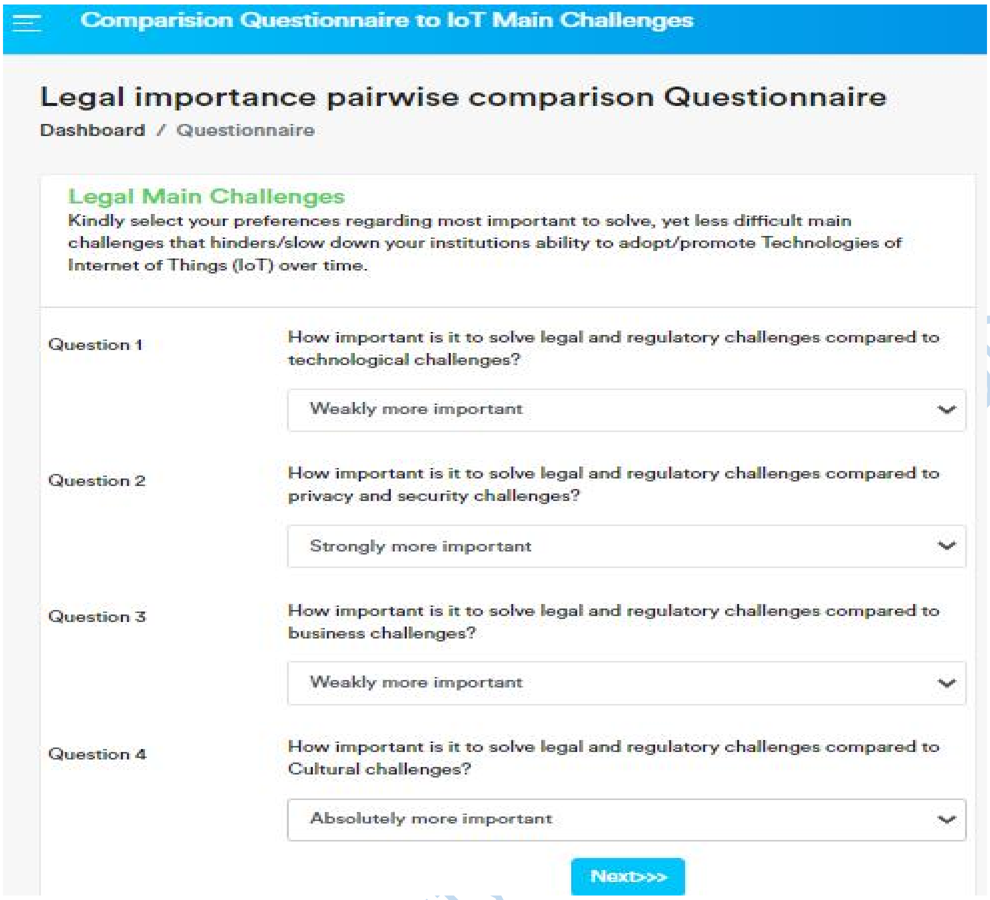
Strongly more difficult

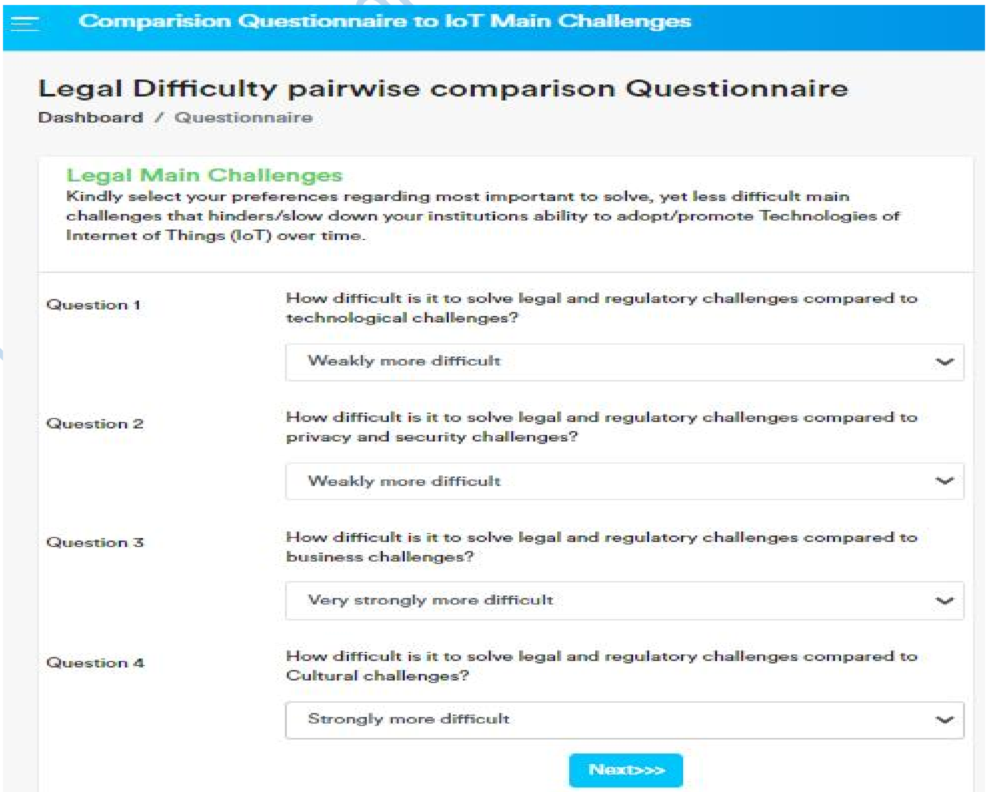
Question 4

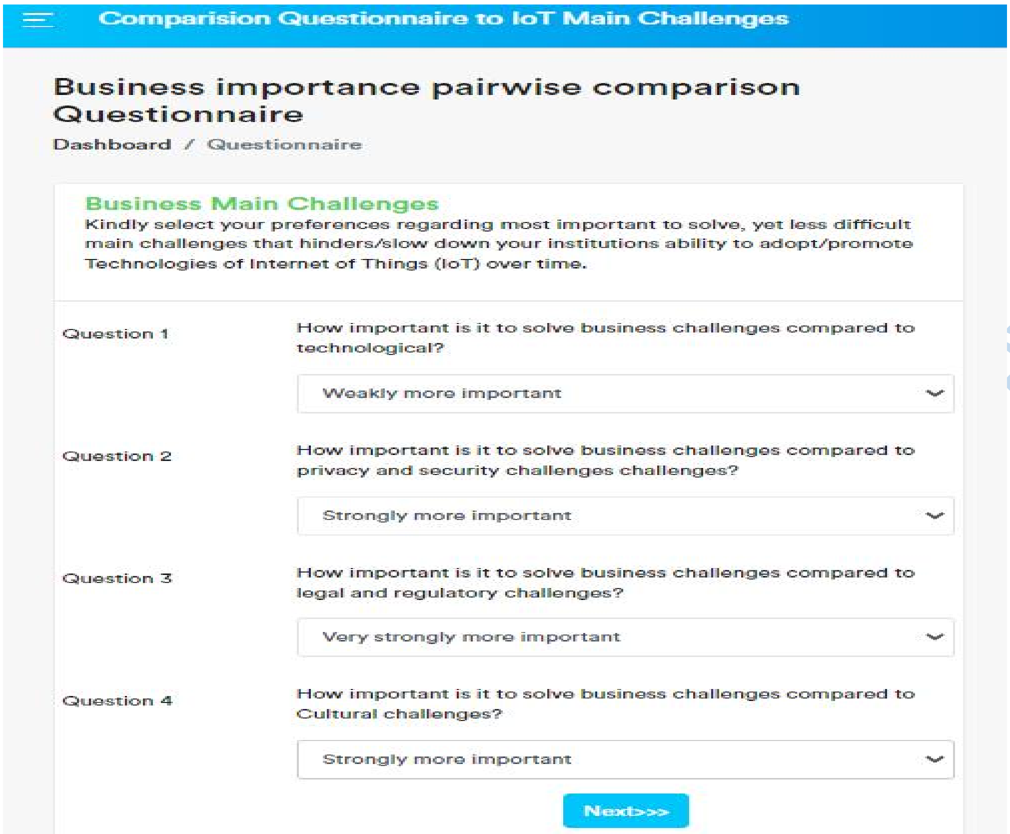
How difficult is it to solve Privacy and security challenges compared to Cultural challenges?

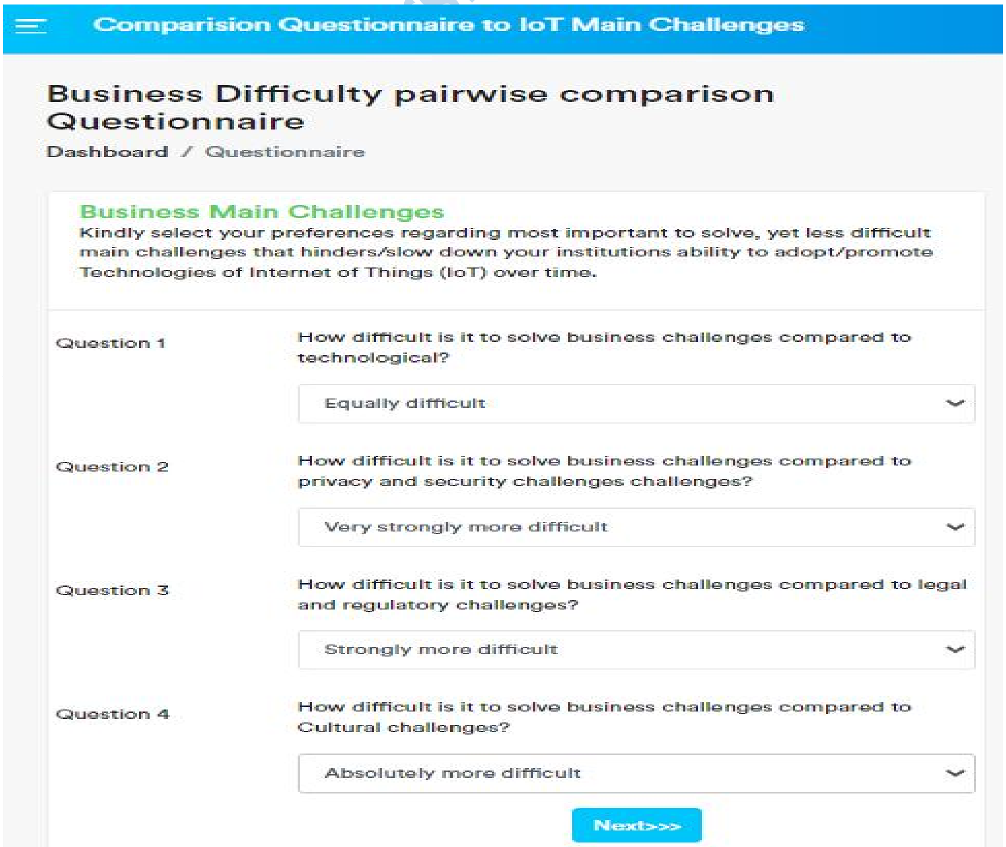
Strongly more difficult

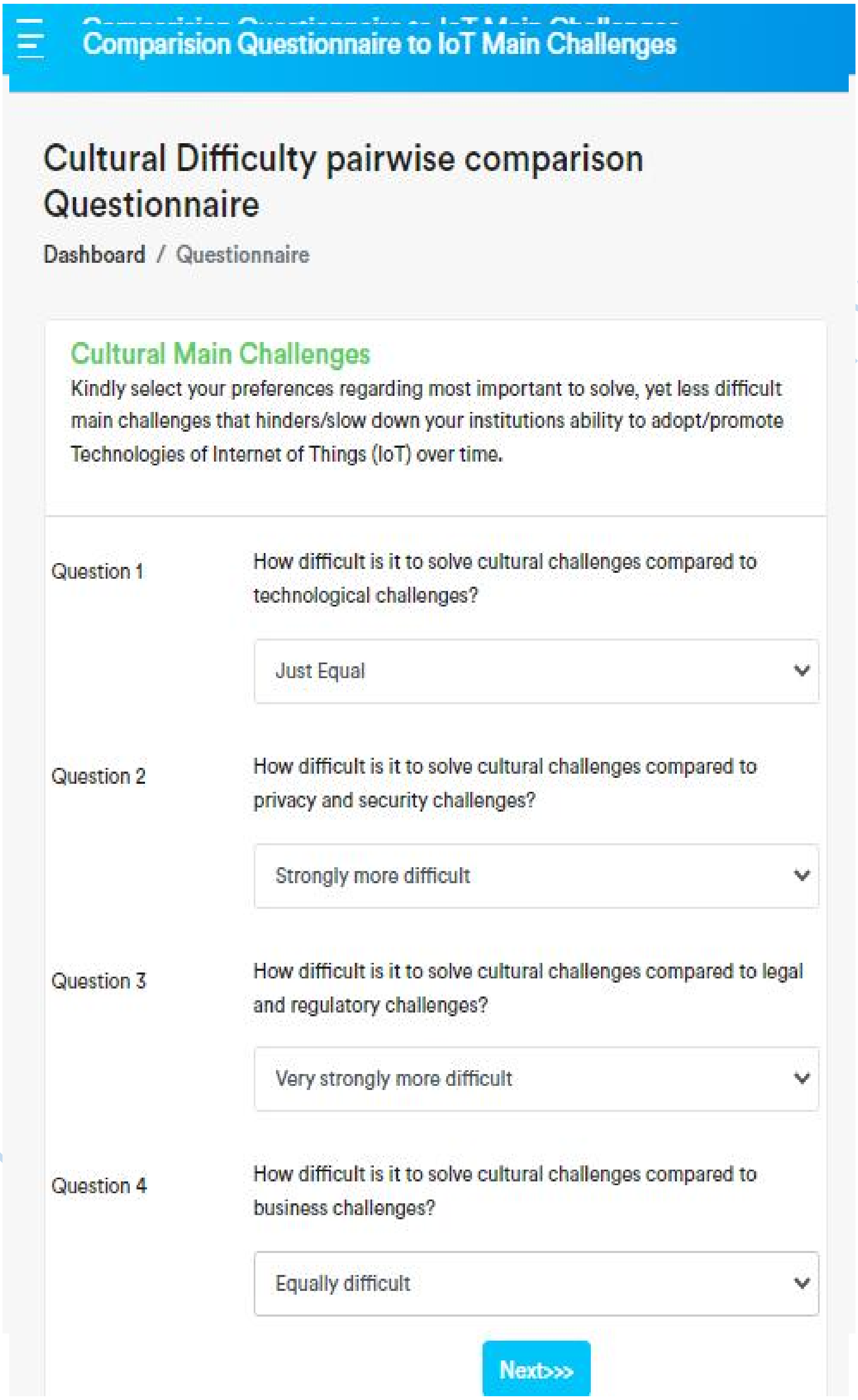
Next>>>


Comparision Questionnaire to IoT Main Challenges
Legal importance pairwise comparison Questionnaire
Dashboard / Questionnaire
Legal Main Challenges
Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.
Question 1
How important is it to solve legal and regulatory challenges compared to technological challenges?
Weakly more important
Question 2
How important is it to solve legal and regulatory challenges compared to privacy and security challenges?
Strongly more important
Question 3
How important is it to solve legal and regulatory challenges compared to business challenges?
Weakly more important
Question 4
How important is it to solve legal and regulatory challenges compared to Cultural challenges?
Absolutely more important
Next>>>


Comparision Questionnaire to IoT Main Challenges
Legal Difficulty pairwise comparison Questionnaire
Dashboard / Questionnaire
Legal Main Challenges
Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.
Question 1
How difficult is it to solve legal and regulatory challenges compared to technological challenges?
Weakly more difficult
Question 2
How difficult is it to solve legal and regulatory challenges compared to privacy and security challenges?
Weakly more difficult
Question 3
How difficult is it to solve legal and regulatory challenges compared to business challenges?
Very strongly more difficult
Question 4
How difficult is it to solve legal and regulatory challenges compared to Cultural challenges?
Strongly more difficult
Next>>>


Comparision Questionnaire to IoT Main Challenges
Business importance pairwise comparison Questionnaire
Dashboard / Questionnaire
Business Main Challenges
Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.
Question 1
How important is it to solve business challenges compared to technological?
Weakly more important
Question 2
How important is it to solve business challenges compared to privacy and security challenges challenges?
Strongly more important
Question 3
How important is it to solve business challenges compared to legal and regulatory challenges?
Very strongly more important
Question 4
How important is it to solve business challenges compared to Cultural challenges?
Strongly more important
Next>>>


Comparision Questionnaire to IoT Main Challenges
Business Difficulty pairwise comparison Questionnaire
Dashboard / Questionnaire
Business Main Challenges
Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.
Question 1
How difficult is it to solve business challenges compared to technological?
Equally difficult
Question 2
How difficult is it to solve business challenges compared to privacy and security challenges challenges?
Very strongly more difficult
Question 3
How difficult is it to solve business challenges compared to legal and regulatory challenges?
Strongly more difficult
Question 4
How difficult is it to solve business challenges compared to Cultural challenges?
Absolutely more difficult
Next>>>



Comparision Questionnaire to IoT Main Challenges

Cultural Difficulty pairwise comparison Questionnaire

Dashboard / Questionnaire

Cultural Main Challenges

Kindly select your preferences regarding most important to solve, yet less difficult main challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How difficult is it to solve cultural challenges compared to technological challenges?

Just Equal

Question 2

How difficult is it to solve cultural challenges compared to privacy and security challenges?

Strongly more difficult

Question 3

How difficult is it to solve cultural challenges compared to legal and regulatory challenges?

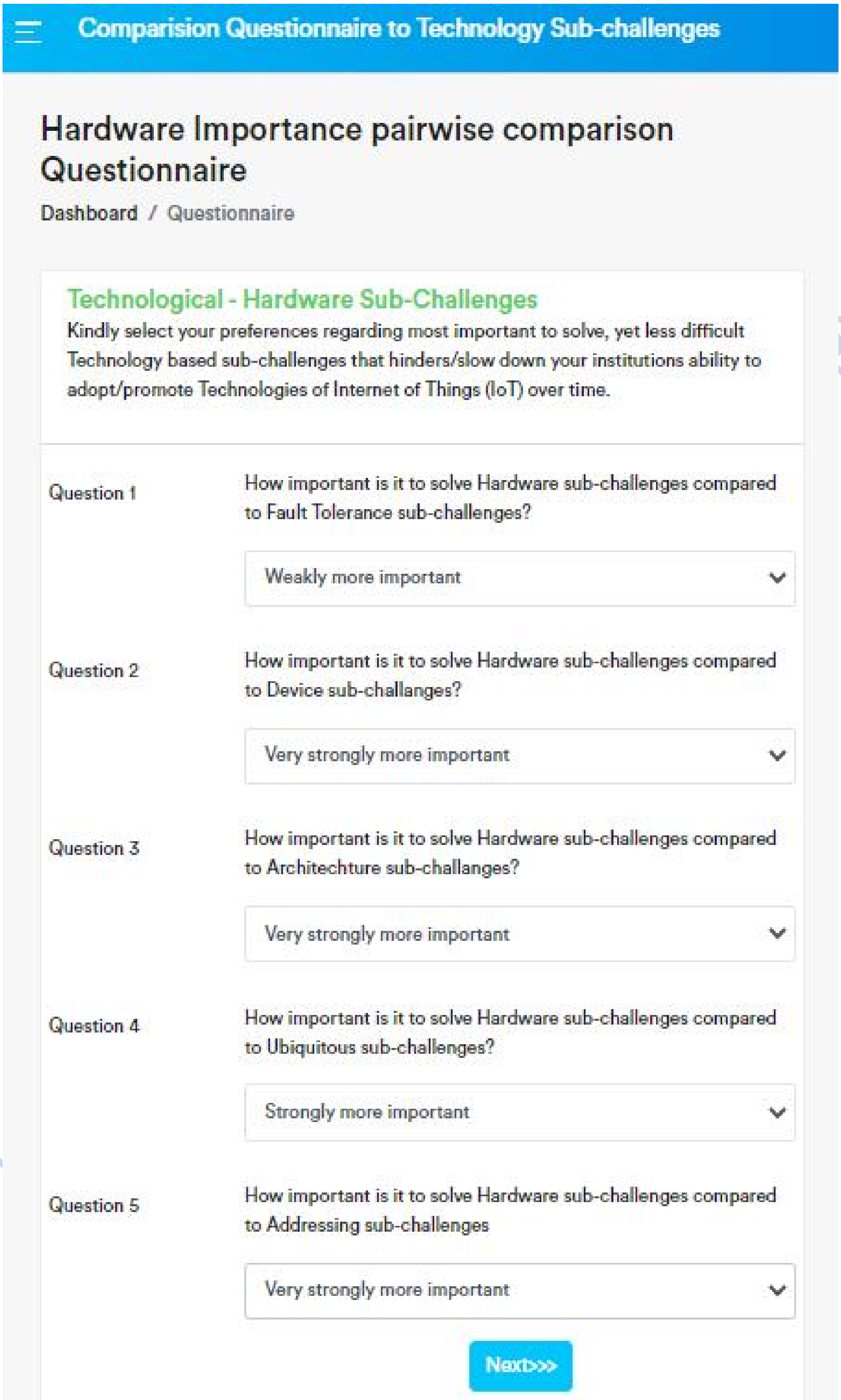
Very strongly more difficult

Question 4

How difficult is it to solve cultural challenges compared to business challenges?

Equally difficult

Next>>>



Comparision Questionnaire to Technology Sub-challenges

Hardware Importance pairwise comparison Questionnaire

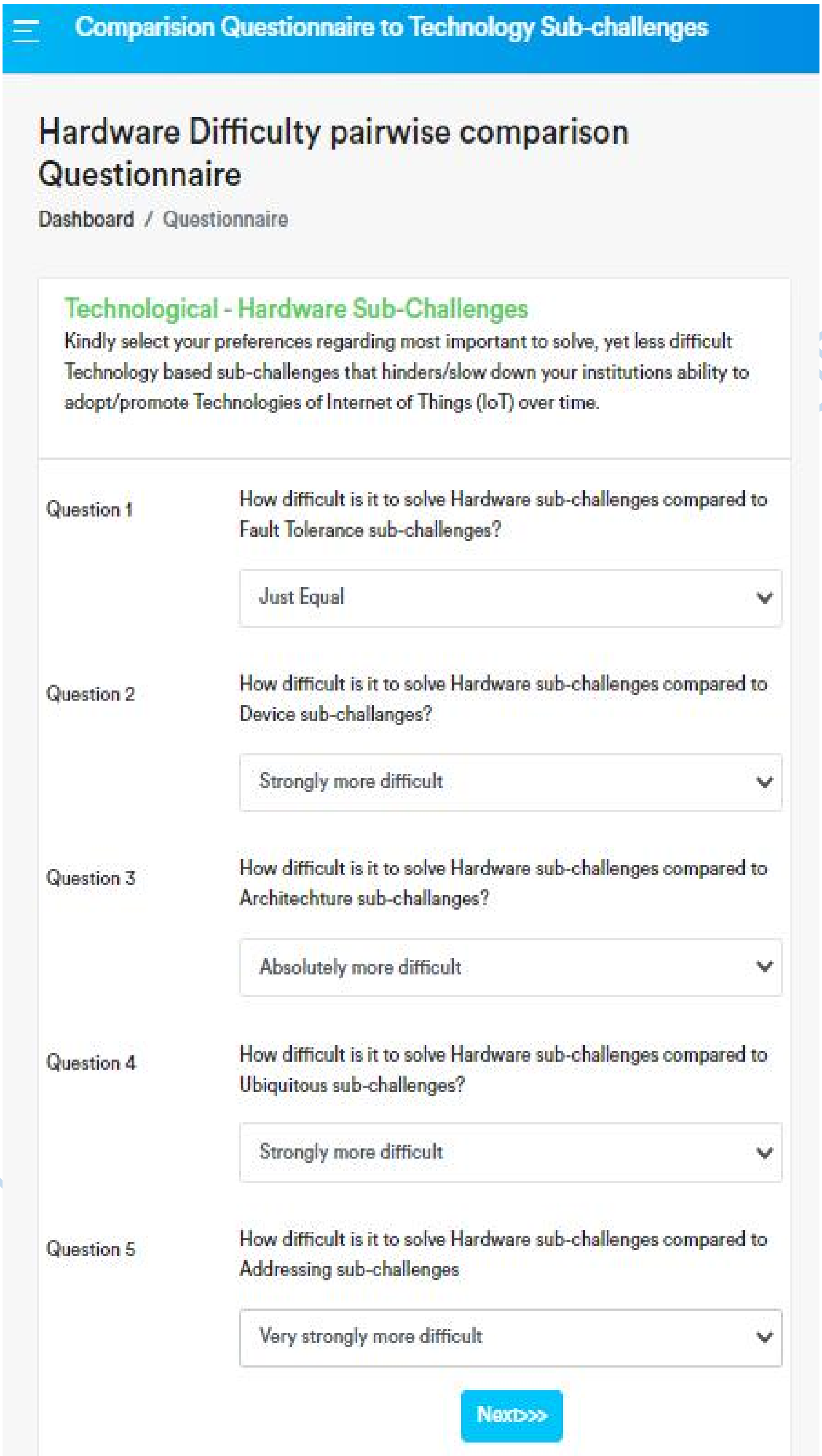
Dashboard / Questionnaire

Technological - Hardware Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1	How important is it to solve Hardware sub-challenges compared to Fault Tolerance sub-challenges? Weakly more important
Question 2	How important is it to solve Hardware sub-challenges compared to Device sub-challanges? Very strongly more important
Question 3	How important is it to solve Hardware sub-challenges compared to Architechture sub-challanges? Very strongly more important
Question 4	How important is it to solve Hardware sub-challenges compared to Ubiquitous sub-challenges? Strongly more important
Question 5	How important is it to solve Hardware sub-challenges compared to Addressing sub-challenges Very strongly more important

Next>>>



Comparision Questionnaire to Technology Sub-challenges

Hardware Difficulty pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Hardware Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How difficult is it to solve Hardware sub-challenges compared to Fault Tolerance sub-challenges?

Just Equal

Question 2

How difficult is it to solve Hardware sub-challenges compared to Device sub-challanges?

Strongly more difficult

Question 3

How difficult is it to solve Hardware sub-challenges compared to Architechture sub-challanges?

Absolutely more difficult

Question 4

How difficult is it to solve Hardware sub-challenges compared to Ubiquitous sub-challenges?

Strongly more difficult

Question 5

How difficult is it to solve Hardware sub-challenges compared to Addressing sub-challenges

Very strongly more difficult

Next>>

Comparision Questionnaire to Technology Sub-challenges

Fault tolerance importance pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Fault Tolerance Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How important is it to solve Fault Tolerance sub-challenges compared to Hardware sub-challenges?

Strongly more important

Question 2

How important is it to solve Fault Tolerance sub-challenges compared to Device sub-challanges?

Equally important

Question 3

How important is it to solve Fault Tolerance sub-challenges compared to Architechture sub-challanges?

Absolutely more important

Question 4

How important is it to solve Fault Tolerance sub-challenges compared to Ubiquitous sub-challenges?

Weakly more important

Question 5

How important is it to solve Fault Tolerance sub-challenges compared to Addressing sub-challenges

Strongly more important

Next>>

Comparision Questionnaire to Technology Sub-challenges

Fault tolerance Difficulty pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Fault tolerance Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How difficult is it to solve Fault Tolerance sub-challenges compared to Hardware sub-challenges?

Weakly more difficult

Question 2

How difficult is it to solve Fault Tolerance sub-challenges compared to Device sub-challanges?

Strongly more difficult

Question 3

How difficult is it to solve Fault Tolerance sub-challenges compared to Architechture sub-challanges?

Strongly more difficult

Question 4

How difficult is it to solve Fault Tolerance sub-challenges compared to Ubiquitous sub-challenges?

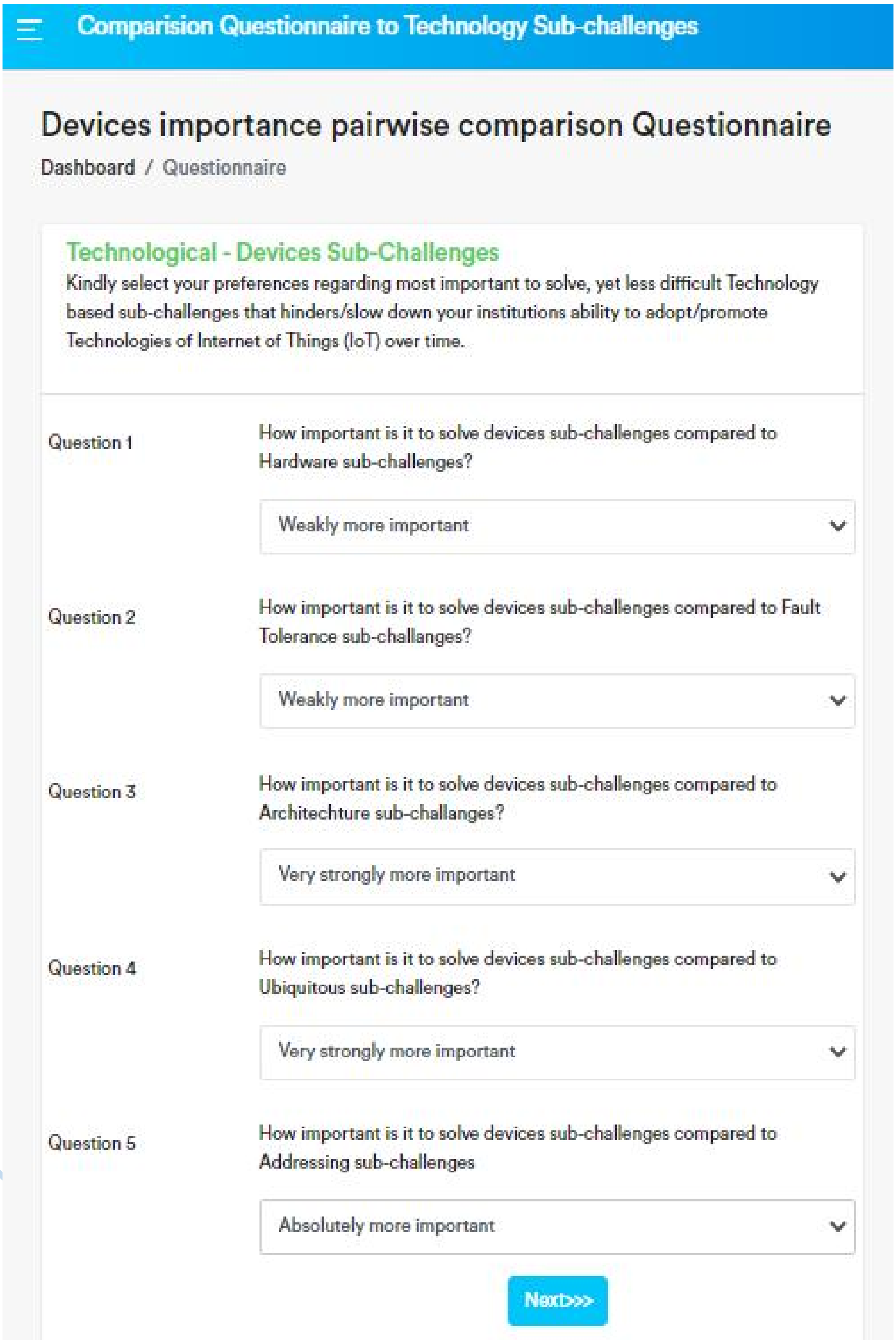
Very strongly more difficult

Question 5

How difficult is it to solve Fault Tolerance sub-challenges compared to Addressing sub-challenges

Very strongly more difficult

Next>>>



Comparision Questionnaire to Technology Sub-challenges

Devices importance pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Devices Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How important is it to solve devices sub-challenges compared to Hardware sub-challenges?

Weakly more important

Question 2

How important is it to solve devices sub-challenges compared to Fault Tolerance sub-challanges?

Weakly more important

Question 3

How important is it to solve devices sub-challenges compared to Architechture sub-challanges?

Very strongly more important

Question 4

How important is it to solve devices sub-challenges compared to Ubiquitous sub-challenges?

Very strongly more important

Question 5

How important is it to solve devices sub-challenges compared to Addressing sub-challenges

Absolutely more important

Next>>>

Comparision Questionnaire to Technology Sub-challenges

Devices Difficulty pairwise comparison Questionnaire

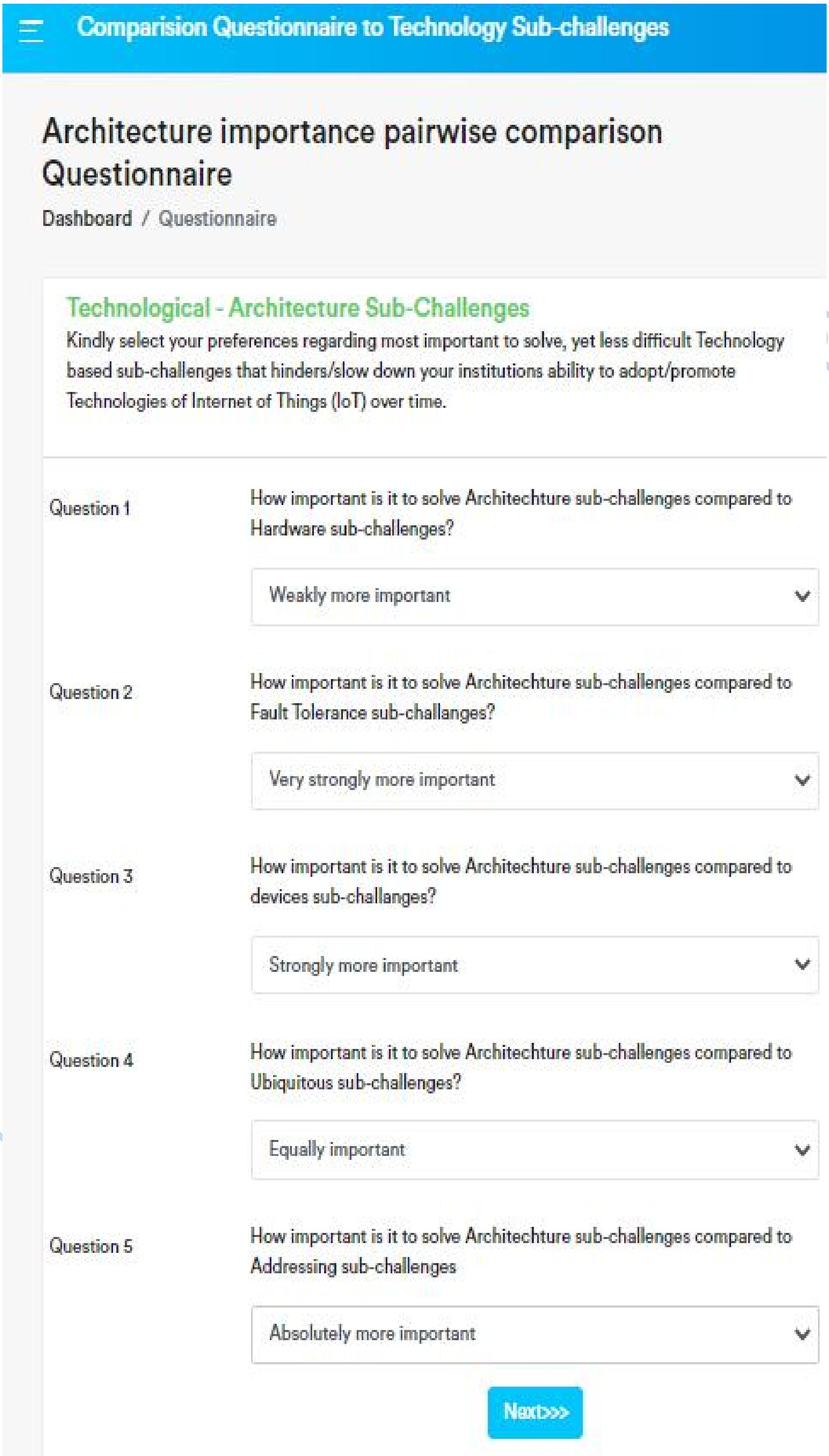
Dashboard / Questionnaire

Technological - Devices Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1	How difficult is it to solve devices sub-challenges compared to Hardware sub-challenges? Strongly more difficult
Question 2	How difficult is it to solve devices sub-challenges compared to Fault Tolerance sub-challanges? Equally difficult
Question 3	How difficult is it to solve devices sub-challenges compared to Architechture sub-challanges? Weakly more difficult
Question 4	How difficult is it to solve devices sub-challenges compared to Ubiquitous sub-challenges? Weakly more difficult
Question 5	How difficult is it to solve devices sub-challenges compared to Addressing sub-challenges Strongly more difficult

Next>>


Comparision Questionnaire to Technology Sub-challenges

Architecture importance pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Architecture Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How important is it to solve Architechture sub-challenges compared to Hardware sub-challenges?

Weakly more important

Question 2

How important is it to solve Architechture sub-challenges compared to Fault Tolerance sub-challanges?

Very strongly more important

Question 3

How important is it to solve Architechture sub-challenges compared to devices sub-challanges?

Strongly more important

Question 4

How important is it to solve Architechture sub-challenges compared to Ubiquitous sub-challenges?

Equally important

Question 5

How important is it to solve Architechture sub-challenges compared to Addressing sub-challenges

Absolutely more important

Next>>>

Comparision Questionnaire to Technology Sub-challenges

Architechture Difficulty pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Architecture Sub-Challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1

How difficult is it to solve Architechture sub-challenges compared to Hardware sub-challenges?

Weakly more difficult

Question 2

How difficult is it to solve Architechture sub-challenges compared to Fault Tolerance sub-challanges?

Strongly more difficult

Question 3

How difficult is it to solve Architechture sub-challenges compared to devices sub-challanges?

Very strongly more difficult

Question 4

How difficult is it to solve Architechture sub-challenges compared to Ubiquitous sub-challenges?

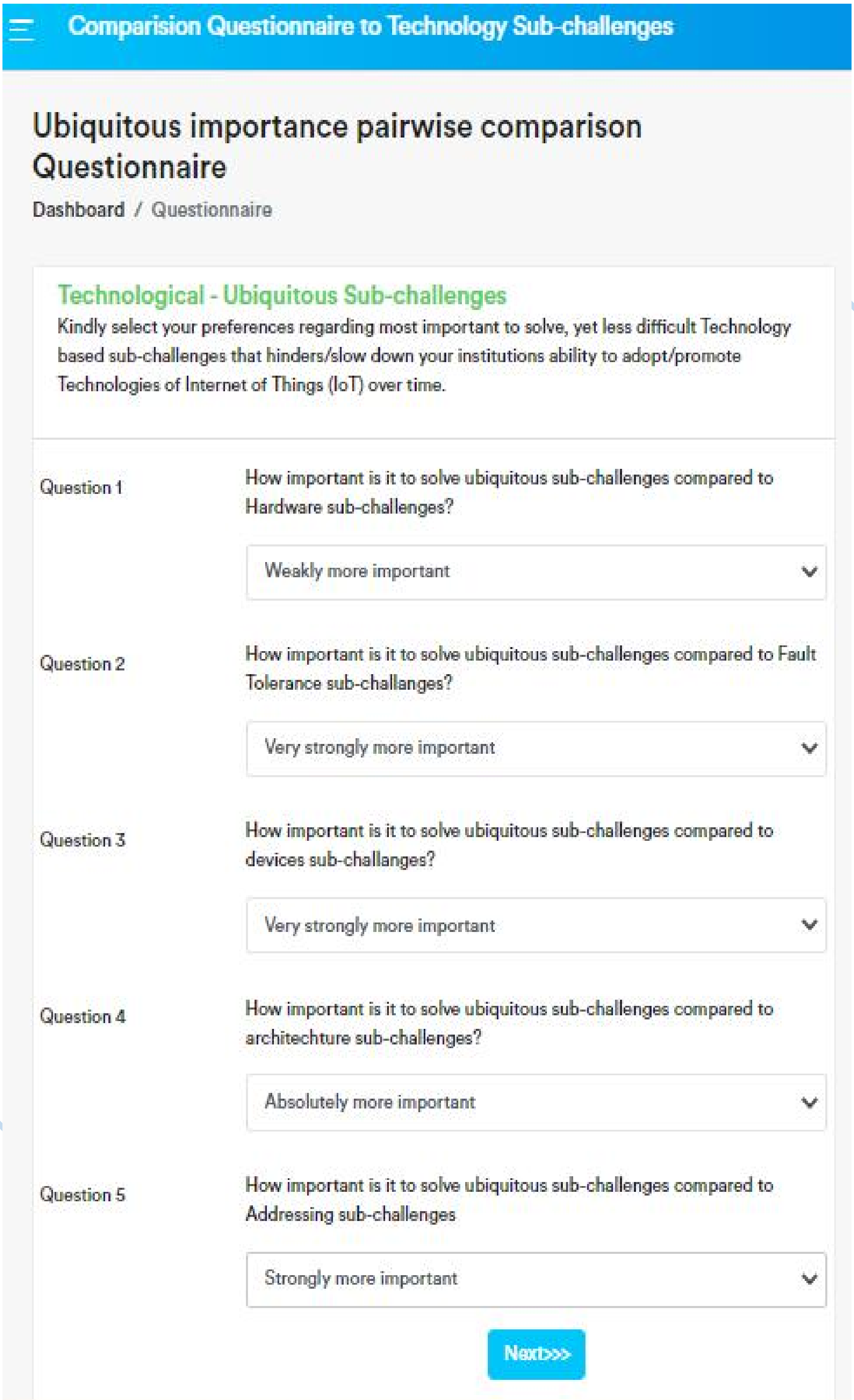
Absolutely more difficult

Question 5

How difficult is it to solve Architechture sub-challenges compared to Addressing sub-challenges

Just Equal

Next>>>



Comparision Questionnaire to Technology Sub-challenges

Ubiquitous importance pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Ubiquitous Sub-challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1 — How important is it to solve ubiquitous sub-challenges compared to Hardware sub-challenges?

Weakly more important

Question 2 — How important is it to solve ubiquitous sub-challenges compared to Fault Tolerance sub-challanges?

Very strongly more important

Question 3 — How important is it to solve ubiquitous sub-challenges compared to devices sub-challanges?

Very strongly more important

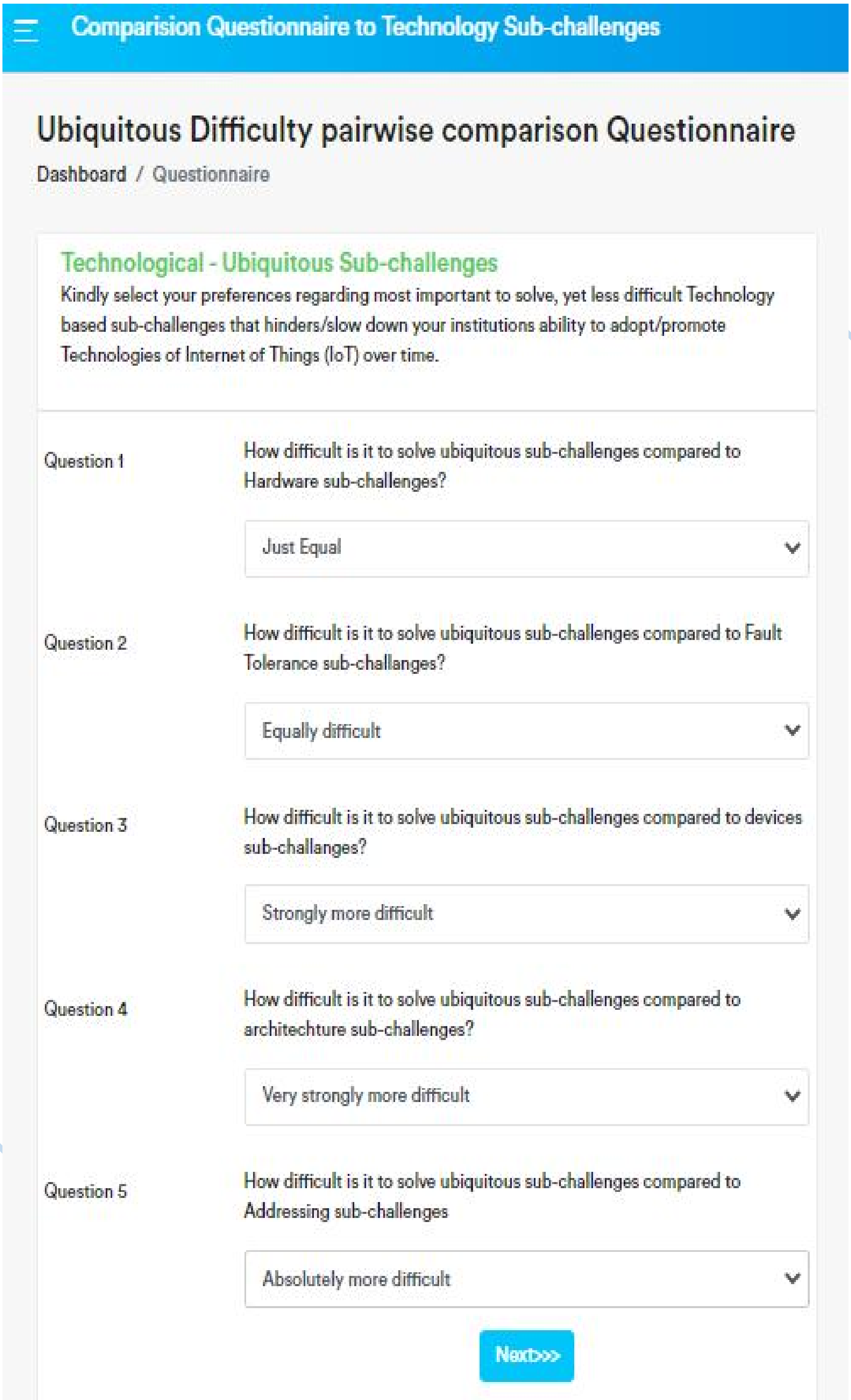
Question 4 — How important is it to solve ubiquitous sub-challenges compared to architechture sub-challenges?

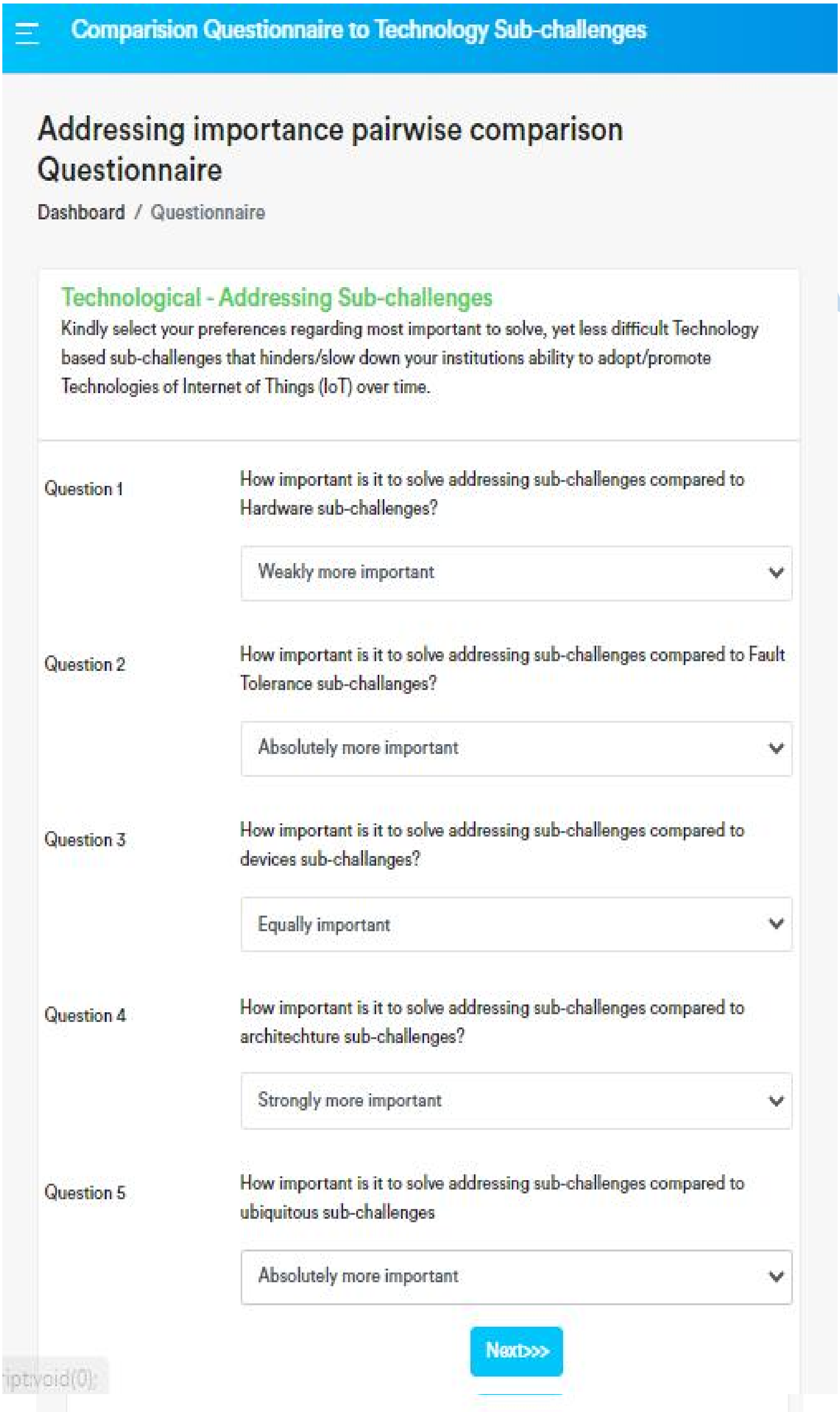
Absolutely more important

Question 5 — How important is it to solve ubiquitous sub-challenges compared to Addressing sub-challenges

Strongly more important

Next>>


Comparision Questionnaire to Technology Sub-challenges
Ubiquitous Difficulty pairwise comparison Questionnaire
Dashboard / Questionnaire
Technological - Ubiquitous Sub-challenges
Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.
Question 1
How difficult is it to solve ubiquitous sub-challenges compared to Hardware sub-challenges?
Just Equal
Question 2
How difficult is it to solve ubiquitous sub-challenges compared to Fault Tolerance sub-challanges?
Equally difficult
Question 3
How difficult is it to solve ubiquitous sub-challenges compared to devices sub-challanges?
Strongly more difficult
Question 4
How difficult is it to solve ubiquitous sub-challenges compared to architechture sub-challenges?
Very strongly more difficult
Question 5
How difficult is it to solve ubiquitous sub-challenges compared to Addressing sub-challenges
Absolutely more difficult
Next>>>


Comparision Questionnaire to Technology Sub-challenges

Addressing importance pairwise comparison Questionnaire

Dashboard / Questionnaire

Technological - Addressing Sub-challenges

Kindly select your preferences regarding most important to solve, yet less difficult Technology based sub-challenges that hinders/slow down your institutions ability to adopt/promote Technologies of Internet of Things (IoT) over time.

Question 1 — How important is it to solve addressing sub-challenges compared to Hardware sub-challenges?

Weakly more important

Question 2 — How important is it to solve addressing sub-challenges compared to Fault Tolerance sub-challanges?

Absolutely more important

Question 3 — How important is it to solve addressing sub-challenges compared to devices sub-challanges?

Equally important

Question 4 — How important is it to solve addressing sub-challenges compared to architechture sub-challenges?

Strongly more important

Question 5 — How important is it to solve addressing sub-challenges compared to ubiquitous sub-challenges

Absolutely more important

Next>>

iptvoid(0);

Appendix iv - Some Basic Code Snippets

1. Dashboard Controller Code Snippets

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.Mvc;
using ayubaweb.Models;
using System.Net.Mail;
using System.Text;


namespace ayubaweb.Controllers
{
    public class DashboardController : Controller
    {
        AyubawebContext db = new AyubawebContext();

        //AyubawebContect db = new AyubawebContect();
        // GET: dashboard

        public ActionResult Index()
        {
            if (Session["Admin"] != null)
            {
                return View();
            }
            else
            {
                return Redirect("~/Thesis/Index");
            }
        }

        public ActionResult InviteByEmail() {
            if (Session["Admin"] != null)
            {
                List<EmailRecords> EmailList = new List<EmailRecords>();

                EmailList = db.EmailConfirmations.Select(a => new EmailRecords { Email = a.Email, EmailId = a.EmailId, Active = a.Active, DateRegister = a.DateRegister }).ToList();
                ViewBag.EmailList = EmailList;
                return View();
            }
            else
```

```
            {
               return Redirect("~/Thesis/Index");
            }
        }

        [HttpPost]
        [ValidateAntiForgeryToken]

        public ActionResult InviteByEmail(InviteEmails Items)
        {
            EmailConfirmation em = new EmailConfirmation();

            try
            {
                List<EmailRecords> EmailList = new List<EmailRecords>();
                EmailList = db.EmailConfirmations.Select(a => new EmailRecords { Email = a.Email, EmailId = a.EmailId, Active = a.Active, DateRegister = a.DateRegister }).ToList();
                ViewBag.EmailList = EmailList;

                if (ModelState.IsValid)
            {
                em.Email = Items.Email;
                em.Active = 0;
                em.DateRegister = DateTime.Now.ToString();
                   db.EmailConfirmations.Add(em);
                db.SaveChanges();
                if ((int)em.EmailId > 0) {
                   //sending email
                   var from = "noreply@minpip.com";
                   MailMessage mail = new MailMessage();
                   mail.To.Add(Items.Email);
                    mail.From = new MailAddress(from);
                    mail.Subject = "Challenges of IoT Adoption";
                      var emailconv = Stringbyte__Convertion(Items.Email);
                   string Body = "<div><h3>Hi</h3><p>Stakeholder Participation Invitation"
                          +"Letter</p><p align=\"justify\">You have been requested to kindly participate as a stakeholder in making choices"
                          +"among challenges/factors that are affecting the company’s ability "
                          +"to fully adopting one or more of the numerous technologies that uses "
                          +"or connects to the internet either directly or indirectly "
                          +" to contribute in the operations of the company.</p>"
                          + "<p align=\"justify\">The process involves completing structured "
                          + "questionnaire on your preferences regarding "
                          +"most important, yet lest difficult among major"
                          +"challenges/factors that affect adoption of technologies"
                          +"of internet of things by your institution/company. "
```

```
                    + "</p>Your participation in the as a stakeholder in this decision event will be of great"
                    +"importance to assist the company in ensuring that it channels its limited resources in solving"
                    +"challenges/factors that are most important yet less "
                    +"difficult to solve to cut up expenses and enhance its productivity."
                    + "To begin, please click the link below."
                    + "<p><a href=\"http://ocalhost:49700/Participant/getEmail/" + emailconv+"\" style=\"display:inline-block; font-weight:400; line-height:1.5; color:#212529;text-align:center;text-decoration:none;vertical-align:middle;cursor:pointer;-webkit-user-select:none;-moz-user-select:none;user-select:none;background-color:transparent;border:1px solid transparent;padding:.375rem .75rem;font-size:1rem;border-radius:.25rem;transition:color .15s ease-in-out,background-color .15s ease-in-out,border-color .15s ease-in-out,box-shadow .15s ease-in-out;color:#fff;background-color:#0d6efd;border-color:#0d6efd;\">Click Here</a></p></div>";

             // http://questionnaire.minpip.com/Participant/getEmail/
                mail.Body = Body;
             mail.IsBodyHtml = true;
             SmtpClient smtp = new SmtpClient();
             smtp.Host = "mail.minpip.com";
             smtp.Port = 8889;
             smtp.UseDefaultCredentials = false;
             smtp.Credentials = new System.Net.NetworkCredential("noreply@minpip.com", "Realtech01"); // Enter seders User name and password
             smtp.EnableSsl = false;
             smtp.Send(mail);
                //add email here

             ViewBag.Error = "Record Successful";
             ViewBag.color = "text text-success";

             //
          }
          else
          {
             ViewBag.Error = "Invalid Record";
                ViewBag.color = "text text-danger";
          }




       }
       else
       {
          ViewBag.Error =bytesString_Convertion("SW52YWxpZCBJbnB1dA==");
```

```
            }
        //
        }
        catch (Exception ex)
        {
            ViewBag.Error = ex.Message.ToString();
            ViewBag.color = "text text-danger";
        }
        return View(Items);
    }

    public static string Stringbyte__Convertion(string Parameter)
    {
        byte[] b = Encoding.ASCII.GetBytes(Parameter);
        return Convert.ToBase64String(b);
    }

    public static string bytesString_Convertion(string Parameter)
    {
        byte[] s = Convert.FromBase64String(Parameter);
        return Encoding.ASCII.GetString(s);
    }


}
}
```


2. Thesis Controller Code Snippets

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.Web.Mvc;
using ayubaweb.Models;

namespace ayubaweb.Controllers
{
    public class ThesisController : Controller
    {
        readonly AyubawebContext db = new AyubawebContext();
        // GET: thensis
        public ActionResult Index()
        {

            return View();
        }
```

```
        [HttpPost]
        [ValidateAntiForgeryToken]
        public ActionResult Index(SignIn Key)
        {
            if(Key == null)
            {
                ViewBag.Error = "Sign in info cannot be null";
            }
            try
            {
                if (ModelState.IsValid)
                {
                    var login = db.AdminUser.Where(x => x.Username == Key.UserName).
                        Where(x => x.Passwords == Key.Passwords).ToList().First();


                    if (login.AUId > 0)
                    {
                        Session["Admin"] = login.Username;
                        return Redirect("~/dashboard/InviteByEmail");
                    }
                    else
                    {
                        return View();
                    }

                }
                else
                {
                    ViewBag.Error = "Invalid Model state";
                }
            }
            catch (Exception ex)
            {

                ViewBag.Error = ex.Message.ToString();
            }
            //
            return View(Key);
        }

    }
}
```

3. Participant Controller Code Snippets

```
using System;
using System.Collections.Generic;
```

```
using System.Linq;
using System.Web;
using System.Web.Mvc;
using ayubaweb.Models;
using System.Data.SqlClient;
using System.Configuration;

namespace ayubaweb.Controllers
{
    public class ParticipantController : Controller
    {

        AyubawebContext db = new AyubawebContext();
        // GET: Participant
        public ActionResult Index()
        {
            if (Session["Email"]!=null)
            {

                return View();
            }
            else
            {
                return RedirectToAction("Error");
            }
        }
        [HttpPost]
        [ValidateAntiForgeryToken]
        public ActionResult Index(Userprofile_class users)
        {
          try
           {
                UserProfile userp = new UserProfile();
```

```
                userp.FullName = users.FullName;
                userp.Email = Request.Form["Email"]; //"adenirangaposa02@gmail.com";
                userp.Country = users.Country;
                userp.AreaSpecialization = users.AreaSpecialization; //"dosomething";
                userp.CurrentAddressOrganization = users.CurrentAddressOrganization; //"dosomethig";
                userp.JobTitle = users.JobTitle; //"YesJob";
                userp.Active = 1;
                userp.DateRegister = DateTime.Now.ToString("dd-MM-yyyy");//"18-11-2022";
                userp.Question1 = Request.Form["Question1"]; //"What is your name";
                userp.Answer1 = users.Answer1;
                userp.Question2 = Request.Form["Question2"]; //"how do You survicve";
                userp.Answer2 = users.Answer2; //"God grace";
                userp.WorkingExperience = Convert.ToInt16(Request.Form["Exp"]);
                db.UserProfiles.Add(userp);
                db.SaveChanges();
                if ((int)userp.UserId > 0)
                {
                  Session["UserId"] = userp.UserId;
                  return RedirectToAction("AreaOrganization");
                }
                else
                {
                  ViewBag.Error = "0 Failed";
                }

              }
              catch (Exception ex)
              {
                Console.WriteLine( ex.Message.ToString());
              }
              return View(users);
            }
```

```
[Route("Participant/getEmail/{ba?}")]
public ActionResult getEmail(string ba) {
    //YmF5ZXN0ZGF2aWRAZ21haWwuY29t
    //bayestdavid@gmail.com
    //return ayubaweb.Controllers.dashboardController.Stringbyte__Convertion("bayestdavid@gmail.com");
    //var Id = ayubaweb.Controllers.dashboardController.bytesString_Convertion(ba);
    var Email = ayubaweb.Controllers.DashboardController.bytesString_Convertion(ba);
    //YWRlbmlyYW5AZ21haWwuY29t
    var confirmation = db.EmailConfirmations.SingleOrDefault(x => x.Email ==Email && x.Active == 0);
    //var ema = confirmation.Email;
    try
    {
      var d = string.IsNullOrEmpty(Convert.ToString(confirmation.EmailId)) ? 0 : confirmation.EmailId;
      if (d > 0)
      {
        confirmation.Active = 1;
        db.SaveChanges();
        Session["EmailId"] = confirmation.EmailId;
        Session["Email"] = confirmation.Email;

        return RedirectToAction("Index");
      }
      else
      {
        return RedirectToAction("Error");
      }
    }
    catch (Exception ex)
    {
```

```
            Console.WriteLine(ex.Message.ToString())
                ;
            }
            return RedirectToAction("Error");
        }
        public ActionResult Error()
        {
            return View();
        }
        public ActionResult AreaOrganization()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}

            string[] size = { "Small", "Medium", "Large","Not sure" };
            string[] employees = { "Less than 20", "20 to 100", "101 to 200", "Less than 
200" };
            string[] natures = { "National", "Multi-national", "Not sure", "Others" };

            List<SelectListItem> option = new List<SelectListItem>();
            foreach(var a in size)
            {
                option.Add(new SelectListItem { Text = a, Value = a });
            }
            ViewData["sizeoption"] = option;
            List<SelectListItem> op_employee = new List<SelectListItem>();
            foreach (var b in employees)
            {
                op_employee.Add(new SelectListItem { Text = b, Value = b });
            }
            ViewData["employee"] = op_employee;
            //
```

```
        List<SelectListItem> op_nation = new List<SelectListItem>();
        foreach(var c in natures)
        {
            op_nation.Add(new SelectListItem { Text = c, Value = c });
        }
        ViewData["nature"] = op_nation;
        //
        List<SelectListItem> YesNo = new List<SelectListItem>() {
                new SelectListItem { Text="Yes",Value="Yes" },
                new SelectListItem {Text="No",Value="No" }
                };
        ViewData["YesNo"] = YesNo;
        return View();
    }
    [HttpPost]
    [ValidateAntiForgeryToken]
    public ActionResult AreaOrganization(SampleOrganization_Class1 sample)
    {
        //
        string[] size = { "Small", "Medium", "Large", "Not sure" };
        string[] employees = { "Less than 20", "20 to 100", "101 to 200", "Less than
200" };
        string[] natures = { "National", "Multi-national", "Not sure", "Others" };
        List<SelectListItem> option = new List<SelectListItem>();
        foreach (var a in size)
        {
            option.Add(new SelectListItem { Text = a, Value = a });
        }
        ViewData["sizeoption"] = option;
        List<SelectListItem> op_employee = new List<SelectListItem>();
        foreach (var b in employees)
        {
            op_employee.Add(new SelectListItem { Text = b, Value = b });
        }
```

```
ViewData["employee"] = op_employee;
//
List<SelectListItem> op_nation = new List<SelectListItem>();
foreach (var c in natures)
{
   op_nation.Add(new SelectListItem { Text = c, Value = c });
}
ViewData["nature"] = op_nation;

//

List<SelectListItem> YesNo = new List<SelectListItem>() {
         new SelectListItem { Text="Yes",Value="Yes" },
         new SelectListItem {Text="No",Value="No" }
         };
ViewData["YesNo"] = YesNo;
try
{
   if (ModelState.IsValid)
   {
      SampleOrganization samp = new SampleOrganization();
      samp.UserId = Convert.ToInt16(Session["UserId"]);
      samp.OrganizationName = sample.OrganizationName;
      samp.Q1 = Request.Form["Q1"];
      samp.A1 = sample.A1;
      samp.Q2 = Request.Form["Q2"];
      samp.A2 = sample.A2;
      samp.Q3 = Request.Form["Q3"];
      samp.A4 = sample.A4;
      samp.Q5 = Request.Form["Q5"];
      samp.A5 = sample.A5;
       samp.Q6 = Request.Form["Q6"];
      samp.A6 = sample.A6;
```

```
            samp.Q7 = Request.Form["Q7"];
            samp.A7 = sample.A7;
            samp.DateRegister = DateTime.Now.ToString("dd-MM-yyyy");
            samp.Active = 1;
            db.SampleOrganizations.Add(samp);
            db.SaveChanges();
            if ((int)samp.SampleId > 0)
            {
               //redirect to next
               return RedirectToAction("Questionnaire");
            }
            else
            {
               ViewBag.Error = "0 ,Failed";
            }
         }
      }
      catch (Exception ex)
      {
         Console.WriteLine(ex.Message.ToString());
      }
      return View(sample);
      //
   }
   public ActionResult success()
   {
      if ((int)Session["EmailId"] < 0)
      {
         Session.Remove("EmailId");
         Session.Remove("UserId");
      }
      return View();
   }
```

```
public ActionResult Questionnaire()
{
    //if ((int)Session["EmailId"] < 0)
    //{
    //    return RedirectToAction("Error");
    //}
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return View();
}
[HttpPost]
[AllowAnonymous]
public ActionResult Questionnaire(QuestionAndAnswer Q)
{
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return RedirectToAction("QuestionnaireTD");
}
public ActionResult QuestionnaireTD()
{
    //if ((int)Session["EmailId"] < 0)
    //{
    //    return RedirectToAction("Error");
    //}
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Difficulty").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return View();
}
```

```
[HttpPost]
[AllowAnonymous]
public ActionResult QuestionnaireTD(QuestionAndAnswer Q)
{
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Difficulty").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return RedirectToAction("QuestionnairePrivImp");
}
public ActionResult QuestionnairePrivImp()
{
    //if ((int)Session["EmailId"] < 0)
    //{
    //    return RedirectToAction("Error");
    //}
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return View();
}
[HttpPost]
[AllowAnonymous]
public ActionResult QuestionnairePrivImp(QuestionAndAnswer Q)
{
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return RedirectToAction("QuestionnairePrivDif");
}
public ActionResult QuestionnairePrivDif()
{
```

```
        //if ((int)Session["EmailId"] < 0)
        //{
        //    return RedirectToAction("Error");
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return View();
    }

    [HttpPost]
    [AllowAnonymous]
    public ActionResult QuestionnairePrivDif(QuestionAndAnswer Q)
    {
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return RedirectToAction("QuestionnaireLegalImp");
    }
    public ActionResult QuestionnaireLegalImp()
    {
        //if ((int)Session["EmailId"] < 0)
        //{
        //    return RedirectToAction("Error");
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Importance").ToList();

        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return View();
    }
```

```
[HttpPost]
[AllowAnonymous]
public ActionResult QuestionnaireLegalImp(QuestionAndAnswer Q)
{
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return RedirectToAction("QuestionnaireLegalDif");
}

public ActionResult QuestionnaireLegalDif()
{
    //if ((int)Session["EmailId"] < 0)
    //{
    //    return RedirectToAction("Error");
    //}
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Difficulty").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return View();
}

[HttpPost]
[AllowAnonymous]
public ActionResult QuestionnaireLegalDif(QuestionAndAnswer Q)
{
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Difficulty").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return RedirectToAction("QuestionnaireBizImp");
```

```
}
public ActionResult QuestionnaireBizImp()
{
    //if ((int)Session["EmailId"] < 0)
    //{
    //    return RedirectToAction("Error");
    //}
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return View();
}

[HttpPost]
[AllowAnonymous]
public ActionResult QuestionnaireBizImp(QuestionAndAnswer Q)
{
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Importance").ToList();
    ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
    return RedirectToAction("QuestionnaireBizDif");
}

public ActionResult QuestionnaireBizDif()
{
    //if ((int)Session["EmailId"] < 0)
    //{
    //    return RedirectToAction("Error");
    //}
    List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
        .Where(x => x.ScaleType == "Difficulty").ToList();
```

```
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }

        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireBizDif(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireCultImp");
        }
        public ActionResult QuestionnaireCultImp()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }
        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireCultImp(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
```

```
            return RedirectToAction("QuestionnaireCultDif");
        }
        public ActionResult QuestionnaireCultDif()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol", "Descriptions");
            return View();
        }
        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireCultDif(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol", "Descriptions");
            return RedirectToAction("QuestionnaireTech_HarImp");
        }
        public ActionResult QuestionnaireTech_HarImp()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol", "Descriptions");
```

```
        return View();
    }

    [HttpPost]
    [AllowAnonymous]
    public ActionResult QuestionnaireTech_HarImp(QuestionAndAnswer Q)
    {
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Importance").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return RedirectToAction("QuestionnaireTech_HarDif");
    }
    public ActionResult QuestionnaireTech_HarDif()
    {
        //if ((int)Session["EmailId"] < 0)
        //{
        //    return RedirectToAction("Error");
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();

        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");

        return View();
    }

    [HttpPost]
    [AllowAnonymous]
    public ActionResult QuestionnaireTech_HarDif(QuestionAndAnswer Q)
    {
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();
```

```
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireTech_FauImp");
        }
        public ActionResult QuestionnaireTech_FauImp()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }
        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireTech_FauImp(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireTech_FauDif");
        }
        public ActionResult QuestionnaireTech_FauDif()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
```

```
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }

        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireTech_FauDif(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireTech_DevImp");
        }
        public ActionResult QuestionnaireTech_DevImp()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }
        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireTech_DevImp(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
```

```
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol", "Descriptions");



            return RedirectToAction("QuestionnaireTech_DevDif");
        }
        public ActionResult QuestionnaireTech_DevDif()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol", "Descriptions");
            return View();
        }

        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireTech_DevDif(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol", "Descriptions");
            return RedirectToAction("QuestionnaireTech_ArcImp");
        }
        public ActionResult QuestionnaireTech_ArcImp()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
```

```
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Importance").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return View();
    }


    [HttpPost]
    [AllowAnonymous]
    public ActionResult QuestionnaireTech_ArcImp(QuestionAndAnswer Q)
    {
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Importance").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return RedirectToAction("QuestionnaireTech_ArcDif");
    }
    public ActionResult QuestionnaireTech_ArcDif()
    {
        //if ((int)Session["EmailId"] < 0)
        //{
        //    return RedirectToAction("Error");
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return View();
    }
    [HttpPost]
    [AllowAnonymous]
    public ActionResult QuestionnaireTech_ArcDif(QuestionAndAnswer Q)
    {
```

```
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireTech_UbiImp");
        }
        public ActionResult QuestionnaireTech_UbiImp()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();


            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }


        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireTech_UbiImp(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireTech_UbiDif");
        }
        public ActionResult QuestionnaireTech_UbiDif()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
```

```
        //    return RedirectToAction("Error");
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return View();
    }

    [HttpPost]
    [AllowAnonymous]
    public ActionResult QuestionnaireTech_UbiDif(QuestionAndAnswer Q)
    {
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Difficulty").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return RedirectToAction("QuestionnaireTech_AddImp");
    }
    public ActionResult QuestionnaireTech_AddImp()
    {
        //if ((int)Session["EmailId"] < 0)
        //{
        //    return RedirectToAction("Error");
        //}
        List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
            .Where(x => x.ScaleType == "Importance").ToList();
        ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
        return View();
    }

    [HttpPost]
    [AllowAnonymous]
```

```
        public ActionResult QuestionnaireTech_AddImp(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Importance").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return RedirectToAction("QuestionnaireTech_AddDif");
        }
        public ActionResult QuestionnaireTech_AddDif()
        {
            //if ((int)Session["EmailId"] < 0)
            //{
            //    return RedirectToAction("Error");
            //}
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }
        [HttpPost]
        [AllowAnonymous]
        public ActionResult QuestionnaireTech_AddDif(QuestionAndAnswer Q)
        {
            List<LinguisticScale> LinguisticScaleList = db.LinguisticScales
                .Where(x => x.ScaleType == "Difficulty").ToList();
            ViewBag.LinguisticScaleList = new SelectList(LinguisticScaleList, "Symbol",
"Descriptions");
            return View();
        }
    }
}
```

Appendix v - Dataset Used as Input Data

Fuzzy Linguistic scales for difficulty and importance

Linguistic scale for difficulty	Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	Just equal	(1,1,1)	(1,1,1)
Equally difficult (ED)	Equally important (EI)	(1/2,1,3/2)	(2/3,1,2)
Weakly more difficult (WMD)	Weakly more important (WMI)	(1,3/2,2)	(1/2,2/3,1)
Strongly more difficult (SMD)	Strongly more important (SMI)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more difficult (VSMD)	Very strongly more important (VSMI)	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more difficult (AMD)	Absolutely more important (AMI)	(5/2,3,7/2)	(2/7,1/3,2/5)

Source: Mohammadzadeh, 2018

Fuzzy AHP Decision Comparison Matrix of IoT Development Main Challenges and Sub-Challenges Datasets

Sample pairwise Comparison Matrix for IoT technology Development Main challenges

factors	Tech	Privacy	Legal	Business	Cultural
Tech	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	(2/3,1,2)	(1,3/2,2)
Privacy	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(1,3/2,2)
Legal	(1/2,2/3,1)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(1,1,1)
Business	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)
Cultural	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)	(1,1,1)

Source: Mohammadzadeh, 2018

Local weight of business challenges input dataset used

Business challenges	Economic and developme	Investing	Business model	Customer expectatio ns	Calcula ted weight
Economic and development	(1,1,1)	(1/2,1,3/2)	(1/2,2/3,1)	(2/3,1,2)	0.23
Investing	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)	(2/3,1,2)	0.26
Business model	(1,3/2,2)	(2/3,1,2)	(1,1,1)	(1,3/2,2)	0.30
Customer expectations	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,2/3,1)	(1,1,1)	0.21

Source: Mohammadzadeh, 2018

Local weight of cultural challenges input dataset used

Cultural Challenges	Trust	Education and Training	Vandalism	Ethics	Calculated Weights
Trust	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	(2/3,1,2)	0.22
Education and training	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(2/3,1,2)	0.31
Vandalism	(1/2,1,3/2)	(1/2,2/3,1)	(1,1,1)	(2/3,1,2)	0.22
Ethics	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	0.25

Source: Mohammadzadeh, 2018

Local Legal challenges input dataset used

Legal challenges	Ownership	Standardization	Cross boarder	liability	Data usage	Calculated weights
Ownership	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(2/3,1,2)	(1/2,1,3/2)	0.20
Standardizat	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/	(2/3,1,2	(1/2,1,3/2)	0.20
Cross	(1/2,1,3/2)	(2/3,1,2)	(1,1,1)	(2/3,1,2	(1/2,1,3/2)	0.20
liability	(1/2,1,3/2)	(1/2,1,3/	(1/2,1,3/	(1,1,1)	(1/2,2/3,1)	0.017
Data usage	(2/3,1,2)	(2/3,1,2)	(2/3,1,2)	(1,3/2,2)	(1,1,1)	0.23

Source: Mohammadzadeh, 2018

Local Technological challenges input dataset used

Technological challenges	Hardware	Fault tolerance	Device	Architecture	Ubiquitous	Addressing	Calculated weights
Hardware	(1,1,1)	(2/3,1,2)	(1/2,1,3/2)	(1/2,2/3,1)	(1/2,1,3/2)	(1/2,1,3/2)	0.15
Fault tolerance	(1/2,1,3/2)	(1,1,1)	(1/2,1,3/2)	(1/2,2/3,1)	(1/2,1,3/2)	(1/2,1,3/2	0.15
Device	(2/3,1,2)	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)	(2/3,1,2)	(2/3,1,2)	0.17
Architecture	(1,3/2,2)	(1,3/2,2)	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(2/3,1,2)	0.19
Ubiquitous	(2/3,1,2)	(2/3,1,2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	0.17
Addressing	(2/3,1,2)	(2/3,1,2)	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	0.17

Source: Mohammadzadeh, 2018

Local Privacy challenges input dataset used

Privacy challenges	conflict	Transparency	Network	IoT device	Data	Calculated Weights
conflict	(1,1,1)	(2/3,1,2)	(2/3,1, 2)	(1,1,1)	(1/2,2/3,1)	0.14
Transparency	(1/2,1, 3/2)	(1,1,1)	(1/2,1, 3/2)	(1/2,1, 3/2)	(2/3,1, 2)	0.21
Network	(1/2,1, 3/2)	(2/3,1,2)	(1,1,1)	(1,3/2, 2)	(2/3,1, 2)	0.23
IoT device	(1,1,1)	(2/3,1,2)	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)	0.18
Data	(1,3/2, 2)	(1/2,1,3/2)	(1/2,1, 3/2)	(1,3/2, 2)	(1,1,1)	0.24

'Source: Mohammadzadeh, 2018

Local Privacy challenges input dataset

factors	Tech	Privacy	Legal	Business	Cultural	Calculated weights
Tech	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	(2/3,1,2)	(1,3/2,2)	0.24
Privacy	(2/3,1,2)	(1,1,1)	(2/3,1,2)	(2/3,1,2)	(1,3/2,2)	0.22
Legal	(1/2,2/3,1)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(1,1,1)	0.18
Business	(1/2,1,3/2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	0.20
Cultural	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)	(1,1,1)	0.16

Source: Mohammadzadeh, 2018

Appendix vi : Table Design and Description

Some of the most basic database table design images are depicted in appendix VI.

- Login Table

REALTECH01\SQL20...- dbo.AdminUsers

	Column Name	Data Type	Allow Nulls
🔑	AUId	int	☐
	Username	varchar(100)	☐
	Passwords	varchar(50)	☐
	Active	int	☑
▶			☐

- User Profile Table

REALTECH01\SQL2016...- dbo.UserProfile

	Column Name	Data Type	Allow Nulls
▶🔑	UserId	int	☐
	FullName	varchar(100)	☑
	Email	varchar(100)	☐
	Country	varchar(50)	☐
	JobTitle	varchar(50)	☐
	CurrentAddressOrganiza...	varchar(200)	☐
	AreaSpecialization	varchar(100)	☐
	WorkingExperience	int	☑
	Question1	text	☑
	Answer1	varchar(50)	☐
	Question2	text	☑
	Answer2	varchar(50)	☐
	DateRegister	varchar(20)	☑
	Active	int	☑

- Linguistic Terms Table (Legend)

REALTECH01\SQL20...DSS - dbo.Legend

Column Name	Data Type	Allow Nulls
LegendId	int	☐
Symbol	varchar(150)	☐
Descriptions	text	☑
Active	int	☑
		☐

- Email Confirmation Table (Legend)

REALTECH01\SQL20...EmailConfirmation

Column Name	Data Type	Allow Nulls
EmailId	int	☐
Email	varchar(100)	☐
DateRegister	varchar(50)	☐
Active	int	☑
		☐

- Question Title Table

REALTECH01\SQL201...dbo.QuestionTitle REALTECH01\SQL20...E

Column Name	Data Type	Allow Nulls
QId	int	☐
Qtype	varchar(20)	☐
Qtitle	text	☑
Active	varchar(50)	☑
		☐

- Response Questions Table

REALTECH01\SQL20....ResponseQuestion

Column Name	Data Type	Allow Nulls
RId	int	☐
UserId	int	☑
QId	int	☑
Question	text	☑
Answer	varchar(100)	☑
DateAnswer	varchar(20)	☑
Active	int	☑
		☐

- Organization Table

REALTECH01\SQL20...ampleOrganization

	Column Name	Data Type	Allow Nulls
▶🔑	SampleId	int	☐
	UserId	int	☑
	OrganizationName	varchar(80)	☑
	Q1	text	☑
	A1	text	☑
	Q2	text	☑
	A2	varchar(20)	☑
	Q3	text	☑
	A4	varchar(20)	☑
	Q5	text	☑
	A5	varchar(20)	☑
	Q6	text	☑
	A6	varchar(20)	☑
	Q7	text	☑
	A7	varchar(20)	☑
	DateRegister	varchar(20)	☑
	Active	int	☑
			☐

Biodata

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3. Title : **Big Data Testing - Challenges And Best Practices**

   Year of publication: February 2021

   Volume: Volume - 63, Issue - 06]

   Journal: Technology Reports of Kansai University (ISSN: 04532198)

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University Compliance Certification

This is to certify that this thesis by Ayuba ATUMAN with Matriculation Number LCU/PG/002023 in the department of Computer Science, Faculty of Engineering and Technology, Lead City University, Ibadan is in full compliance with the approved University's Format and Style.

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Signature Date