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MEEDS-A DECISION SUPPORT SYSTEM FOR SELECTING THE MOST USEFUL DEVELOPMENTAL PROJECTS IN DEVELOPING COUNTRIES- CASE OF GHANA

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ABSTRACT

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Several sustainable development indicators have been used to monitor and measure the progress of various countries. Several reports and data available about countries progress prove that development has not been equal in all regions. On the brighter side, the data can be used to inform decision making in areas that are experiencing deficiencies. In this research, a decision support system(DSS) is built to help governments and NGOs to properly choose projects that align with the needs of the people. We approached this research by utilizing Abraham Maslow's proven psychological framework on the hierarchy of needs as the main criteria for choosing projects for sustainable development. The system ranks development projects based on the needs priority and how much it has been fulfilled. It ranks projects that meet an urgent need that is also lacking fulfillment higher than other project alternatives. The social progress index (SPI), a comprehensive open data that measures the social progress of counties were correlated to the needs indicated by Maslow's Hierarchy. The needs were then used as criteria in the AHP decision analysis model to build a classic DSS to aid in selecting the most appropriate development project.

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LIST OF SYMBOLS AND ABBREVIATIONS

CR	Consistency Ratio
DSR	Design Science Research
DSS	Decision Support System
MDG	Millennium Development Goals
SDG	Sustainable Development Goals
SaaS	Software as a Service
SOA	Service Oriented Architecture
SPI	Social Progress Index
AHP	Analytical Hierarchical Process
ICT	Information Communication System ()
MEEDS	Meet Needs DSS

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1 INTRODUCTION

The idea of sustainable development emerged in 1987 from the Brundtland report: “A development that meets the needs of the present without compromising the ability of future generations to meet their own needs” The global change agenda report from the World Commission on Environment and Development: “Our Common Future”. The main focus for deliberation of the global change agenda was the relationship that existed between environmental degradation, inequality, and poverty. [2]

The Millennium Development Goals (MDGs) was set in the year 2000 as a strategy and a guideline to help fight poverty, inequality and to protect the environment. The year 2015 marked the completion of MDGs. In a report of the MDGs which was forwarded by Ban Ki-Moon, the Secretary-General of UN, he stated that “By putting people and their immediate needs at the forefront, the MDGs reshaped decision-making in developed and developing countries alike. Yet for all the remarkable gains, I am keenly aware that inequalities persist, and that progress has been uneven”. Even though the MDGs sought to meet the needs of the people first which is the ideal approach towards a sustainable development, the goals could not be fully achieved within the time frame projected.[3] (United Nations 2015 pg. 3) The success of MDGs achieved was highly skewed to some specific regions - the developed countries. This is because the developed countries are far advanced in meeting their basic needs (water, food, sanitation, and shelter), hence their ability to attain the MDG goals faster and better. While their counterpart countries in Africa and Asia were grabbling with solving the basic needs of its people.

Almost all developing countries struggle with very basic needs such as access to potable drinking water and sanitation, food and nutrition, basic health and environmental quality. But not all the needs can be met at the same time due to the lack of resources and infrastructure. Therefore, there is a need to prioritize the needs for progressive development in the developing countries. Prioritization of needs means that the most important primary needs must be focused on first. Such primary needs ensure the survival of the people and for them to be able to thrive and live quality lives.

For example, education is important but why should a country put resources into increasing access to basic education when necessities in life such as access to drinking water and food cannot be accessed by more than 50 percent of the population of a country.

The theory of Motivation framework [4] by Abraham Maslow called the hierarchy of human needs which will be further explained in chapter two explains that every person first

meets his survival needs such as water and food before that person tries to satisfy safety needs such as shelter, safe neighborhood, and steady employment. The rest of the needs are social needs, esteem needs, self-actualization, and self-transcendence. These needs need to be studied in different contexts to figure out what should be emphasized in sense of sustainable development in each country.

Data from sustainable development indicators, sustainable development index and social progress index (SPI) exhibits the needs of the several countries and can be used for this study.

In this thesis, a DSS is built to help country leaders choose the right project that can help meet the basic needs of the people. In the past, countries have embarked on projects to increase the Gross Domestic Product and Gross National Income as a way of competing with other countries for the neglect of the basic needs of the majority.

The approach of countries meeting higher levels of needs before first meeting the basic needs of the people only favors the rich minority in the country and sends shocks to the poorer population [5] and breeds several problems such as inequality, migration, an increase in crime rates because the people will always find ways of meeting their own needs. The right decision-making process that will help the country to select the useful project for the country is needed if the survival needs of the country are to be met. A DSS that is equipped with the country's needs data is important to assist managers of countries to choose best-fit solutions to meet their needs. This will ensure that projects selected for a country will meet the countries needs progressively to prevent the harm that can be caused when basic needs are unmet.

In this thesis, a web-based Multi-Criteria DSS is proposed and developed to solve this problem. The system allows the decision maker to input several project alternatives under consideration then decide which of the basic needs the project will impact. The system then determines which of the projects is the most useful to the country. The system uses the Analytical Hierarchical Process (AHP) which is known for its efficacy in helping to solve complex group decision making. In this thesis, Information Communication System (ICT) is used to solve a social problem, that is, the use of a DSS to select the right solutions to meet basic needs for sustainable social development.

1.1 Motivation

Global Sustainable Development Goal Report, 2016 [6] sought to answer three questions. First, who are those being or at risk of being left behind? Second, how can strategies and policies reach them in practice? And third, what types of strategies and policies would be appropriate to leave no one behind? An Information System such as a DSS can be used as an enabling tool for decision making on the three broad questions mentioned above. [6]

In the same report, there is a need for an evaluation based on scientific evidence to access the impact of the sustainable development interventions. The evaluation will highlight the impacts of the various interventions that sought to improve the lives of people and to "leave no one behind". This evaluation should also access the cost and benefits to cancel or improve projects that are not improving the wellbeing of the "left behind". There might be a need to invest in a framework that will assist in this evaluation of sustainable development interventions. [6]

The Data Revolution Group paper; "A world that counts", 2014 [7], emphasized the mobilization of data for Sustainable development. Recommendations from the paper on page 24 also suggested there is a need to strengthen the capacity of every country's data analytics, SDGs analysis and to have a visualization platform. The road to sustainable development becomes relative to a country's needs. The path to sustainability based on a country's context, for example, their needs, their development path, and their available resources. Josephs Tainter in his article[8] stated four questions that must be answered by every society to know which part of sustainable development it strongly needs. (i) What to sustain? (ii) For whom? (iii) For how long? and (iv) At what cost? To answer this question, it can be very complex and in such a situation there is a need to apply a model that can aid complex decision making. Making sustainable decisions is a complex exercise due to all the various considerations that must be accounted for as stated by Tainter. In this thesis, we will use AHP which will be explained further in chapter two and three to break down the complex process of choosing the most useful projects that are aimed towards meeting the basic survival needs of a people. The model has been used by several institutions as a decision model building DSSs. The DSS proposed in this paper will use data available on each country to help decide on which intervention will be most beneficial to the country and highlight the intervention which will not be helpful for a country.

1.2 Problem Definition

Report from the World Bank Independent Evaluation Group proves that millions of USD have been spent on several projects in the developing countries to fight poverty and foster equitable economic growth [9]. Most of the projects that the world bank invested in failed fully or partially [10] due to several reasons. Some of the reasons why those projects failed were because they focused on the economic impact and the technical viability of the project and not the impact it will have on the people in society or how the project will impact the people. For projects to be useful and sustainable for the people, it should be valuable to the people. [8]

A case in point, world bank invested in an e-services project at cost of US$113.73 million in the Republic of Ghana for two main reasons.

(i) To create the enabling environment for information technology-enabled services and to increase public-private partnership (PPP).

(ii) To digitize the public services to enable the government to leverage on the efficiency and the transparency e-services offers.

Some of the e-services were:

(a) Certified a true copy of birth certificate

(b) Online marriage registration

(c) Company registration

(d) Criminal background check

(e) Fingerprint analysis

(f) Background check for visa and job applications

(g) Marriage licenses.

A wide area network was created to host and manage the e-services but there was no funding for maintaining this infrastructure after the implementation of the project. The absence of funding for maintenance means that the government must provide funding for the projects. Meanwhile, only 43 percent of the total population of Ghana has access to clean drinking water and shelter. The government's focus will be to address the basic needs of the people. It is, therefore, no wonder that only 10% of Ghanaians use the e-services. Other factors affecting the success of the project include low Internet penetration, low/unstable connectivity and lack of education.

It is, therefore, considering these and similar challenges that we propose a DSS that will assist institutions like the world bank and governments to invest in and implement the right kind of project – projects that meet the needs of the people.

1.3 Research Contribution

There has been a lot of work within the scientific community regarding building models and systems to enhance the making of sustainable decisions. This thesis proposes an additional tool for assisting sustainable decision making.

1) Making sustainable decisions includes choosing and implementing projects that are useful to the people for whom it is meant for. By useful, we mean projects that are targeted towards addressing the current pressing needs of the people. In this thesis, a DSS for choosing from among project alternatives the (i) most useful and (ii) most likely successful based on a given set of criteria is designed and built.
2) Again, this thesis provides a set of standard criteria adopted from the SPI [11], these criteria would become the needs of any given country. These standard criteria are then prioritized based on Abraham Maslow's [4] framework of need. This thesis contributes a standardized means for prioritizing needs for a given country. This prioritized need list serves as criteria input for the decision-making model.
3) There are several decision-making models available, in this thesis, we will make use of the Analytical Hierarchy Process. A key limitation to this methodology is being able to attain an appreciable consistency ratio(*ci*) [12]. Lower consistency ratio (<=0.1) means the decision is close to accurate. In this thesis we propose a means to improve the *ci*, further details on this is provided in section 3.

1.4 Delimitations

This thesis is limited to calving the criteria needed for choosing the right projects for social sustainability in developing countries. It uses Maslow's hierarchy of needs as a criterion to select and rank projects based on their impact on each need. Ghana, a country in Africa is the main use case. This research proved that data available on countries can be used to help country's leadership decision-making to take next steps towards sustainable development. There are several other criteria that can be used to select the most useful project but that will be for future research.

1.5 Research Questions

The overarching aim of this research is to answer the question:" Can **a DSS be used to prioritize and select socio-developmental projects**?"

Embedded in this are other sub-research questions around which the hypothesis of this thesis is built. These are:

i. Why do socio-developmental projects fail in their implementing countries?

ii. What is the link between the success of developmental projects and a country's basic human needs satisfaction?

iii. What are the identifiable taxonomies under which developmental projects can be grouped?

iv. How effective and efficient will such a system be in choosing the right project?

1.6 Research Methodology

In this thesis, a research methodology referred to as design science will be used. This research methodology is mostly used in researches in the field of ICT. A key goal of this methodology is the delivery of an artifact in the form of a piece of software, a model, a method or a construct [11][13]. It is an iterative process, this ensures that the artifact under design or development could be developed by targeting the smallest unit of achievement. At each cycle, the quality of the of the artifact is improved and the artifact gets closer to answering the problems defined in the thesis [11].

Following from *Figure 11* below is our research process will include 6 steps.

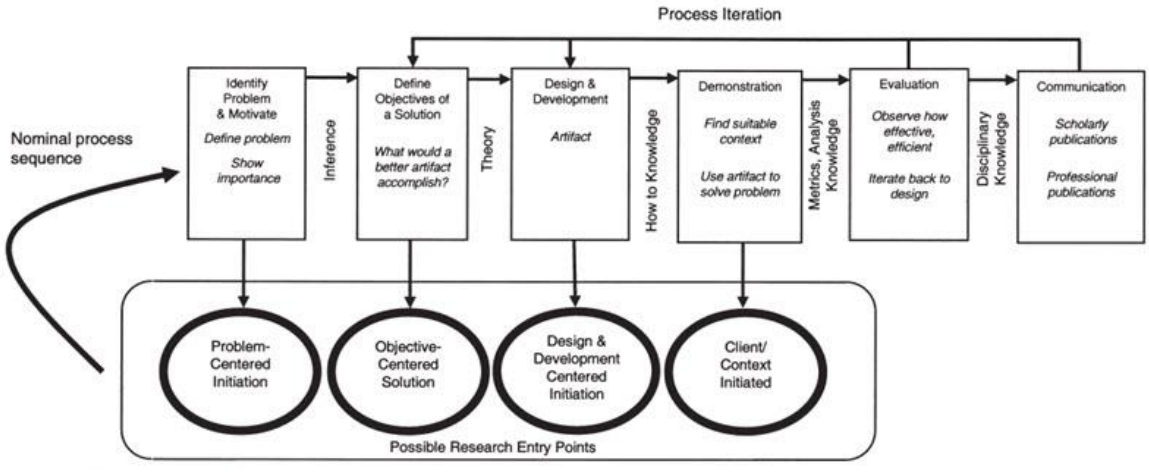


Figure 1. DSRM Process Model

Figure 1: DSRM Process Model[51]

Identification and definition of the problem
In this step, the problem we are solving is identified, it must be real-world problem needing a relevant solution. To identify the problem, we did the following: (1) problem definition, (2) literature review of related work and (3) assessing the importance of the assumed solution to the defined hypothesis. Research questions stated in the section 1.5 above are a direct result of this step.

Define Objectives of Solution (Refer to section 1.1)
In this step, the solution to the problem is defined. It includes specific requirements that the artifact should possess to qualify as a solution to the stated problem. Aspiration is drawn from a comparison of solutions to similar problems as identified.

Design & Development
The third step is to undertake the creation of the artifact. Various activities like determining the system architecture, technology selection, acceptance criteria and functionality determination.

Demonstration
In this step, the developed artifact is demonstrated using real-world data. The artifact is used to solve real-world problem in a defined simulated context.

Evaluation
In this step, we test to evaluate the validity of the artifact by verifying if the artifact meets the defined objectives in step two and whether the artifact provides a solution to the stated problem. Results of the experimentation in step four are analyzed and discussed.

Communication
Finally, the conclusions drawn from the discussion of the results of the simulation is presented in the form of this thesis paper. Publication presentation to colleagues and Professors and users of the proposed artifact.

1.7 Sustainability

This master's programme focuses on using ICT for sustainability. Therefore, it is a requirement that theses undertaken during this programme contribute towards one of the dimensions (economic, environmental and social) of sustainability[14] [15]. Sustainability according to the UN is when the current generation satisfy their needs while enabling future generations to satisfy their needs" [1]. Sustainability does not deal with only environmental sustenance; the definition is expanded to capture economic development and social equity [16] The main dimension of sustainability that this thesis seeks to contribute to is the social sustainability. Social sustainability has several directions to it that benefit human well-being. The nature of the dimensions of sustainability is such that all the dimension is interrelated. Hence, this thesis has implications or could be adapted for the other dimensions such as economic, environmental and some technical aspects of sustainability.

Formerly, sustainability of a software has been evaluated to assess how the software can last for a long time in terms of how easy it can scale or be maintained in case of any future changes to it context[17][18]. But nowadays the evaluation of the effects of a software system on sustainable development has become very necessary because every software system also has implicit effects on the society and environment.
Below is a diagram adapted from this paper [19] to evaluate the impact of the software system in the entire ecosystem. To illustrate the immediate effect, enabling effect and structural effect.

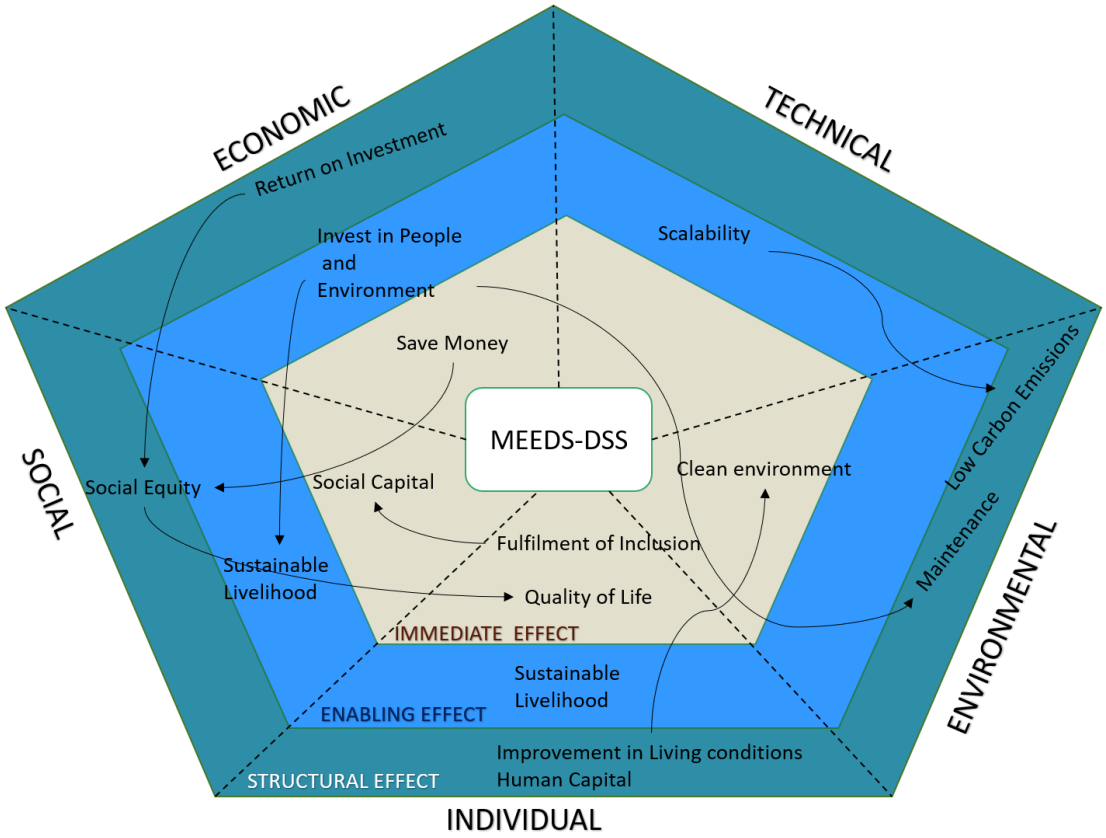


Figure 2 Sustainability Evaluation

1.8 Structure of the thesis

This section is a presentation of how this thesis is structured, how the various components sections are layout.

Chapter 1, of this document is an introduction of the thesis, dealing with the motivation of the thesis, problem definition, research contribution, goals of the research, research methodology and provide an initial synopsis on motivation.

Chapter 2 provides an extensive literature review of related works within sustainability and DSS. Researches that have been carried out around social sustainability and the DSSs that assist in making sustainable decisions.

Chapter 3, details of the system architecture and design and considerations for the design. implementation, and development methodology is given.

Chapter 4, this chapter is concern with the system implementation and deployment and the considerations for the implementation.

Chapter 5, the results of the thesis are discussed. The results from testing the DSS with real-world projects compared to the case studies for each project will be fully discussed.

Suggestions for future work will be given in **Chapter 6**, areas of focus or how this thesis could be extended will be captured and discussed in this chapter.
conclusions drawn from the research will be stated here and a summary of the thesis and the document will be captured hear also.

2 RELATED WORK

This chapter presents the related work in social sustainability and DSSs that have been used to aid decision making in projects geared towards better livelihoods or social development of a community or country. Since this paper focuses on DSS for choosing best-suited projects for a country's development there was the need to look up other researches on project selection.

The DSS and the area of focus will be defined and after that, all related works will be adequately explored. There are few DSSs that were found that have been made for selecting the best-suited projects for a country. Most of the research papers found focused on various resources solution such as water, energy and technology solutions. Researches that focused on the most appropriate means of selection of various inputs for successful project completion or how to incorporate more stakeholder into the decision-making process were also reviewed.

2.1 Social Sustainability

Social Sustainability is one of the three pillars of sustainable development and yet the most misunderstood and overlooked in research and in implementation. According to the noble prize winner Amartya Sen [20] [21], A socially sustainable community must show that the members have access to basic human needs (Quality of life), freedom of speech, encourage interrelation, strong institutions or governance and enjoy equality or equity.

The social sustainability also is tightly linked to people before it spans the areas of sustainable development. Social life in their paper designing for social sustainability [22] have created a framework that measures the social sustainability of communities with four dimensions that is related to the definition given by Amartya, they are - amenities, infrastructure, social and cultural life. They are of the view that social sustainability is the human aspect of the technologies and systems being developed to reduce carbon footprint and to regulate the consumption of resources. They researched into the need for amenities and infrastructure to be designed to encourage interrelation, comfort, and safety. That can only be achieved by finding the necessities of the people in the places where they live and

work. If social sustainability is achieved it tends to improve the behavior of the people in the community. Interrelation and connectivity create comfort, a sense of belonging and reduces crimes in the community.

2.2 Sustainable Livelihoods

The sustainable livelihood[5] is a framework developed by the Department For International Development-UK(DFID) for analyzing people's living conditions with a special focus on the living complexities of the poor. Livelihood[23] include all survival needs but not limited to food, water, shelter, and income. The framework is a way to understand the opportunities and constraints the poor face and their tactics of survival. The framework also takes a holistic approach to understand poverty and how the knowledge can be used to frame and change policies and conditions that make the poor suffer more. The figure below shows the framework that reflects the connection of the event that affects the poor and portions that could be changed to help the poor to be empowered[24]. When institutional or government policies do not favor the poor, the poor face several vulnerabilities. In the vulnerability context, there are shocks when for example the prices of food increases sharply or there is an increase in the price of transportation.

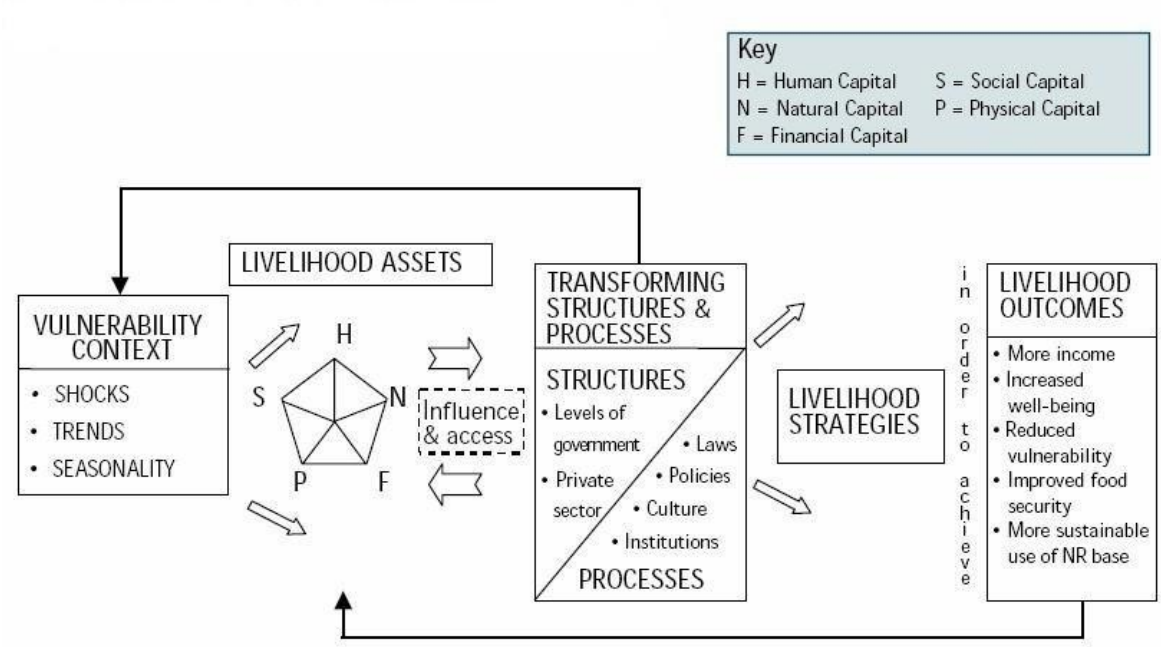


Figure 1 Sustainability Livelihood framework [25]

The Framework has an embedded pentagon as illustrated below which describes the human assets, they are social capital, human capital, natural capital, physical capital and financial capital. These assets are what each individual has gained if the government and institution favor their growth[26]. If the poor in the community will be able to thrive and be comfortable then the process of decision making should be adjusted to favor the poor so that there will be no one left behind[27].

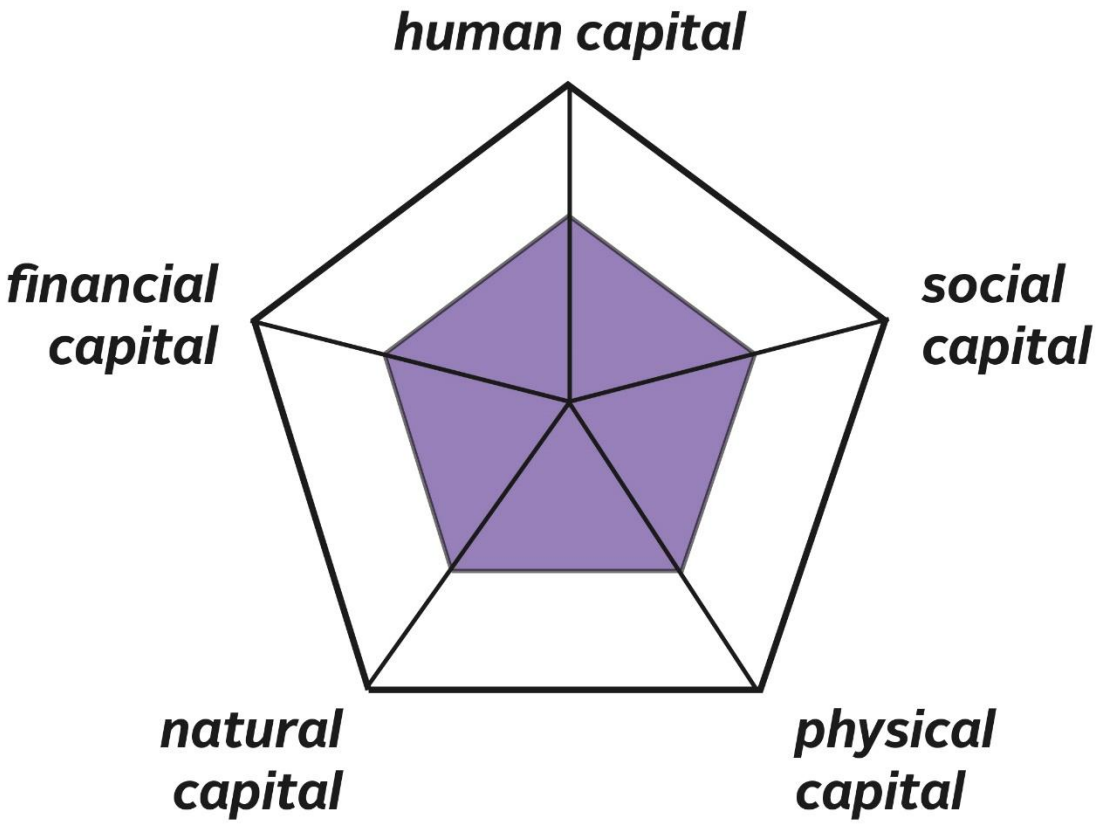


Figure 2 Sustainable livelihoods Human Pentagon [23]

There is a need for a universal growth and opportunity for all for social sustainability to be realized. The human development report in 2016 captioned "Human Development" described the poor, the vulnerable and those who have not been able to live to their full potential as the "Left Behind"[28]. They described further that 2030 agenda is to leave no one behind and even though some areas have recorded improvement this is not universal and that some groups of people are going to experience the problem of being deprived of development. So many groups of people appear to be experiencing transformation in

access to education and work, but the quality is very low, some groups experience more deprivation than others. Millions of people continue to struggle with access to nutrition, water, and shelter, others also struggle to have political freedom and personal rights.

The information system can also support decision making or change the way decisions are made to ensure inclusion and equity. There are various indicators and measurements for sustainable development[29] [28] [11] [30] [31]. These indicators serve as a means of monitoring progress to know which areas are lacking. The indicator data can be used to inform decision making at the government level to know which solution are most useful considering what the country is lacking. This converges to the ability to use the data available to make next decisions.

Social sustainability which is the human aspect of sustainable development is the focus of this thesis. We will use the sustainability framework as a guide to building the proposed system. Sustainable livelihood framework is used for building systems and transforming processes that will favor the poor or the left behind[28]. We are focusing on the developing countries because of poverty rates and how the new processes in decision making can increase their wellbeing and reduce their vulnerabilities and improve access to solutions targeted towards meeting their basic human needs.

2.3 Decision Support System Sustainable for Decision making

Definition of DSS from the Cambridge Business English Dictionary © Cambridge University Press is “a computer program that can arrange and sort enormous amounts of data, and that is used to help people in companies and organizations make important decisions based on the data”. DSS gives assistance to the decision makers by reducing the complexity and human errors during the decision making but it does not give final decisions. DSS has been used in the business intelligence to aid in decision making for so many years but in recent years it has been used to help in taking sustainable decisions or making sustainable choices.

Sustainable development decision is a very broad discipline and complex and hence requires several mechanisms to arrive at satisfactory sustainable decisions. Sustainable

decision making [32] is a decision process that turns a society into a more sustainable one. If a society is said to be sustainable, by what metrics do we use to determine that they are sustainable? Within the sustainable development, there are three main dimensions - social, environmental and economical. Each category is also very broad, all societies try to be sustainable in all three dimensions. Most rich countries have met most of their targets[33] while the poor countries are lagging behind all three dimensions, especially the social aspect- ensuring the quality of life[34] and human well-being.

In the past, the use of DSS in sustainable development decision has been towards economic and environmental aspects. For instance, DSSs focusing on assisting in choosing the right resources that will be more sustainable by comparing other alternatives or choosing the right resource that has less impact on the climate [33]. These systems have been very helpful because they have assisted communities to take the right decision on the choice of resources to help them to reduce their impact on climate change, save resources and money [33]. Directly, these DSSs affect environmental sustainability because they are resource oriented. Indirectly it has consequences for the social sustainability since it impacts on the equality of life of the people. Currently, there are few DSSs that focus on the selection of solutions that focus on the well-being of people directly. A DSS like what this thesis is proposing is what is needed in poor or developing countries to help them select the right solution to improve their quality and push towards better sustainable society. Previously and even currently, there has been a transfer of technologies to developing countries without considering the people's social context and their needs. In the same way, those systems concentrate on the economic and technical aspect of sustainability. All the projects/solutions are good to have, but for developing countries, the needs of social well-being and quality of life are higher and must be prioritized to ensure universal development and to "leave no one behind".

2.4 Decision Support System for Sustainable Development

In this section, several approaches of DSS towards sustainable development and climate change will be reviewed to assess their focus and their contribution to sustainable development.

2.4.1 Decision Support Systems for Developmental Projects

The first paper we will review is a multi-criteria decision-support approach to Sustainable Rural Energy in Developing Countries called SURE-DSS. [35]Many factors have contributed to the failure of rural energy projects, including inadequate technical information, the lack of sustained financial resources, and capacity limitations at the local level to maintain equipment. This is to say that mostly the technical and economic outlook determines the selection of energy technology for a community. But considering only these factors are not adequate because the humans in the community are also a contributor to the success or failure of the project. SURE - DSS tackles this problem with a comprehensive approach to energy selection where all the relevant stakeholders including the people are considered in the decision of the suitable energy technology. In their paper, they stated several models that have been developed to aid decision of energy technology selection. But most of them neglect the individuals and the household's opinions even when they can affect and be affected by this project.

There are some other models that only sought for inputs from the individuals in the community after the project was completed. The SURE-DSS system considers the impact an energy choice will have on five dimensions; Economic, Technical, Social, Human and Environmental in a pentagon form [35]. To ensure that less impact on climate change is achieved in the long run. It also draws on sustainable livelihoods which is a people-centered approach and deems it important to connect several components to livelihoods

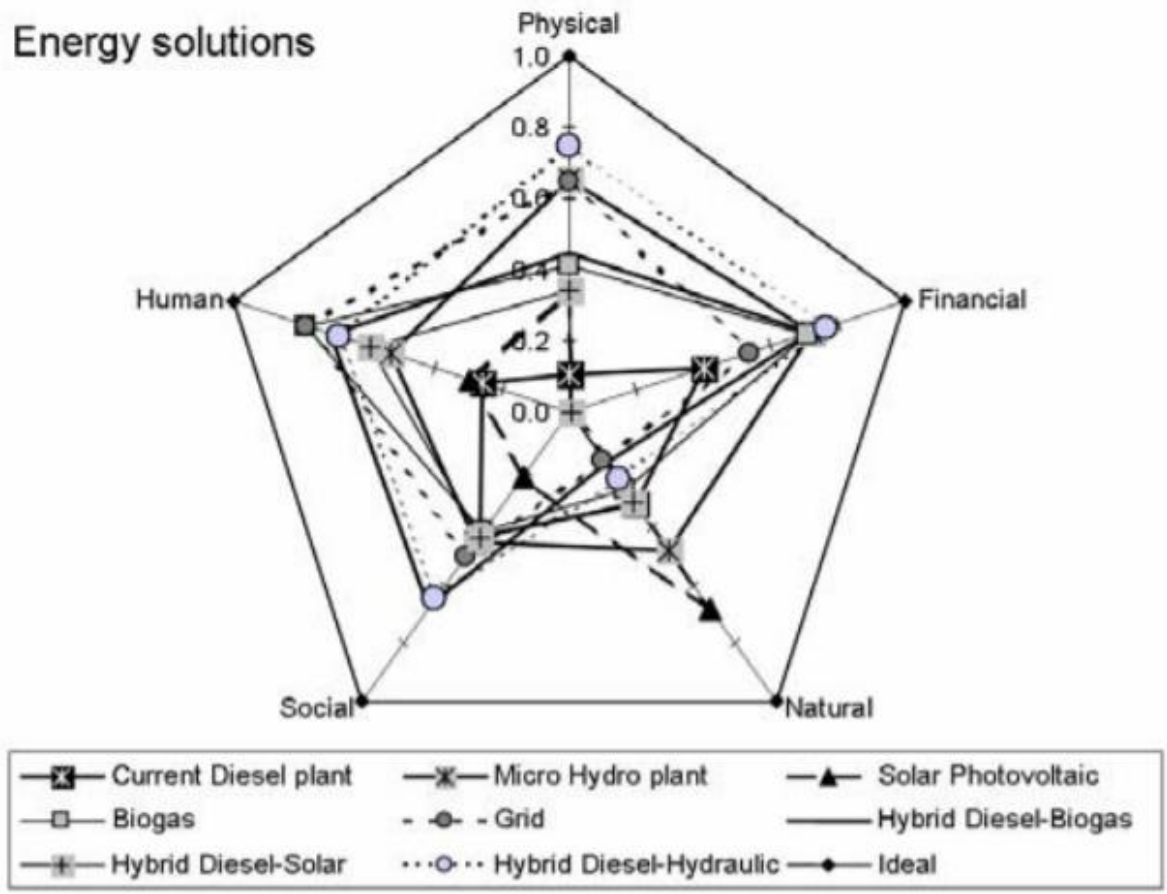


Figure 3: SURE DSS [35]

A system like SURE-DSS will be very useful as the next step when a country has established that their needs at a material point are energy and they need to make a sustainable choice. But it will not be beneficial if a country has several project alternatives for different needs and they need to select the most useful project. This SURE-DSS can also be modified to select the most sustainable choice solution for any kind of need, for example, water, sanitation, and transportation.

In the same area of sustainable resource selection, this second paper reviewed [36] aims at bringing engineers and community planners together in one system to take the right decision in selecting the best sustainable wastewater management solution. Past systems for wastewater solutions consider only technical and economic parameter but this DSS prototype has been developed to solve the problem of taking a decision by involving key stakeholders. This is done by incorporating their opinions into DSS to make them part of the decision-making process. [36] The prototype automatically generates designs based

upon ontology from the domain of experts and non-experts, components and community constrain [36].

The third paper reviewed [37] presents an AHP-fuzzy decision support model to evaluate the sustainable development of a region. It makes use of the indexes of the three dimensions of sustainable development. - economic, environmental resources and social. The authors divided the indexes into two groups, the first and second level indexes. They conducted an empirical study where experts gave grades to the indexes. (excellent=4, good=3, common=2, poor=1) After that, an AHP - analytic hierarchy process was performed on the values given by the experts to confirm the weight of the indexes. Finally, to make it more scientific, a clustered analytics and weight revision were conducted on the weight. The weights results reveal which of dimension or index is improving and which of them needs more attention. This helps decision makers to have a broad picture of the status of the community and the next plan for the community towards achieving a more sustainable community. The figure 4 below shows the indexes that were to be graded by the experts. [37] This paper raises a very good point on rating the performance of sustainable development of the community by its own members. The people in the community are the best people to rate how they are faring and what kind of problems they face. But then how can the decision-makers ensure that they meet their need properly? Considering Lack of resources which needs will be urgent? By what measure can they use to determine that a need is urgent? There are no clear criteria, so this might result in politics or in a power struggle. The one who might have the power, or the money will select what he thinks might be good and that decision might be favoring only a group of people. That is why a standard and an objective criterion would be timely in such situations to reduce the complexities of decision making.

First level index U_i	Second level index U_{ij}
Economic development U1	U11 Per Capita GDP
	U12 Growth Rate of GDP
	U13 Proportion of Tertiary Industries GDP
	U14 Labor Productivity
	U15 contract foreign capital
	U16 Per Capita Volume of Retail Sales
Social progress U2	U21Population Density
	U22 Fault Rate of Government Decision
	U23 Frequency of Criminal Case
	U24 Number of University Students Every Million People
	U25 Unemployment Rate
	U2 Per Capita Medical Facilities Possessed
	U27 Engel Coefficient
Environment U3	U31 TSP and SD Content in Atmosphere
	U32 Organic Content of Soil
	U33 Green Coverage Rate of Urban Construction Region
	U34Water Pollution Index
	U35 Noise Average Value
	U36 Comprehensive Control Rate of Three Wastes
Resources U4	U41 Resources Consumption of Unit Output Value
	U42 Proportion of Various Resources Consumption
	U43 Total Amount of Resources
	U44 Rationality of Resources Development Plan
	U45 Resources Transform Rate
Systematic Harmony U5	U51 Proportion of Ecological Construction Investment to GDP
	U52 Social-environment Coordinates Coefficient
	U53 Economic-environment Coordinates Coefficient

Figure 4: Sustainability Development Assessment of a region [[37]***]***

The fourth paper reviewed was a mobile application based sustainable irrigation water usage DSS. [38] The system combined three data sources; Model Networks (including the Bureau of Meteorology-SILO database, Australian Cosmic Ray Sensor Network database (CosmOz), and Australian Water Availability Project (AWAP) database) to give recommendations to farmers on android mobile to either buy water for irrigation or not. It

checks the three integrated data for groundwater balance and average water available and used that information to inform farmers to make quick decisions to protect the farms and ensure a good harvest. The researched paper is a classic example of the power of IOT in DSS to catalyze quick decision-making. Nowadays the use of IoT data for making quick decisions has been utilized in several sectors especially for home automation for resource usage monitoring and management. This scenario can be applied in several business instances to manage their time and resources and assist in quick decision making.

The use of IoT data approach for decision making has been to be applied in the fifth paper we will review, that is a DSS for waste management optimization [39]. The paper uses a mathematical model to investigate and propose an improvement for routing problem for waste management collection trucks, to reduce carbon emission and save money for a municipality. The Melbourne city of Australia a was chosen for this study and environmental sustainability was the focal point of the thesis. The research proposed a superior process to collect garbage as compared to the current process by optimizing the routing of the waste management vehicles that move around the city to collect the rubbish. The opensource JSPIRIT library was selected for the proposed system. The authors experimented with three scenarios to test the most energy saving and cost-efficient routing process which will eventually reduce carbon footprint.

In their experiment, there was a simulation of sensors in the garbage cans that send a message when the garbage is 80 to 100 percent full. The first scenario was without the sensors and it mimicked the current way of operation with a specialized track that can collect only one type of waste, for example, bio or plastic. And for the second and third scenarios, the unspecialized truck with compartments and sensors in garbage cans were incorporated. The only difference between the second and third was the fact that the third scenario the garbage must send a message for pickup only when it was 100% full. The experiment proved the third scenario was the most cost-effective followed by the second scenario. The worst cost efficient one was the first scenario that mimicked the current way the vehicles transported the waste and this scenario also required more vehicles. The research established a point that DSS like theirs can help the truck drivers, driving around to collect garbage to be informed about their optimized route before the step out. This mathematical model if implement will improve vehicle routing problem, reduce carbon emission and save the city money.

The last paper in this category is a big data proposal approach to support decision-making process [40]. This paper uses multidisciplinary measures like data mining and artificial intelligence to process data to aid in decision making for the government, business and non-profit. Their system architecture consists of 3 levels, the **first level** is the API for users who describe their problem, objectives and other requirements. The **middle level** is the processing and modeling and previous decision made. It contains mechanisms for data mining and mathematical formulas that mimics human values on economic, environment and business factors. And the **bottom level** is the raw data. Once a user input a problem, the system selects the right model and the right solution to the problem and stores it for future reference.

The main reason for this study is the fact that nowadays sustainability is being considered at both business and government level. And both actors; businesses and the government are trying to make decisions that are sustainable which brings about the need to consider the cross dependencies and impact on other actors like the environment. The Kuhn-Tucker approach was adapted based on the linear bilevel programming theory in the research to optimize the performance of the system for multiple users who have different needs. The system has been designed to aid in collaborative decision making within a sustainable ecosystem. This will create an enabling environment for transparency for sustainable decisions made by several actors with an ecosystem.

2.4.2 Needs Identification and prioritization Decision Support System

Needs identification and prioritization are important for several reasons, the former can (1) help an organization to identify solutions to meet those needs effectively, (2) also help the organization to take quick decisions on the next action to take to meet those needs. The latter (1) ensures the restructuring of the objectives of a system to reduce the harm that can be caused when important needs are not met. Kaiser et al [41] explained their approach of developing a DSS that aids in prioritizing needs to help in decision making for organizational learning.

They used systemic thinking approach to prioritize needs of a company. BEWEXTRA Framework was adopted to identify, analyze and validate the needs of the organization

through three different views modules, which are, internal view, external view, and the systemic view. In each of the views, there were several methodologies to select their acceptance criteria and to validate the needs identified.

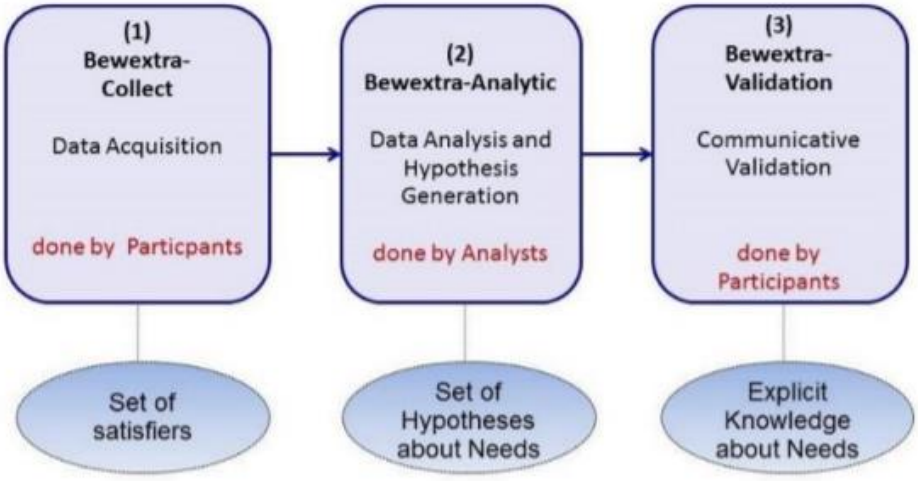


Figure 5: BEWEXTRA Framework[38]

In the Internal View, needs were collected and validated with the employees. In the External view the needs were validated by the other stakeholders and experts who have knowledge of the organization but do not interact with the system, and the systemic view is the valuation of how each of the needs being satisfied will affect the other needs satisfaction as well as the impact of each of the needs to the system's survival and continuity. During the systemic view module, a Cross Impact matrix (CIM) was used for the needs assessment. A mathematical model was developed to calculate the index of all the needs. The indexes ranged from 1 to 10 where 1 signify the least import or critical need [41].

In the next related work on needs selection and prioritization, this paper [42] enhances the Technology Needs Assessment TNA, which is used during Technology Transfer (TT) to meet the energy needs of the country for sustainable development while mitigating carbon emissions.

Problem with the current TNA is the inability to prioritize the needs of the people and to properly align actions to be taken to meet those needs in the case of developing countries. [42], [43] This paper [42] uses a Linguistic Decision-making method based on the

linguistic ordered weighted average to discover the energy needs and priorities of a country. Since this process of the decision-making process involves mostly qualitative studies, the strategy used should be linguistic to appropriately interpret the results into a right representation of the respondents' answers for the better decision making [42]. The figure below shows the linguistic terms used to capture the needs priorities of all the stakeholders

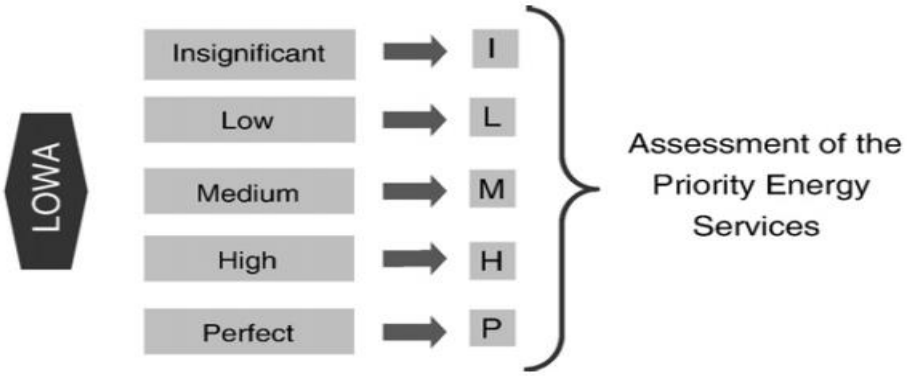


Figure 6: Assessment of the Priority Energy Services[39]

The authors conducted the research in 5 countries, namely, Kenya, China, Chile, Israel, and Thailand. In each of the countries, they selected stakeholders and key actors in the energy service industry. The stakeholders selected included among others governmental organizations, non-governmental organizations (NGOs), energy companies (products and services), industrial sectors, industrial associations, legal and financial bodies, researchers and developers (R&D). Results showed that each country had unique needs and priority when it comes to energy needs. Therefore, to meet the energy needs of different countries it is extremely important to use this method to conduct a comprehensive interview of all stakeholders in order not to develop or supply a product that alters the countries' plans and does not meet their main need for energy. Figure 7 shows each country and their priorities for energy.

Cross-country comparison of prioritized energy service needs.

Country	Energy service needs and priorities
Chile	N1: electricity for industry N3: electricity for households (rural) N10: energy efficiency in industry
China	N1: electricity for industry N6: heat for industry N10: energy efficiency in industry N11: municipal solid waste management for energy
Israel	N1: electricity for industry N3–4: electricity for households (rural and urban) N5: electricity for service sectors N10:energy efficiency in industry
Kenya	N3–4: electricity for households (rural and urban) N5: electricity for service sector N9: energy for cooling for all Sectors N10: energy efficiency in industry N11: municipal solid waste management for energy
Thailand	N1: electricity for industry N2: electricity for agriculture N10: energy efficiency in industry N11: municipal solid waste management for energy

Figure 7: Cross-country comparison of prioritized energy service needs[39]

From the above, related works, there is a skew towards resources more than people. And this research seeks to balance the research focus and to not only include people to be the direct beneficiaries of the solution but also to make people the center for sustainable decision making.

In the next section, we will explain Maslow's hierarchy of needs and how we intend to use it in our DSS research which is people-centered and the data and the case study to test the system's efficacy

2.5 Maslow's Hierarchy of needs as criteria for decision making

The hierarchy of needs is a theory of motivation designed by Abraham Maslow. It is a pyramid representing the various levels of human needs. In this theory [4]Maslow makes the point that motivation is based on needs and that certain needs are more pressing than others. That needs which are of higher priority must be fulfilled first before higher needs are attended. He says that at the bottom and most pressing needs is the need for physical survival. Maslow strengthens his arguments of needs being hierarchical in this extract below.

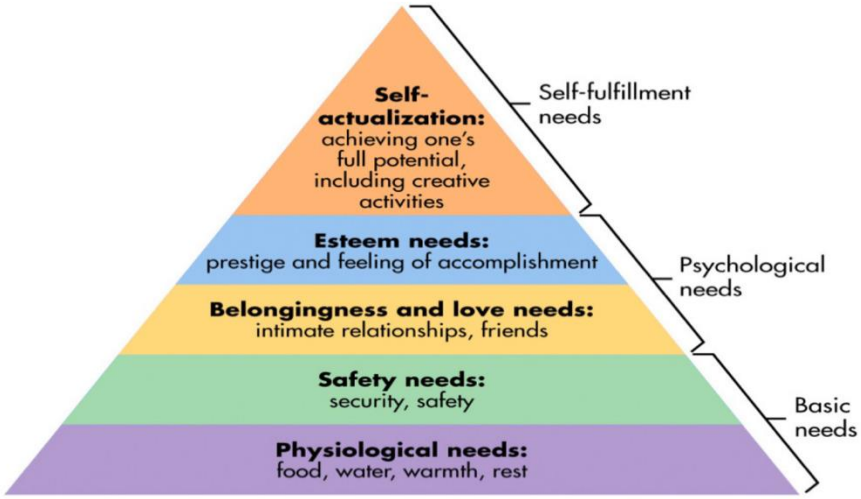


Figure 8: Maslow's Hierarchy of Needs[4]

"It is quite true that man lives by bread alone – when there is not bread. But what happens to man's desires when there is plenty of bread and when his belly is chronically filled? At once other (and "higher") needs to emerge" [4] According to Maslow when these new need/desires are fulfilled new ones emerge, and so on. This is what Maslow mean by saying" that the basic human needs are organized into a hierarchy of relative repetency" (Maslow, 1943, P. 375). The above quote suggests that human needs are fulfilled from the highly prioritized to the less important. Thus, the individual is not motivated to satisfy higher needs if higher priority needs are unfulfilled.

Since society is a collection of individuals we can situate Maslow's theory within the larger context of societal needs. What we mean is that the needs of societies are no different from the needs of the individuals within that society. The societal needs are a collection of that of the individuals and the vice versa. We must, however, point out that, we do not mean all the individuals within the society have the same needs at the same time, but on the average, they are similar. Therefore, societies are motivated by their most important basic needs first before those up in the hierarchy.

In this thesis, basing our arguments on Maslow's theory of needs, we argue that sustainable decisions are only attainable/achievable when those decisions address the needs of the targeted society. According to Hersh [32], sustainable decisions are decisions meant to contribute towards the transition to a sustainable society. Hence, projects that are meant

to transform societies must first address the societies immediate needs. Societies can only move towards higher levels of motivation (needs fulfillment) such as those in the psychological needs and self-fulfillment needs brackets once their basic needs have been fulfilled. It is imperative, therefore, that sustainable projects are designed with societal needs placed at the center of the decision.

In this thesis, we would design DSS that uses Maslow's framework of needs to prioritize the needs of countries and consequently use the outcome in selecting the most useful projects from alternative projects for a given country.

2.6 Social Progress Index

SPI [16] measures the social and environmental aspect of indicators of national performance of a country and excludes the economic indicators. The SPI framework has three main architectural sets. They are **Dimensions**, **Components,** and **Indicators**.
The average score of the **dimensions** becomes the SPI of a country. The dimensions are Basic human needs, Foundations of wellbeing and Opportunity.
Each dimension has four **Components** and the weighted average score of the four components results in the score of that dimension. For instance
for the Basic Human Needs dimensions, there are four components and those are

(a) Nutrition and basic medical care,
(b) Water and Sanitation,
(c) Shelter
(d) and Personal safety.

And each of the components also has several **indicators** that characterize that component and can be measured for every country. Principal Component Analysis is used to apply weights on each of the indicators [16]. The weighted average of the component's indicators makes up the value of the component in question.
For example, the indicators of Nutrition and Basic Medical Care are

(a) Undernourishment
(b) The depth of food deficit
(c) Maternal mortality rate

(d) Child mortality rate

(e) Deaths from infectious diseases

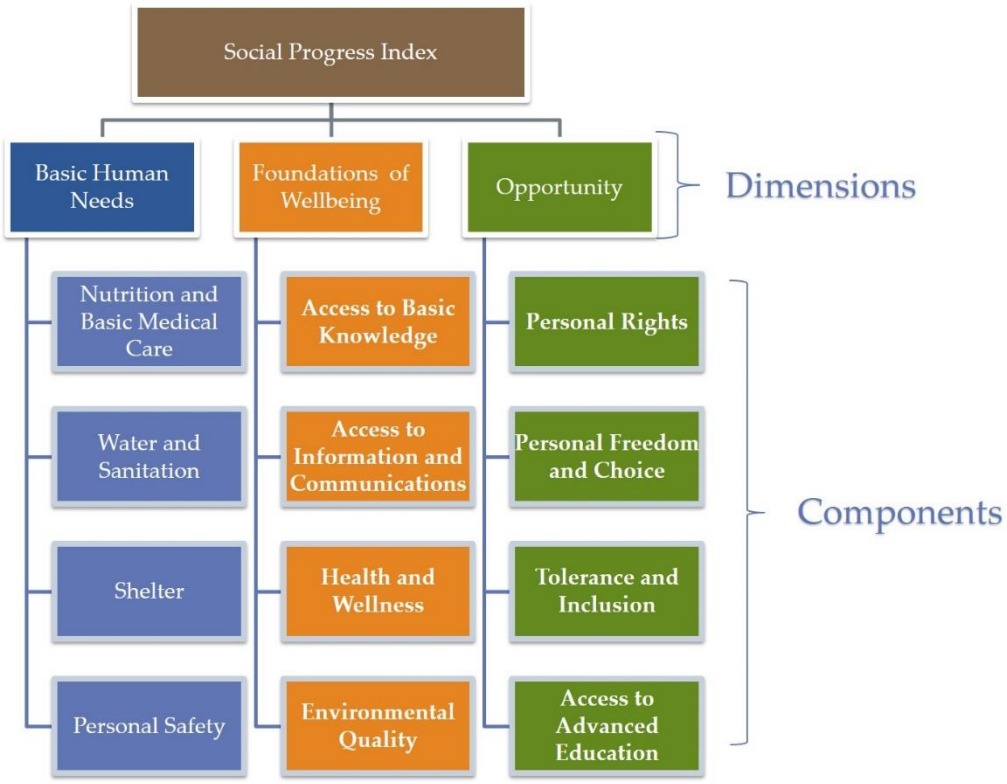


Figure 9: Social Progress Index Dimensions and Components. Adopted from Social Progress Index

The validity of the Social Progress Index

The SPI indicators are taken from sources that use the right consistent methodology [16]. There are three caveats to the data selection. The indicator should be; (1) accepted with the right choice of measure, (II) must be accessible publicly for transparency and (II) and obtainability of that indicator by all countries [16].

Sources of the data aggregated by the Social Progress data are extensive and includes the following:

(a) Food and Agriculture Organization of the United Nations

(b) World Health Organization

(c) UN Inter-Agency Group for Child Mortality Estimation

(d) Institute for Health Metrics and Evaluation

(e) WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation

(f) Sustainable Energy for All

(g) World Economic Forum Global Competitiveness Report

(h) Institute for Health Metrics and Evaluation
(i) UN Office on Drugs and Crime
(j) UN Educational, Scientific, and Cultural Organization
(k) International Telecommunications Union
(l) Reporters Without Borders
(m) Institute for Health Metrics and Evaluation
(n) Yale Centre for Environmental Law & Policy and Columbia University Centre for International Earth Science Information Network Environmental Performance Index
(o) World Resources Institute
(p) Freedom House
(q) World Justice Project Rule of Law Index Heritage Foundation Gallup World Poll
(r) Pew Research Centre Government Restrictions Index
(s) OECD Gender, Institutions and Development Database
(t) United Nations Population Division
(u) Transparency International
(v) Gallup World Poll
(w) Fund for Peace Fragile States Index
(x) Pew Research Centre Social Hostilities Index

The research by Michael et al [44] [11] on the SPI, reflects this issue of meeting needs from the social and environmental point of view and it excludes all economic efforts such us Gross Domestic Product(GDP). The research removed all economic indicators because the economic indicators do not reflect the true condition of the inhabitants of the country. The SPI revealed that the high GDP does not mean that the basic needs of the country are being met [44].

A snapshot of a countries SPI helps the country to know which areas are lacking and where effort needs to be focused.

Therefore the SPI gives a social picture of the status of the country. Maslow's theory of needs also helps us to know which type of needs the country is seeking to meet.

The view of each country in the SPI reveals what the country is struggling to have, and it is important that the country tries to meet its basic needs before secondary the tertiary needs. Tackling basic needs first ensures to the benefit of the majority of people in the country.

Many developing countries are pressured to compete globally and to have certain facilities that they cannot sustain or do not need urgently.

2.7 World Bank Project Cycle

The World Bank project cycle consists [45] of 6 stages from conception to completion and it lasts for at least 4 years. The stages are namely (i) Identification, (ii) Preparation, (iii) Appraisal. (iv) Negotiation/Approval, (v) Implementation/Support and (vi) Completion/Evaluation.

Identification of the project must be in line with the country's priorities that have been produced by both the bank and country in the country partnership framework. The main priorities are to be in line with the bank's objectives for reducing poverty and enhancing the standards of living.

Also, the projects identified can be a form of infrastructure that is needed or geared towards other areas such as education, nutrition, health and fiscal management.

A review of the country partnership framework of Ghana[46] [47] reveals that the priorities of the strategy to reduce poverty and to bring economic growth to the people correlates with the world bank's objectives. But unfortunately, the effort to meet needs is not progressively from lower (survival higher priority needs) to higher. If the country's partnership framework can reflect the real needs of the people that will have an influence on the kind of solutions selected for the country. Ghana's Data for Sustainable Development Roadmap Forum [48] mainly strengthens the data collection avenues and to improve upon the monitoring of SDG efforts. In collaboration with the Global Partnership for Sustainable Development Data (GPSS), Ghana Statistical Service (GSS) and Ghana UN Group Data Unit. The other important measure they are also putting in place is also to use the several data and measures to inform decision making and resource allocation to help address the goal of the SDGs. The kind of projects that the world bank invest in has been grouped under the following taxonomy.

Projects Taxonomy[49]

Transport and Information and Communication Technology (ICT)

Social Protection and Labour

Macro Economics and Fiscal Management
Social, Urban, rural and Resilience
Finance Market
Water
Agriculture
Energy and Extractives
Education
Health Nutrition and population
Trade and competitiveness
Environment and natural resources
Poverty and Equity
Governance

2.8 Decision-Making model (AHP)

The analytic hierarchy process (AHP) is a technique developed by Thomas Saaty [50] [51] to resolve complex decision making by breaking the complex problems into a hierarchy. This technique is based on mathematics and psychology. AHP is normally used in group decision making and in fields such as government, business, industry, and education. The AHP is also a heuristic algorithm [48]. The results of AHP does not give the final correct solution for a problem but it gives the approximate solutions based on several criteria to assist in the decision. It is very useful for group decision making and for both qualitative and quantitative decision making [52], [53].

Some of the drawbacks of the AHP is the complexity when there is an increase in the number of criteria, but this draw is reduced immensely when the process is automated as the case of this thesis. To ensure that decisions are accurate enough, AHP has a Consistency Ratio (cr) check. For decisions to be consistent the cr must be less than 0.1 ($cr =< 0.1$). the closer cr is to 0, the more accurate or consistent the decision is. For one to arrive at a consistent decision it involves a lot of iterations, changing the values of the criteria importance until a consistent decision arrives. The iterations are subjective, the user of the model adjust the criteria importance value at his whim.
It does not also give room to add or remove criteria to the list after the final decision has been made. It will require restarting the entire process because each criterion can affect the

outcome greatly. To address we came up with the relative importance and distance calculator formulas (see section 3.4.5) for details.
According to Rosaria and Roberto[50], AHP as a tool is useful for breaking complex decisions to pairwise comparisons using expert opinions judgments to set priority. To use AHP, the goal had to be defined and criteria based on which alternatives will be compared defined.
AHP was selected over the other decision-making models because the process and usage of the problem we are addressing with this thesis could easily be broken down to a hierarchy of decision-making steps which what AHP provides. Also, once the pairwise comparisons were going to be automated the complex calculations were eliminated.

2.9 Case Study for projects in Ghana

We selected Ghana as the case for this thesis and we needed to review some projects that were run in Ghana to bring development. These following projects were selected from mainly the world bank and other non-governmental global organizations. The theme from the following projects will be used to evaluate our proposed system in the later chapter.

2.9.1 Gender Parity Education in Ghana

The Education For all Project (EFA) experienced some shortfalls in the Gender Parity Index (GPI) in the Junior High school level [54]. The participation of girls in education as compared to boys was lower even though there have been several efforts to get them in school. About 32 districts mostly in the northern regions received a GPI of less than 0.8. The Northern region of Ghana is one of the poorest regions in Ghana, one of the solutions tabled was to make the school more girl-friendly so that the girls can come to the school [54]. That was definitely not the right solution.[54] Meanwhile, evidence from the World Food Program showed a different outlook on the problem of gender disparity in education that confronted the northern part of Ghana. They introduced a program captioned “Take-Home Ration”. This program was introduced to encourage girls to come to school.
Girls who attended school for at least 15 days of the month were given a portion of rice, maize beans, oil, and salt to be taken home. To serve as a motivation for the girl’s family to allow the girl to go to school in the expectation that at the end of the months she will

bring food home. It also encourages the girl to concentrate in class knowing that there will be food at home.[55]

2.9.2 Republic of Ghana E-Ghana Project

The E-Ghana Project as evaluated and reported by the Independent Evaluation Group[56]. The overall cost of the project was US$113.73 million. The International Development Association delivered (IDA) US$84.70 million and European Union (EU) and United Kingdom Department for International Development (DFID) who were partners also contributed US$27.32 million and the rest were from other donors. There were two main objectives of the project (i) to create the enabling environment for Information technology-enabled services and to increase public-private partnership (PPP) (ii) to digitize the public services to enable the government to leverage on the efficiency and transparency e-services offers.

One of the public sectors that benefited from the project was the Ghana Revenue Authority. Their process automation was successful and added 400,000 taxpayers. The tax collected increased by Total Revenue Integrated Processing System (TRIPS) appreciated from 1 % in 2012 to 61.7% in 2016. Also, a monetary management System called Ghana Integrated Financial Management Information System (GIFMIS) was also developed to handle monetary management, accountability, and transparency. The Project was successful however the Public Expenditure Financial Accountability Assessment indicators revealed that there was no meaningful change in transparency.

The other e-services were (i) certified true copy of birth certificate, (ii) online marriage registration, (iii) company registration, (iv) criminal background check, (v) fingerprint analysis, (vi) background check for visa and job applications, and (vi) marriage licenses. This project's sustainability is highly not guaranteed because even though the e-services has been implemented only 10% of the people of Ghana use the e-services because of lack of internet penetration, low connectivity and lack of education.

For the services to run successfully a Wide Area Network was built for all e-services. But this project may collapse because of lack of maintenance funding allocation and institutional support as stated in the report by the Independent Evaluation Development group of the world bank.

Even though e-services are important, Ghana has higher priorities like access to clean water & sanitation and shelter which only 43% of the populations can access. Apart from that internet penetration and quality of connection which is most important for an e-services project is not adequate to sustain this project. Therefore, before the Bank of Ghana or the Government of Ghana select a project, the priority and the infrastructure available to ensure that the project will be successful and sustainable should be considered.

2.9.3 Second Urban Environmental Sanitation Project and Small Towns Water Supply and Sanitation Project, Second Phase of APL Project.

This project [57] was approved by the world bank on July 27, 2004, and it was closed on April 30, 2010, after a one-year extension. The cost of the project was US$51 million. This project targeted six rural regions of Ghana and the objective was to increase access to sustainable water supply and sanitation**.** The main objectives of the project were providing access to potable drinking water to about six small towns in six regions of the borrower**.** The outcome of the project when it was evaluated by IEG was moderately satisfactory. The project was very useful and important to the people; therefore, the project was readily accepted with much enthusiasm. And it even resulted in an overbooking because it was meant for 55000 people but in the end, an additional 12,000 people benefitted from the project.

In summary, this chapter elaborated on the domain of the research and reviewed the related works and approaches of DSS for sustainable development. After diving into needs selection and selection approaches, the main body of knowledge or theories in this thesis was explained in the detail. They are Abraham Maslow's hierarchy of needs, SPI and AHP. The world bank's process for selecting and implementing projects in Ghana was also reviewed and finally, the main case studies for testing and evaluating the system to be developed was given.
In the next section, the design and implementation of the DSS proposed will be explained in detail.

3 MEEDS

In this chapter our proposed solution to the identified problem in *chapter 1 section 1.2*. As has been established in earlier chapters, the process of making sustainable decisions is complex. Any technological solution developed to provide the needed assistance in making such decisions must be comprehensive. It should abstract nuisances that complicate the decision process and provide a very simple intuitive user interface that makes it easy for the decision maker to use. For our proposed solution to meet that requirement, ***MEEDS*** was designed as a web application built on a service-oriented architecture. Prepopulated in the database of the application is every country's *SPI scores* and a predesigned *AHP pairwise matrix* form. This makes it easy for the decisions makers to enter projects and select which needs the projects impacts and *MEEDS* perform all the complex decision process and produces the most useful for the country.
The service-oriented architecture will it possible in the future for other developers and researches plug into *MEEDS* to make use of its needs ranking services.

3.1 System Requirements

For the solution to successfully assist decision makers to make sustainable decisions in terms of selecting the most useful project for a given community or country we defined these requirements. These will ensure that the system performs flawlessly.

Usability / Interactive*:* Users of the MEEDS will be varied ranging from the technology savvy to the uninitiated into technology. Hence, MEEDS must be designed to be very interactive and easier to use. Application responsiveness should highly consider so that users are not restricted to the kind of device which they use.

Scalability*:* The data available on the UN member countries which will be used are immense. Hence the design of MEEDS is based on a paradigm of system design that allows for easy plug and plays by third parties to add to the primary SPI data already in the system. It should also allow for third parties to make use of its need's ranking/prioritization service.

***Availability**:* MEEDS, when deployed, must be constantly accessible to users and developers who would like to plug into its services. The proposed solution should be designed in such a way that it is always accessible anywhere.

Real-Time Performance: The system should produce results in real time, to shorten the decision-making duration which will improve the experience the user will have with the system.

Accuracy: The system should be able to provide accurate results on needs ranking and provide accurate choice with regards to the selection of most useful projects. The proposed decision should have a ***consistency ratio*** of **< *0.1***.

3.2 Main Features of MEEDs

For the proposed solution to meet the requirements defined above, it should contain these core features. These cover the major services that the user must derive from the proposed solution.

Project Ranking Service**:* this is the ability to rank sustainable projects based on the needs for a given country using AHP decision-making model. AHP uses two inputs the criteria and alternatives, the criteria used in ***MEEDS are the prioritized needs of the country. The alternatives are the sustainable projects being compared for usefulness.

***Project Success Service**:* the project success service is like the Project ranking service. The difference is that we use the infrastructural availability of a country as the criteria input for AHP. This is so because the success of sustainable projects depends on the available infrastructure in the implementation country.

Needs Prioritization Service: one important feature of the application is to be able to rank/prioritized needs of the country. This prioritizes a country's needs using Maslow's hierarchy of need and the country's SPI scores. The goal of this service is to allow users to generate a list of prioritized needs of a country by selecting the country from a drop-down of countries.

3.3 System Design

MEEDs is designed using a service-oriented architecture, the ensures that the various features are decoupled and encapsulated of into various services [58]. Each service is further broken into microservices, this will ensure scalability and maintenance as the further developments evolve around the solution. The DSS we propose will change frequently to accommodate new scores from the SPI. The proposed solution would have to scale to cover every UN member country. To achieve these changes and growth there need to be an architecture that allows for agility in the sense that part of the system could be easily isolated, and changes made to it without affecting the other components.
The figure below is a detail design proposal of ***MEEDS***

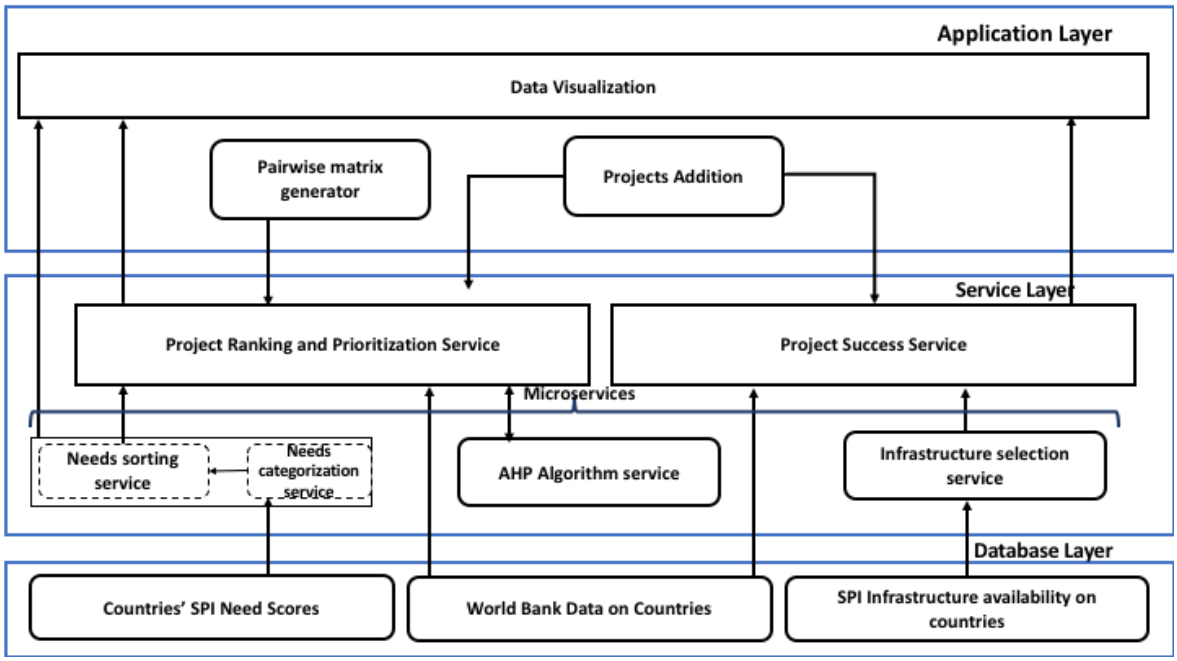


Figure 11: MEEDS Detail System Architecture

3.3.1 Database layer

The *database layer* is used to store open data that will be used to make decisions. The major data sources are SPI scores for countries and world bank data on countries. The SPI score will provide scores for the needs of every country and the infrastructure that are available for successful implementation of projects. In this layer will be a data access layer that will provide read and write access to the data. The data access layer sets the basis for

the service layer which will implement web services to expose the resources stored in the databases.

3.3.2 Service Layer

The Service layer is used for decoupling the various functionalities of the application into components. Each component handling one piece of the complex system. It is made up of two major services (the project ranking service and the project success service) which are the major features of ***MEEDS.*** These services run on top of three microservices which perform core functions.

Project Ranking and Prioritization Service

This service is responsible for ranking projects and prioritizing based on the needs of the country or community. It relies on three micro-services to accomplish this task.
The ***Needs categorization service*** willl implement web services that access the needs of a country stored in the database, then categorizes the needs under two groups – **Foundations of Wellbeing** and **Basic Human Needs.**

The categorized needs are then pushed to the ***Needs sorting service*** which is responsible for sorting the needs based on their raw SPI score, it uses a sorting algorithm referred to as *Selection sort algorithm* based on the formula below. Needs are ranked respective to other needs in the same category. For instance, needs under *Basic Human Needs* are ranked separately from needs under *Foundations of Wellbeing.*

$$(n-1) + (n-2) + \ldots + 1 = \sum_{i-1}^{n-1} i = \sum_{1-1}^{n-1} \binom{i}{1}$$

The final microservice is the *AHP algorithm service,* which is responsible for generating the actual project ranking based on the prioritized needs and the projects entered by the user. This service handles the complex activity of decision making by breaking complex decisions to pairwise comparisons using expert opinions to set priority. Three major activities happen in this service, **firstly** a pairwise comparison of ranked needs from the *Needs sorting service* happens. To be able to compute the weights for the different criteria, a pairwise comparison matrix A was created. The matrix is $m \times m$ real matrix where m

is the number of criteria considered. Every entry a_{jk} of the matrix A is a representation of the importance of the j_{th} criterion relative to the k_{th} criterion. When $a_{jk>1}$ then j_{th} criterion is more important than the k_{th} criterion, while if $a_{jk<1}$ then the j_{th} criterion is less important than the k_{th} criterion. If they are the same, then $a_{jk=1}$. Once the matrix A is built, A_{norm} which is the normalized pairwise will be derived from A. $A_{norm} = a_{jk} / \sum_{i=1}^{m} a_{kj}$. Then the criteria weight vector $\boldsymbol{w}$ will be built by averaging the entries on each row ofA_{norm}. $W_j = \sum_{i=1}^{m} a_{jk} / m$ (where m is the m-dimensional column vector).

Secondly, alternative pairwise of projects also happens here:

a) The matrix of alternatives is an $\boldsymbol{n} \times \boldsymbol{m}$ real matrix $\boldsymbol{S}$. Every entry $\boldsymbol{s_{ij}}$ of $\boldsymbol{S}$ is a representation of the score of the alternative with respect to the criterion.

b) To do this, a pairwise comparison matrix $\boldsymbol{B^{(j)}}$ is first built for each of the m criteria, $\boldsymbol{j = 1, \ldots, m}$. the matrix $\boldsymbol{B^{(j)}}$ is an $\boldsymbol{n} \times \boldsymbol{n}$ real matrix, where n is the number of alternatives available.

c) Each $\boldsymbol{b_{ih}}^{(j)}$ of matrix $\boldsymbol{B^{(j)}}$ represents the evaluation of the i^{th} alternative compared to the h^{th} alternative with respect to the j^{th} criterion.

d) Where $\boldsymbol{b_{ih}}^{(j)} > 1$, i^{th} alternative is better than h^{th} alternative, while if $\boldsymbol{b_{ih}}^{(j)} < 1$, then the i^{th} alternative is worse than the h^{th} alternative. Where they are equivalent the entry is 1.

Next, each pairwise matrix is normalized and the score vector calculated as in matrix A. The vector $s^{(j)}$ contains the scores of the evaluated options with respect to the j^{th} criterion [$s^{(i)}$ ... s^{m}].

The table below explains the weights used to represent the impact of the project on each of the needs against all the other projects. Below is the interpretation of each need.

Using the weight vector w and the score matrix S, a vector of v score is determined using the formula $v = S \times w$.

The global score is rearranged in decreasing order to provide the alternatives ranking. That is the most useful alternative (project) will be the alternative with the highest score.

Finally, the consistency of the decision is determined. The accuracy of decisions is verified by calculating the Consistency Index (*CI*) [59], this calculation is performed for each matrix to ensure consistency in the evaluations.

CI was obtained by first computing the scalar x as the average of the elements of the vector whose j^{th} element is the j^{th} element of the vector $A \times w$ to the corresponding element of the vector w.

$$\mathrm{CI} = \mathrm{x} - \mathrm{m} / \mathrm{m} - 1$$

A perfectly consistent decision maker should always obtain $\mathrm{CI} = 0$, when $\mathrm{CI} > 0.10$, the decision index is inconsistent. The process of improving the consistency ratio involves a lot of iterations, changing the values of the criteria importance until a consistent decision arrives. In this solution, consistency ratio check is simplified by using the ***Distance Calculator(d)*** and ***Relative Importance (rm).*** $\boldsymbol{d_{kj}}$ is the difference between k_{th} and j_{th} position on the needs ranking of two needs $d_{jk} = k_{th} - j_{th}$. $\boldsymbol{rm_{jk}}$ relative importance of the two given criteria is determined based on the formula

(0.1) $rm_{jk} = d_{jk} + 1$

(0.2) Where $d_{jk} = 0,\ a_{jk} = 1$

(1.3) Where d_{jk} is < 0, then d_{jk} is negated and the rm_{jk} inversed.

For instance, in the table below the d_{jk} between Water & Sanitation and Shelter would be calculated as follows

d = 2 -1 = 1

rm = 1 + 1 = 2.

Rm which is *2* will then be used to populate the *needs pairwise matrix.*

Criteria	*SPI Score*	*Rank*
Water and Sanitation	43	1
Shelter	43	2
Personal Safety	69	3
Nutrition and Basic Medical Care	86	4
Health and Wellness	57	5
Environmental Quality	62	6

Access to Information and Communications	72	7
Access to Basic Knowledge	86	8

Project Success Service

This service is responsible for determining if a project will be successful in each country based on the infrastructure available in that country. It runs on the ***infrastructure selection service,*** this microservice is responsible for selecting from the database the infrastructure available for a given country. The *project success service* is a RESTful service that pushes the results via HTTP request to the visualization layer.

3.3.3 Application Layer

The *Application Layer* is the part of the system that the user interacts with directly. It performs two major activities firstly, providing a data collection component and secondly, the data visualization components. The ***project addition*** module will be used by users to enter projects to be compared and ranked. Once projects are entered, then the ***pairwise matrix generator*** will generator a matrix for the user to populate. In populating the matrix, the user based on his/her expert opinion assigns weights to each project relative to the each about each need. Under each need, projects are assigned weights to determine which of them impacts the need more. The table below shows the interpretation of the weights.

3.3.4 Data visualization layer

The other component in this layer, the *Data Visualization* component is where a summary of the results of the decision are displayed to the user in graphs and other visualization formats. The summarized information will include other country-specific data and give a cultural synopsis of the country. The visualization will be delivered via a responsive web application, making it possible to view the results via mobile phones and other small devices.

4 IMPLEMENTATION AND DEPLOYMENT

To validate the proposed solution, we developed a prototype of the system. The system was implemented, deployed and tested with real-world test cases. This chapter presents the details of the MEEDS prototype implementation and deployment. The design of the system is such that it makes decision making easy by providing users an interface for collecting information to process for decision making and provide a visualization of the results of the decision-making process.

4.1 Prototype Design

The figure below is a design of MEEDS prototype and the describes the flow of data. As discussed in the chapter it is a based on an SOA to allow for a loosely coupled system. It contains various components such as User interface, database server, web services and the visualization components. The web services is the core of the application where the algorithms for data processing resides.

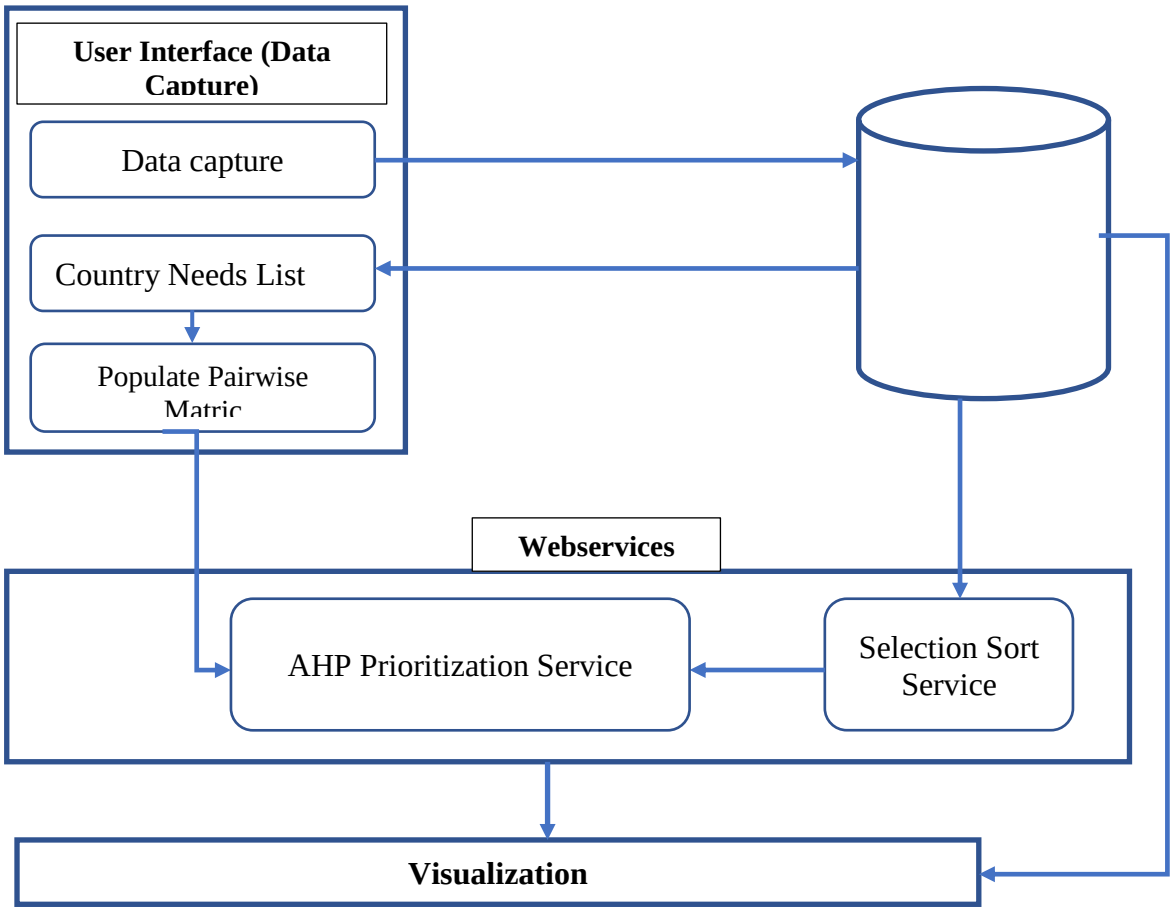


Figure 12: MEEDS Prototype

Web services this is the core of the system, it is made up of several microservices each responsible for a specific algorithm that processes the data. The web services are designed as RESTful services that receive and send a request via HTTP protocol. Two key microservices are the *AHP prioritization service,* which is both a client sending requests to other services and a server serving resources to other services. It contains the *AHP prioritization algorithm* which is responsible for handling the actual decision-making process.
The other important service *Selection sort service* which is responsible for selecting the country-specific needs from the database and sorting them using the selection sort algorithm. Web services [60] provides "sustainable business value, help increased agility and cost-effectiveness"

User Interface this is the part of the application that the user interacts with directly. It has a subcomponent for collecting information on the projects from the user. *Data capture* components provide the user with a form to create multiple projects to be compared. In the proposed system, the number of projects to be compared is limited to 4. Once the number of projects and the country is created a corresponding pairwise matrix is presented to the user. The pairwise matrix is based on the needs of the country which are retrieved from ***Database.*** The *database* is prepopulated using SPI and world data on all OECD countries. The user completes the matrix by comparing the importance of each need with regards to a given project. The completed pairwise matrix is posted to the *AHP algorithm service* for processing.
The results of the decision-making process sent via an HTTP request to the ***visualization*** model. The visualization enables the user to see not just the results of the decision but also country-specific information necessary for the success of the project.

4.2 Implementation details

The prototype implementation was performed as follows. Firstly, we defined what needs must be considered in making a sustainable decision and based on that the database is populated with the needs of the country. Secondly, the algorithm service for performing the needs prioritization and the project ranking is developed. Finally, the web interface users use to interact with the web services is developed.

4.2.1 Defining the taxonomy and database population

As discussed earlier, making decisions sustainable decisions means that the decisions impact directly the needs of the people who are beneficiaries of the decision. The question is, which of the needs are important for consideration? Our assumption is that there exist a set of needs that are necessary for consideration. We had to validate the process of standardizing needs criteria for project selection, several meetings were held with Associate Professor Karan Mitra (Ph.D.), Associate Professor Saguna Saguna (Ph.D.) and Professor Jari Porras. Currently, there does not exist a taxonomy considered as standard needs to consider in making sustainable decisions.

In order, to select the needs for creating the taxonomy, three criteria needed to be fulfilled: *(1)* the need must be accepted with the right choice of measure – should be measurable, *(II)* must be accessible publicly for transparency and *(III)* the need must be obtainable by all countries.

The SPI indicators were selected because the criteria for selecting their needs fulfills all of the above. The table below is a list of the selected needs - this will become the standard taxonomy for making sustainable decisions.

Dimensions	Basic Human Needs	Foundation of Wellbeing
Components	Nutrition and Basic Medical Care	Access to Basic Knowledge
	Water and Sanitation	Access to Information and Communications
	Shelter	Health and Wellness
	Personal Safety	Environmental Quality

Figure 13: Illustration of selected standard needs

The database server has built on top of a data wrapper layer that communicating with the data capture interface. The SPI data on all UN member countries were extracted into a *CSV* file with the help of the wrapper used to populate the *database* which runs on the *mongo dB* database engine. *Mongo dB* is a dynamic database which provides a greater benefit to data

analytics and scalability. *MongoDB* stores items in a JSON format and allow flexibility in reading and writing files.[61]

4.2.2 The decision-making process

The core engine of the proposed solution is the *AHP algorithm service* [62]. Successful accurate decisions are reliant on the performance of this service. This service was developed using the JavaScript engine of chrome v8 and runs on the NodeJS. It has proven to be very efficient and very fast in rendering service because it uses non-blocking I/O and event-driven model. Mongoose was used to model the object in Nodejs.[63]

The AHP algorithm service was developed to perform the actual decision making in selecting the most useful project. When performing this task four activities occur: *performs alternatives pairwise comparison, requests prioritized needs, criteria pairwise comparison,* and finally *performs a consistency check.* The theoretical operations of AHP are detailed in chapter 2 and 3. The decision hierarchy of the prototype using four projects is depicted in the diagram below.

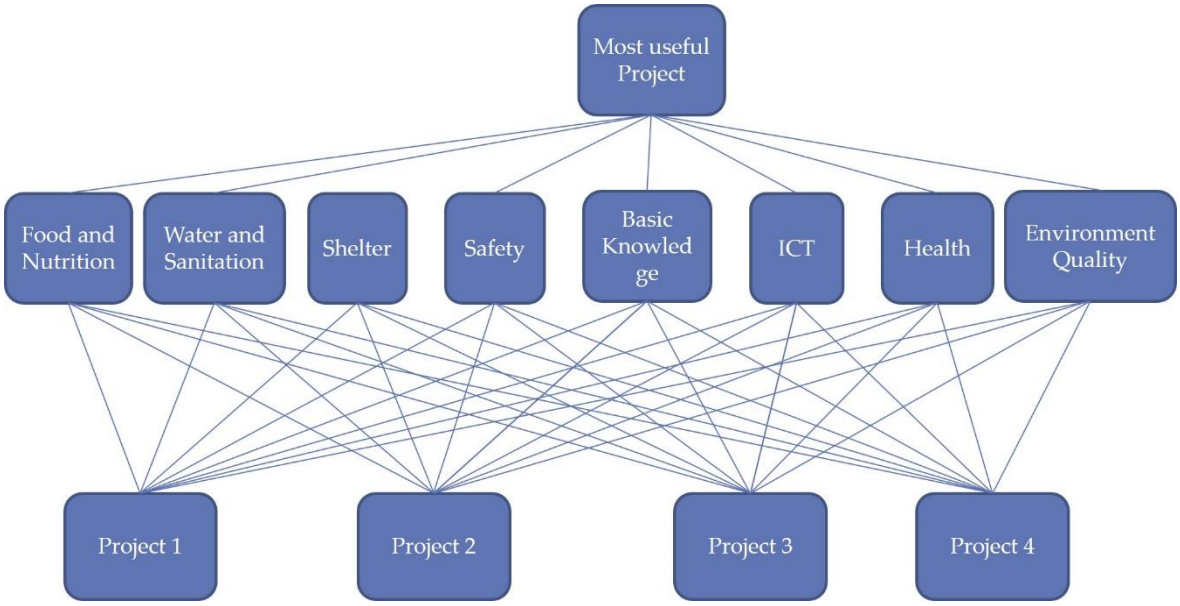


Figure 14: Decision Hierarchy involving 4 projects

The purpose of ***alternatives(projects) pairwise comparison*** activity is to assign weights to the needs. This is done at the code level by creating an *n* x *n* matrix of the projects, where *n* is the number of projects to be compared. The matrix is populated using weights shown in

the table below. The weight is a numerical representation of the relative impact the project has on the need under consideration. This process is repeated for every need.

Weight	*Meaning to water and sanitation, shelter, nutrition and health and other projects*
1	Equally impacted by the project
2	Equally to moderately impacted by the project
3	Moderately impacted by the project
5	Strongly impacted by the project
7	Very Strongly impacted by the project
9	Extremely impacted by the project

The ***criteria pairwise comparison*** activity performs generates an *8x8* matrix of the needs. The activity compares each project against each other. The weighs assigned are based on the ranking of the needs from the ranking service. The process of selecting the most useful projects, the needs the highly ranked needs are given high consideration. The weights used to populate the matrix are shown in the table above. The table below is an excel validation version of the pairwise comparison matrix simplifies by [64] Barnard.

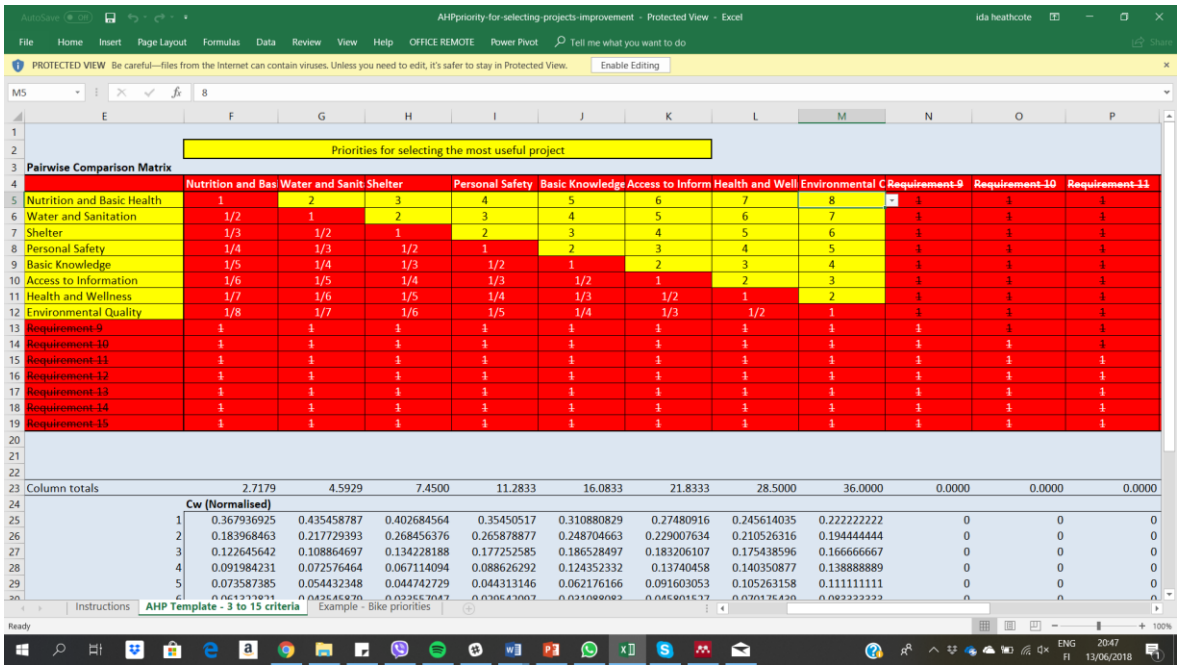


Figure 16: Pairwise matrix of Criteria (Needs)

The ***request prioritized needs*** activity makes an HTTP request to needs ranking service for a ranked/prioritized need of a given country. It is this prioritized need that is used by the *criteria pairwise comparison* activity to populate the *8*x*8* needs a matrix.

Figure 17: Unsorted list of needs(upper row) verses sorted list o needs(lower row)

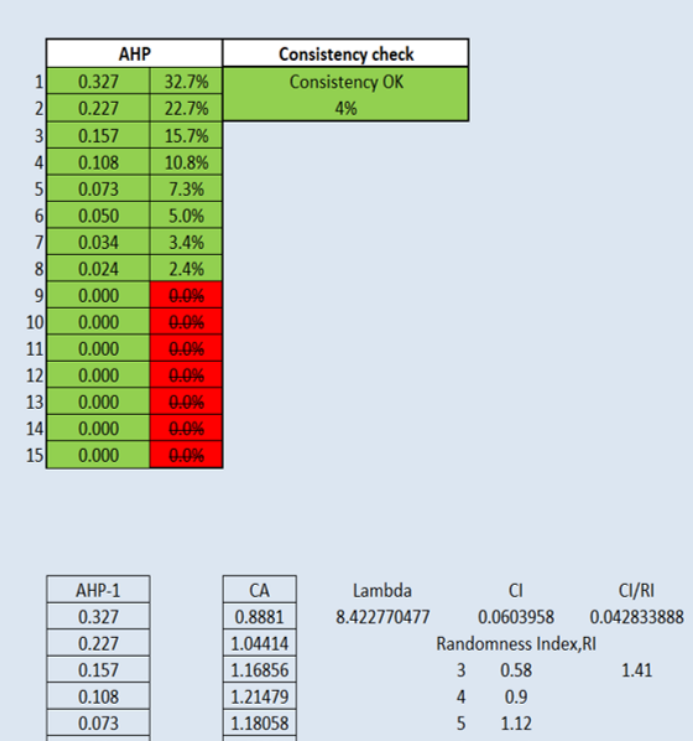
The final activity of the service is to *perform a consistency check.* A major requirement for this prototype is that the consistency index cannot be greater than 10%. This activity is responsible for ensuring that. To improve the *consistency ration (cr),* a distance calculator and relative importance equation were proposed to automate the population of the criteria comparison matrix.

Distance Calculator. $d_{jk} = k^{th} - j^{th}$

Relative Importance. $rm_{jk} = d_{jk} + 1$

Users of AHP usually manually change the weights of the comparison matrix until a decent *cr* is attained, making the process tedious. Using the above equations simplifies the process.

When this equation was applied there was a significant improvement in the consistency ratio. Below show screenshots of the improved consistency ratio. The consistency is 0.04(4%).



	AHP		Consistency check
1	0.327	32.7%	Consistency OK
2	0.227	22.7%	4%
3	0.157	15.7%	
4	0.108	10.8%	
5	0.073	7.3%	
6	0.050	5.0%	
7	0.034	3.4%	
8	0.024	2.4%	
9	0.000	0.0%	
10	0.000	0.0%	
11	0.000	0.0%	
12	0.000	0.0%	
13	0.000	0.0%	
14	0.000	0.0%	
15	0.000	0.0%	

AHP-1	CA	Lambda	CI	CI/RI
0.327	0.8881	8.422770477	0.0603958	0.042833888
0.227	1.04414		Randomness Index,RI	
0.157	1.16856		3 0.58	1.41
0.108	1.21479		4 0.9	
0.073	1.18058		5 1.12	

Figure 18: Improved Consistency Ratio

4.3 Deployment

To validate the prototype, the application was deployed and hosted on Amazon elastic beanstalk for seamless hosting and easy and abstract management of the infrastructure. Part of the deployment includes populating the database with the SPI data on all countries. Real world past projects carried out by the world bank in Ghana was used to validate the system and the result compared with the case studies done on those projects. The database was deployed to a cloud-based database service cloud9. Deploying the entire solution in the cloud ensures the availability of the system. It also abstracts the managing of the infrastructure, so the focus can be put on improving the solution.

4.4 Web application design (user interface and results visualization)

In this thesis, we argue that projects that are meant to contribute to SDG and improve the living conditions largely fail because they do not put the needs of the beneficiary at the center of the project selection and planning. The assumption, that sustainable projects that were successfully implemented in one country will be successful in another country does not hold. Even though they may belong to the same social economic classification (developing, lower middle income, middle income and developed). Current approaches to

sustainable decision making are aimed towards economic sustainable and social sustainability paradigms with little focus on the social sustainability. However, none of the studies related work uses a decision-making model that uses the needs of a given country as the criteria for making sustainable decisions.

The thesis addresses this research gap, we propose an encompassing solution that places the needs of a country at the center of decision making. By making decisions centered around needs beneficiaries are put at the center of the decision. In this proposed approach, all the needs that fall under *Basic Human Needs* and *Foundations of Wellbeing* which are the survival needs are scored, prioritized and given to the user to make very informed decisions, as well as the AHP decision-making model simplifies the decision-making process. We argue that when decision-makers have access to a system that simplifies the decision-making process based on a prioritized needs list of a country, they will be empowered to make sustainable decisions since the process is now simplified and straightforward.

4.4.1 User interface

There is so much disparate information regarding the social economic progress of countries. To make sustainable decisions, one must sift through them to choose which data to rely on for decision making, otherwise, researchers would have to employed to carry out feasibility studies. This thesis proposes the use of SPI (detail in chapter 2), this narrows the available information. To abstract the complexities of using the data, every country SPI scores are stored in the application during deployment. When users interact with the system, they are presented with already populated data.

The user interface design for collecting data is straightforward, simple and easy to use. The approach is to motivate users to use the application. Different designs were created and tested with colleagues and two people at the position of decision making to select the most intuitive design. Responsiveness was also inculcated in the design so that users are not restricted to only one device when interacting with the application. Both small and large devices can access the application without diminishing the user experience. The target user

group are late technology adopters. Therefore, it is important to present them an easier to understand and friendly to use interface.

Figure 18 represents the page for selecting a country, projects and a pairwise matrix of the desktop.

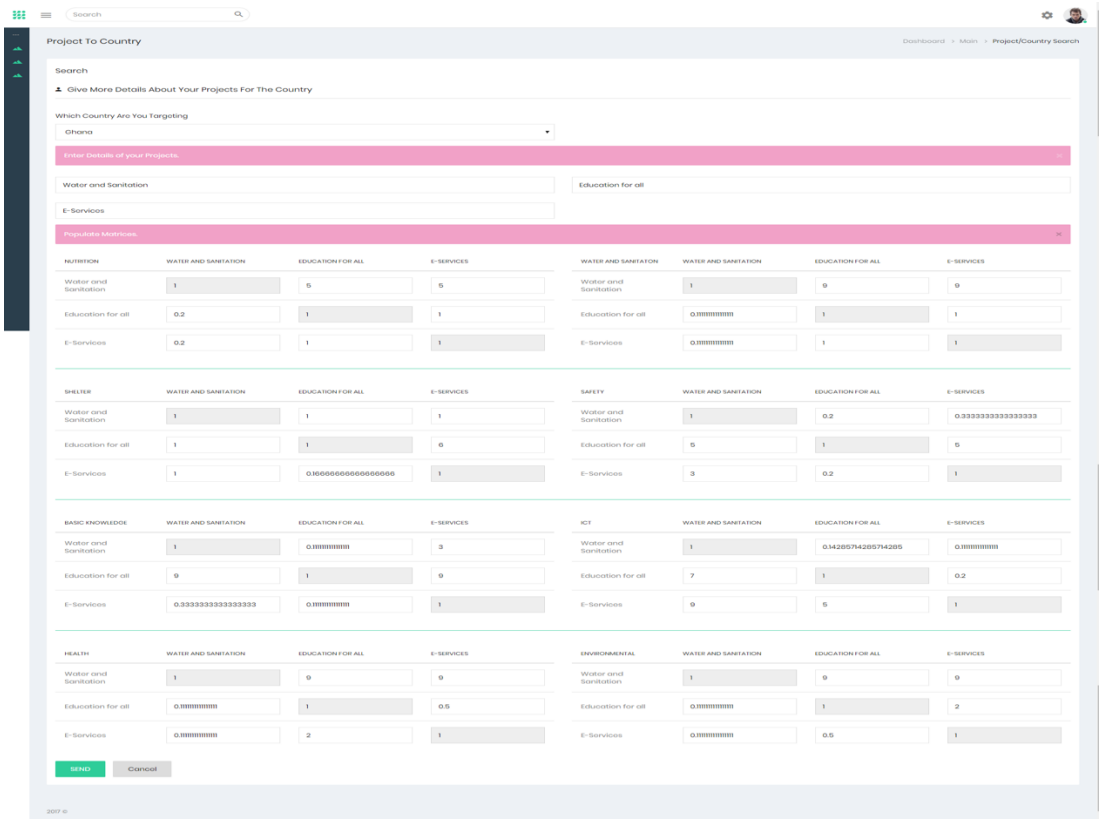


Figure 19: Project addition, country selection and pairwise matrix form (desktop view)

Figure 31 and 32 represents the page for selecting a country, projects and pairwise matrix of a mobile app

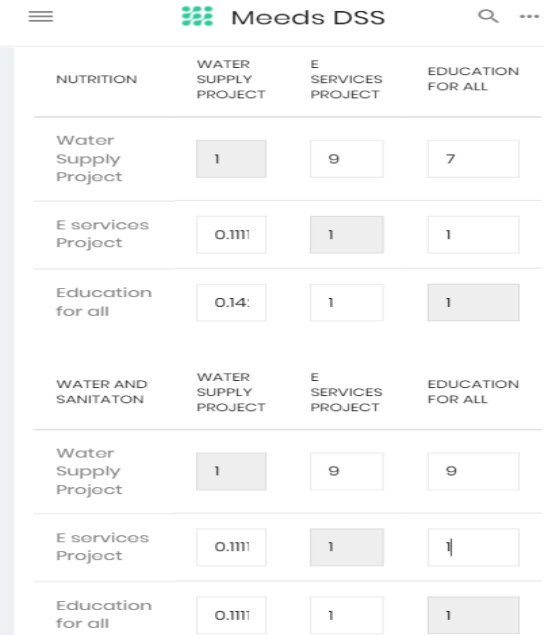


Figure 20: Mobile version of matrix population

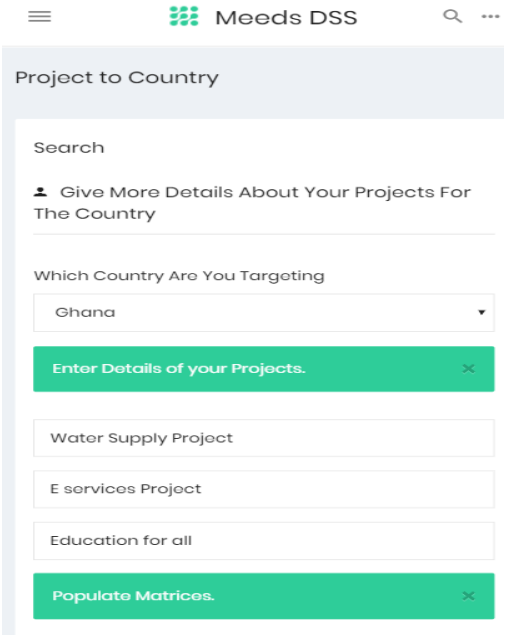


Figure 20: Mobile version of results

4.4.2 Data visualization

From the decision-making process in the *AHP algorithm service*, we had results of the most useful projects for the selected country. The country name taken from data capture is used to fetch the needs of the country, the needs and the project added in the data capture are used generate the pairwise matrix. The weights used in populating the matrix are sent to the *AHP algorithm service* for decision making. The results it churns out is a ranking of the projects in order of usefulness, the *consistency index (ci)* and country-specific information like cultural information and gender parity information.
This information needed to be presented to the user in a readable and meaningful way. Various data visualization approaches were studied to determine the best possible way to present the information.

We propose an integrated dashboard that will at glance present to the user all the information returned because of the decision process. *Figure 33* demonstrates an example dashboard

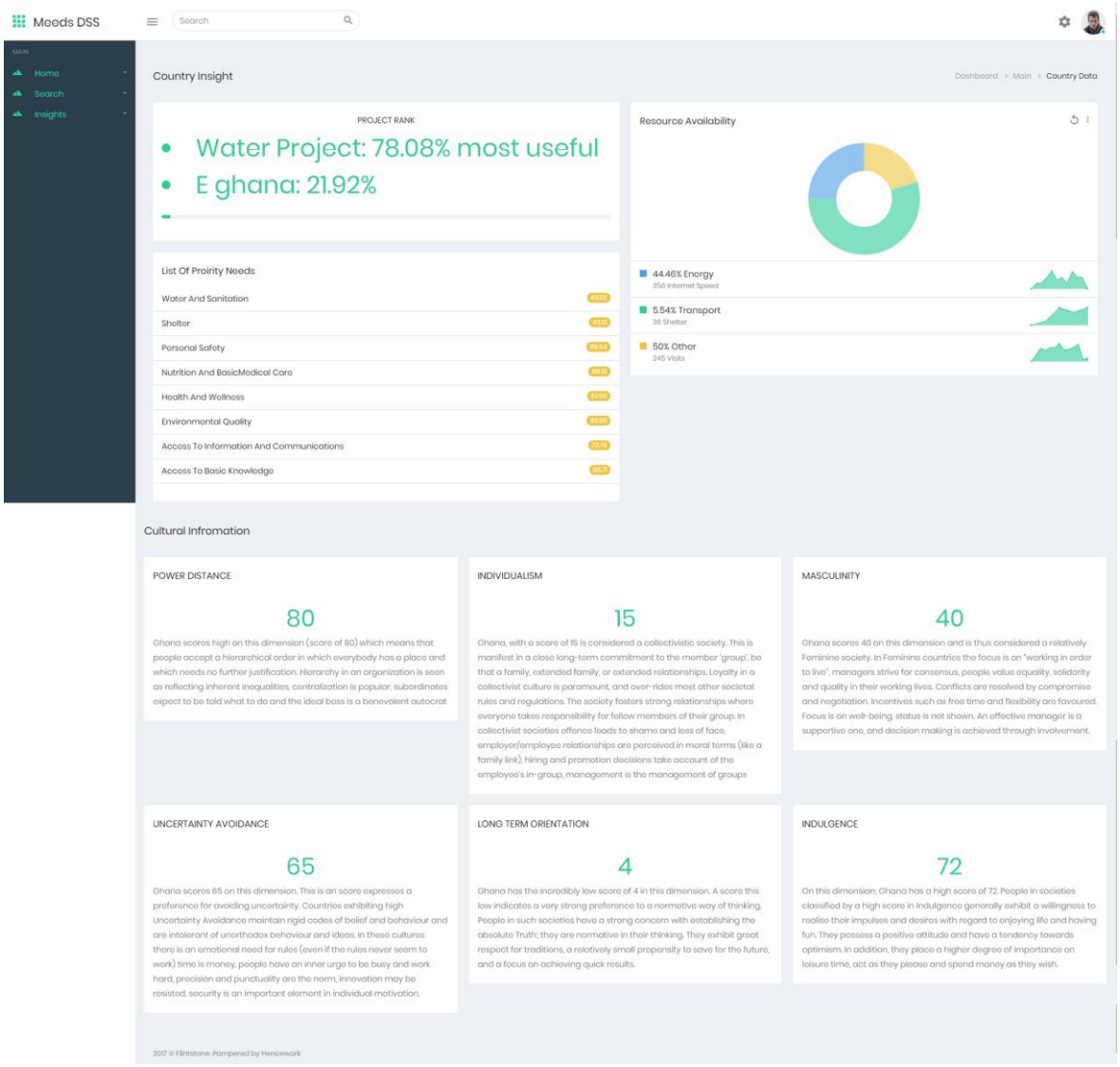


Figure 21 – Visualization of the decision-making process (Ghana example)

At the top right corner is the result of the project ranking, the projects are displayed with their score of useful. It is displayed in ascending order. On the dashboard is also displayed the cultural information on the country and the resources available in that country. Besides the project ranking, the cultural information provides added insight into the cultural leaning of the country, the culture and values system of the country also has an impact on the success of the project.

Project ranking can also be viewed in a bar graph which provides a pictorial comparison of all projects.

Figure 22 – Bar graph of ranked projects

On the dashboard is displayed the needs ranked and displayed in descending order.

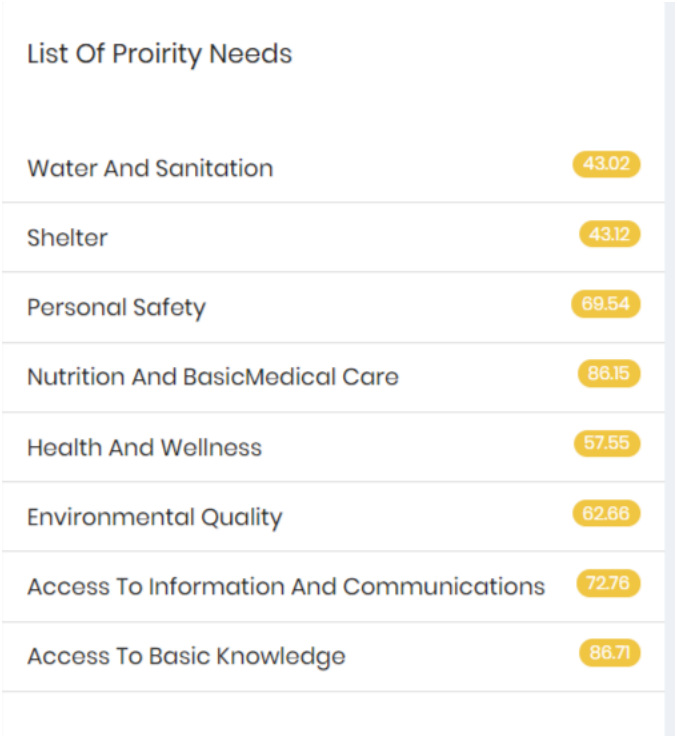


Figure 23 – List of prioritized needs in descending order

A closer look at the figure above shows that although Nutrition and Basic Medical Care have a score of 86.15 it is ranked ahead of Health and Wellness which has a score of 57.56. this is because they belong to different categories. The former is under Basic Human Needs while the latter is under foundations of well-being, needs under Basic Human Needs have higher priority over needs under foundations of well-being.

Google chart API, express, bootstrap, and jQuery were used to implement the visualization. Google charts provide APIs for creating simple to complex graphs. Bootstrap provides tools for implementing the dashboard. jQuery and express are used to make the HTTP request to the web services without having to refresh the current page. Using the google charts which are JavaScript classes provide cross-compatibility and cross-platform portability.

5 RESULTS AND DISCUSSION

This chapter deals with the results of the test performed in this thesis using real data from 3 case studies using SPI scores from Ghana, Nigeria, and Mexico. The various case studies and test cases will be discussed. The results of the projects stated in the case studies will be compared with the results from our study. Also, the sustainable impact of the proposed system is analyzed and discussed.

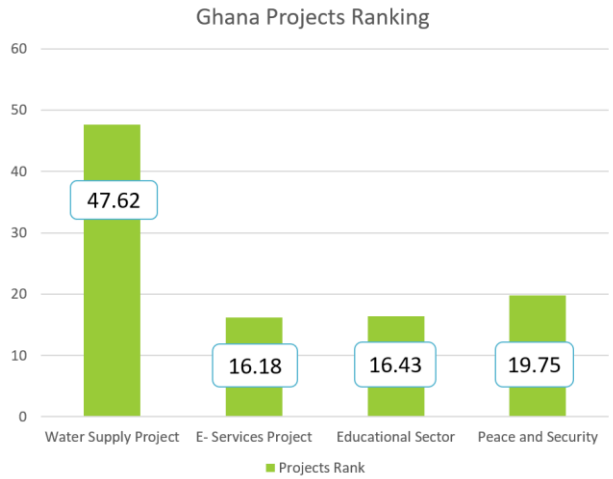
5.1 Case study test results

To determine whether the proposed system will be effective and efficient to assist decision makers to make sustainable decisions. That enables them to to select from several projects the one that is useful for the country based on their needs, we conducted an experiment using the prototype. The experiment was conducted using three projects that were carried out in Ghana. The goal was to (i) determine if *MEEDS* were used to determine if the project was useful for Ghana and (ii) a controlled experiment was carried with Nigeria and Mexico using the same test data.

5.1.1 Ghana in context

In sections 2.9.1, 2.92, and 2.93 details of projects chosen as test data is given. They were implemented to meet the unique needs of the people of Ghana. Case studies conducted after the project showed that some of the projects were not so useful based on the country's needs. As stated earlier useful projects meet the needs of the people. Hence project that is not targeted towards the most pressing needs of the people should be ranked very low. Four projects were created and added to MEED the pairwise comparison matrix was then built from the *MEED*'s UI using values based on the importance of the alternatives to each need.

The result of the decision of comparing the four projects for Ghana is shown in Figure 33 below. On the right of the graph is the needs ranking of Ghana in order of priority from high to low. The graph is a bar graph of the result of the decision.



Ghana Needs Ranking

Criteria	SPI Score	Rank
Water and Sanitation	43.02	1
Shelter	43.12	2
Personal Safety	69.54	3
Nutrition and Basic Medical Care	86.15	4
Health and Wellness	57.55	5
Environmental Quality	62.66	6
Access to Information and Communications	72.76	7
Access to Basic Knowledge	86.71	8

Figure 24: Left - Graph showing each compared project's usefulness. Right - Table of prioritized needs from MEEDS for Ghana

There are a few observations to be made.

It is observed that projects that were targeted towards the highly ranked need of Ghana – ***Water and Sanitation*** had a high score. The case study [53] on the ***water and sanitation*** project concluded that the project was oversubscribed. From the graph, ***water and sanitation*** were selected as the most useful project. This could account for it's oversubscription. The case study on the e-services show that the project was undersubscribed, we can attribute the failure to ***Access to information and Communications*** not being a pressing need for Ghana, correspondingly, from the graph it was the project ranked very low.

It will be observed in the ranking table that, although Health and Wellness has an SPI score of 57.55 is it ranked lower than Personal Safety and Nutrition & Basic Medical Care with scores of 69.54 and 86.15 respectively. This is because Health and Wellness belong to a different need Dimension which is Foundations of Wellbeing, needs in the dimension are given less priority to those under the Basic Human Needs.

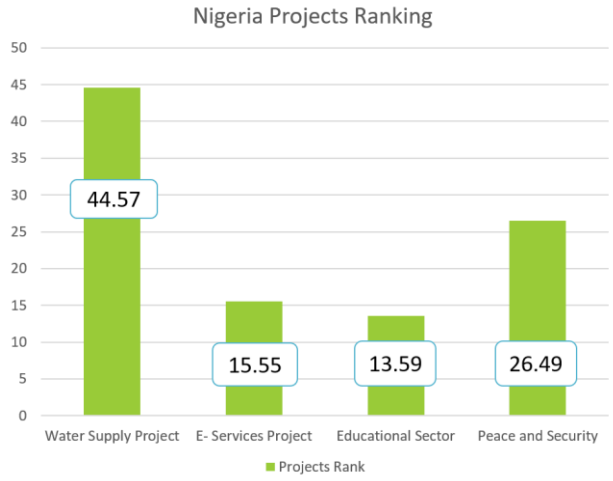
Although Water and Sanitation, and Personal Safety have the same SPI score one is ranked higher than the other. This is explained by the fact that the values used to populate the alternative pairwise matrix differ from those of Ghana.

5.1.2 Nigeria

The results of the test carried out using the same data for Nigeria is displayed in **Figure 34.** The outcome is like that of Ghana, this could be due to Nigeria and Ghana being developing countries. In the table showing the ranks, three observations would be made.

A similar observation as in that of Ghana regarding the Basic Human Needs to be ranked higher over that of Foundations of Wellbeing.

The final observation is that position two in Ghana's ranking is Shelter whereas position two in Nigeria's ranking is Personal Safety. This means that for Ghana shelter is ranked higher than Personal Safety.



Nigeria Needs Ranking

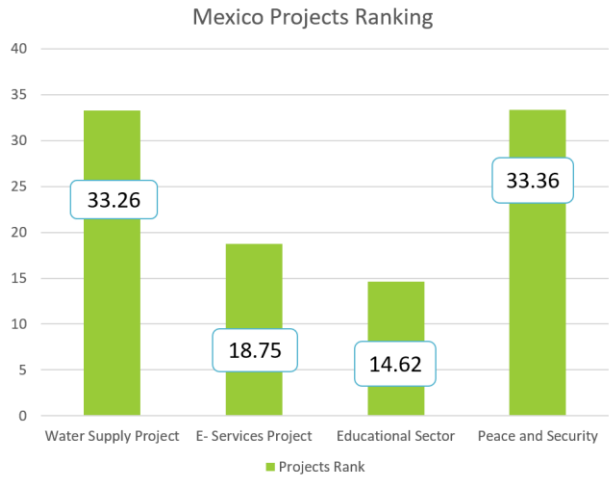
Criteria	SPI Score	Rank
Water and Sanitation	30.54	1
Personal Safety	42.93	2
Shelter	45.25	3
Nutrition and Basic Medical Care	72.88	4
Environmental Quality	61.35	5
Health and Wellness	62.53	6
Access to Information and Communications	66.04	7
Access to Basic Knowledge	62.94	8

Figure 25:: Left - Graph showing each compared project's usefulness. Right - Table of prioritized needs from MEEDS for Nigeria

5.1.3 Mexico

Finally, a third country was used against the same test cases (four case studies). Ghana and Nigeria are both developing countries whereas Mexico is a middle-income country. Hence the author's assumption was that the needs of Mexico should be different. The table of ranking shows that the most basic pressing need for Mexico is Personal Safety followed by

Shelter. Water and Sanitation are ranked lower than they were in Ghana and Nigeria.



Mexico Needs Ranking

Criteria	SPI Score	Rank
Water and Sanitation	43	1
Personal Safety	43	2
Shelter	69	3
Health and Wellness	86	4
Nutrition and Basic Medical Care	57	5
Environmental Quality	62	6
Access to Information and Communications	72	7
Access to Basic Knowledge	86	8

Figure 26:: Left - Graph showing each compared project's usefulness. Right - Table of prioritized needs from MEEDS for Mexico

5.2 Impact of MEEDS on Sustainability

MEEDs is a socially sustainable system meant to assist decision makers to to make sustainable decisions. It is therefore important that we perform sustainable analysis on the system based on Sustainable livelihood pentagon[5]

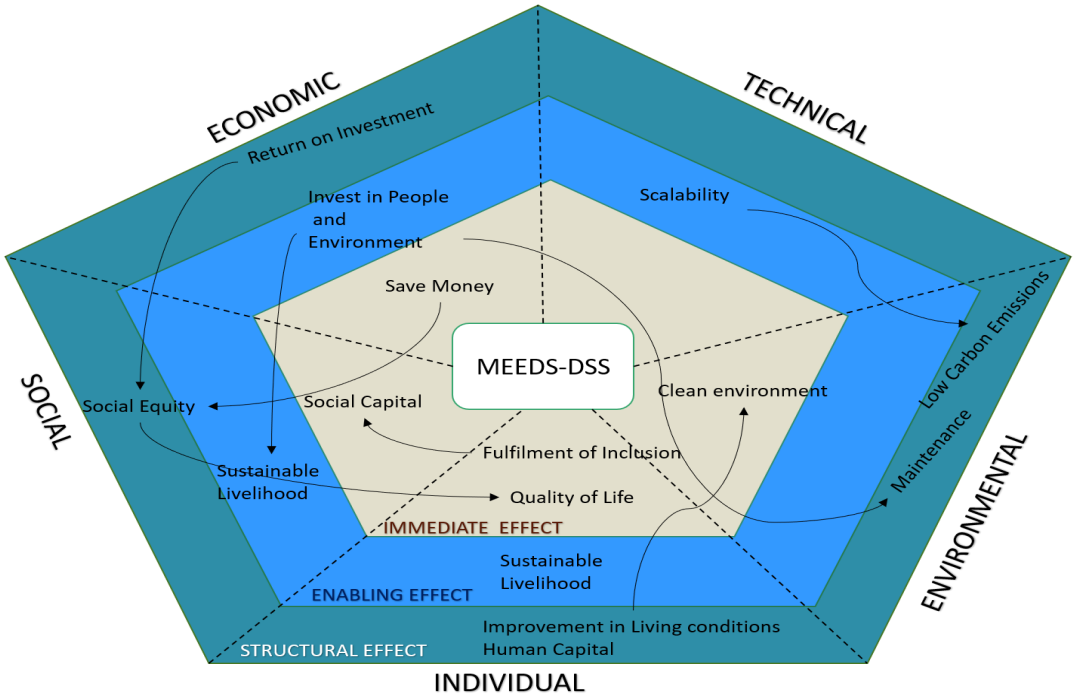


Figure 27 Sustainability Evaluation

Social and Individual Aspect, according to the diagram above the system will have an immediate effect on the quality of life of the people in the society because the system will help countries undertake projects that meet their most prioritized basic needs such as, water, sanitation, and food. This will make the people have a fulfillment of inclusion because their needs have been attended. The fulfillment of their needs liberates them and motivate them to aspire to fulfill other needs [3]. The improvement in their quality of life engenders happiness and a sense of inclusion. Enabling effect in sustainable livelihoods is the ability for the people to be resilient to changes in the society.

Economic aspect, the proposed system will affect economic sustainability directly. That is, the proposed system ensures that the most useful and needful projects are implemented. Selecting the most useful projects ensures the success of the project, successful projects means saving money in the sense that unsuccessful projects will be avoided. The money will be used to invest in other projects that will improve the living conditions of the people. For instance, jobs could be created for the people, enabling them to contribute back to the society.

Environmentally, the proposed system will ensure that highly prioritized needs are met, when this happens the people are motivated to keep the environment clean and society will have enough capital to invest in clean energy and plant more trees.

Technically, the system will be built using a service-oriented architecture which will ensure scalability. Using this architecture will also ensure that the system is easily maintained. That is a service could be shut down for maintenance without affecting the complete system. NodeJS developed by the Linux Foundation will be used to build the services. NodeJS is proven to be faster and consumes fewer energy resources when it used in building application [63].

5.3 Discussion

In comparing projects for the purposes of selecting the most needful for Ghana, the winning project should be targeting towards a need ranked higher than projects targeting lower ranked needs.

The result from AHP service put Water and Sanitation as the most needful and E-Services as less needful for Ghana. Reports from the projects indicate that the Water Supply and

Sanitation Project exceeded its target indicating remarkable success. Whereas the Education Sector Project fell short of its target recording a moderately unsatisfactory result. The findings contained in the case study are consistent with results from our *MEEDS* which selected Water Supply and Sanitation Project as the most needful for Ghana. The results show the significance of a system such as the MEEDS in helping NGOs, governments and donor agencies select the most useful projects for the countries or making sustainable decisions.

The decision to rank all Basic Human Needs ahead of Foundations of Wellbeing is justified in the sense that until all human basic needs are significantly satisfied, attempts to addressing to all other needs are mostly going to fail even with adequate monetary support and infrastructural availability both of which impact the success of projects. An example is the e-services project mentioned above which had enough funding from the World Bank but failed in terms of patronage and meeting the expectations of the project implementers.

MEEDS provide another layer of usefulness to its users, besides proving a ranking of needs of a country and assisting in selecting the most valuable needs, it displays for the user several country-specific data ranging from infrastructural availability to cultural aspirations and values of the country. Having this information all gathered in one place provide project implementors more than just the ability to easily select the most useful project but also all socio-cultural information needed for the success of the project.

6 FUTURE WORK AND CONCLUSIONS

The focus of this thesis which is part of the Erasmus Mundus Master Program in Pervasive Computing and Communication was to provide a DSS that will enable decision makers or implementors of sustainable decisions to compare and choose projects that are useful for the country of implementation. The main research question answered was how can a DSS be used to prioritize and select socio-developmental projects? The question was subdivided to four questions to clarify the various components of the question

i. Why do socio-developmental projects fail in their implementing countries?
ii. What is the link between the success of developmental projects and a country's basic human needs satisfaction?
iii. What are the identifiable taxonomies under which developmental projects can be grouped?
iv. How effective and efficient will such a system be in choosing the right project?

To answer the main question, we proposed, designed, implemented and deployed *MEEDS*. *MEEDS* is DSS built around the Analytical Hierarchy Process (AHP) decision model. The system gathers open data of countries progress and needs assessment and used that to assist users to choose a most useful project for a given country. A critical study of three the case studies on projects conducted in Ghana and available literature proved that social-developmental projects or projects meant to bring about sustainable development fail because they do not place the beneficiary at the center of the project implementation. This realization solves the first sub-question. For projects to be beneficial for a given people it must address their most pressing need, without solving their basic needs, they will not subscribe to projects meant to meet higher needs. Therefore, there is a strong correlation between needs satisfaction of basic needs and success of sustainable projects.

Having established the relationship between needs satisfaction and project success we proceeded to find out if we could define, classified and standardized needs, this classified needs then become the criteria for consideration in choosing useful projects for a given country or people. Using Maslow's hierarchy of need and SPI scores eight needs well selected and classified under to groups. Firstly, ***Basic Human Needs*** *– nutrition and basic medical care, water and sanitation, shelter and personal safety*. Secondly, ***Foundations of***

Wellbeing *– access to basic knowledge, access to information and communication, health and wellness, environmental quality*.

Based on the answer to the sub-questions we designed the system which can capture users, the inputs are the projects to be compared and the country of implementation. Using the captured information and the classified needs the system performs a decision analysis and shows the users a the most useful project for the country selected. The information is displayed on a dashboard to provide meaning to the user. The key importance of the system was choosing the most useful project; hence the decision needs to be effective, efficient and accurate. Therefore, formulas - *Distance calculator and Relative importance* for automating the population of the pairwise matrix was proposed and used. When the formulas were applied in the system *Consistency index (ci)* raised from 1.2 to 0.04. A $ci < 0.1$ is accurate enough.

The developed prototype was then deployed on *AWS* and real-world projects were used to validate it. Results from the experiment were successful, it tallied with the findings in the case studies conducted after the project was implemented. It successfully selected the most useful most for the countries they were used in the validation. The feature for prioritizing the needs of the country was very useful because it provided users of the system as a means to prioritize the needs of the country, even if they were no comparing projects. Ghana a developing country in Africa was selected as the primary case study to evaluate the system process of the DSS. And our DSS successfully rank contesting world bank funded projects based on the needs of Ghana. As more proof to show that every country's needs are different, we tested with two other countries. Nigeria in Africa and Mexico in South America with the same projects according to their specific needs. And the system ranked the projects differently

To fulfill the aim of this research we performed a sustainability test of the system. The result of the analyses was presented in chapter 5. Although the system was for social sustainability, it had a consequential impact on environmental, technical, economic and individual sustainability. The goal of achieving sustainability through helping in making sustainable decisions by choosing useful projects was achieved.

This thesis is the first to directly address the social sustainability from the point of view of the needs of the people using AHP decision-making model and providing a means to automating the population of the pairwise matrix and improving the consistency index. This research has established that it is highly possible to incorporate a DSS into socially sustainable decision making at the governmental level and with social organizations to rank project that benefits the people's wellbeing. But what is lacking is the future impact of those project and their success rate by considering another parameter like infrastructure and culture.

The ranking solution according to needs of the country is just the first step to progressive social development for sustainability. The next step for this research is to give a recommendation on the process of implementing the project to choose sustainable inputs. The third step will be to measure the long-term impact on the environment and plan a compensation.

It will be important to also have a set of projects for each need fulfillment and the right way to implement it in each country according to country-specific contexts like culture, history, climate and geographical location.

Apart from the above recommendation, other probabilistic models like Bayesian probability could be used to make more conclusive predictions on the probability of failure and success of the solutions based on other criterion and historical data such as culture, climate, infrastructure, and adoption rate.

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APPENDIX

Criteria pairwise comparisons

In this section, we describe the generation of the criteria matrix for the construction of the pairwise comparison of the criteria.

To be able to compute the weights for the different criteria, a pairwise comparison matrix A was created. The matrix is $m \times m$ real matrix where m is the number of criteria considered. Every entry a_{jk} of the matrix A is a representation of the importance of the j_{th} criterion relative to the k_{th} criterion. When $a_{jk>1}$ then j_{th} criterion is more important than the k_{th} criterion, while if $a_{jk<1}$ then the j_{th} criterion is less important than the k_{th} criterion. If they are the same, then $a_{jk=1}$.

To determine the relative importance between two criterion and to assign the appropriate numerical scale the selected needs(criteria) were sorted and ranked.

The needs were grouped into two categories based on Abraham Maslow's theory of need. The needs under each category were sorted using the sorting algorithm - "Selection Sort" based on their raw SPI score.

$$(n-1) + (n-2) + \ldots + 1 = \sum_{i-1}^{n-1} i = \sum_{1-1}^{n-1} \binom{i}{1}$$

Then the sorted categories were put together and ranged from 1- 8, 1 being highly needed as shown in Table 1.

Table 1 ranked needs

Criteria	*SPI Score*	*Rank*
Water and Sanitation	43	1
Shelter	43	2
Personal Safety	69	3
Nutrition and Basic Medical Care	86	4
Health and Wellness	57	5

Environmental Quality	62	6
Access to Information and Communications	72	7
Access to Basic Knowledge	86	8

Based on the criteria ranking a distance D is calculated d_{kj}, d_{kj} is the difference between k_{th} and j_{th} position on the criteria ranking $d_{kj} = k_{th} - j_{th}$. Finally, the relative importance of the two given criteria is determined based on the formula

(0.3) $a_{jk} = d_{jk} + 1$

(0.4) Where $d_{jk} = 0$, $a_{jk} = 1$

Where d_{jk} is < 0, then d_{jk} is negated and the a_{jk} inversed (see section 4.4.5 for details)

The relative importance between two criteria was measured according to the numerical scale from 1 to 9, where the j_{th} criterion is equally or more important than the k_{th} criterion. Once the matrix A was built, A_{norm} which is the normalized pairwise was derived from A. $A_{norm} = a_{jk} / \sum_{i=1}^{m} a_{kj}$. Then the criteria weight vector $\boldsymbol{w}$ was built by averaging the entries on each row ofA_{norm}. $W_j = \sum_{i=1}^{m} a_{jk} / m$ (where m is the m-dimensional column vector).

Alternatives pair wise comparison

e) The matrix of alternatives is an $\boldsymbol{n} \times \boldsymbol{m}$ real matrix $\boldsymbol{S}$. Every entry $\boldsymbol{s_{ij}}$ of $\boldsymbol{S}$ is a representation of the score of the alternative with respect to the criterion.

f) To do this, a pairwise comparison matrix $\boldsymbol{B^{(j)}}$ is first built for each of the m criteria, $\boldsymbol{j = 1, \dots, m}$. the matrix $\boldsymbol{B^{(j)}}$ is an $\boldsymbol{n} \times \boldsymbol{n}$ real matrix, where n is the number of alternatives available.

g) Each $\boldsymbol{b_{ih}}^{(j)}$ of matrix $\boldsymbol{B^{(j)}}$ represents the evaluation of the i^{th} alternative compared to the h^{th} alternative with respect to the j^{th} criterion.

h) Where $\boldsymbol{b_{ih}}^{(j)} > 1$, i^{th} alternative is better than h^{th} alternative, while if $\boldsymbol{b_{ih}}^{(j)} < 1$, then the i^{th} alternative is worse than the h^{th} alternative. Where they are equivalent the entry is 1.

Next, each pairwise matrix is normalized and the score vector calculated as in matrix A. The vector $s^{(j)}$ contains the scores of the evaluated options with respect to the j^{th} criterion [$s^{(i)}$ ... s^{m}].

The table below explains the weights used to represent the impact of the project on each of the needs against all the other projects. Below is the interpretation of each need.

Weight	*Meaning to water and sanitation, shelter, nutrition and health and other projects*
1	Equally impacted by the project
2	Equally to moderately impacted by the project
3	Moderately impacted by the project
5	Strongly impacted by the project
7	Very Strongly impacted by the project
9	Extremely impacted by the project

Figure 3: Table of weighted values for pairwise comparisons

Ranking the alternatives

Using the weight vector w and the score matrix S, a vector of *v* score is determined using the formula $v = S \times w$.

The global score is rearranged in decreasing order to provide the alternatives ranking. That is the most useful alternative (project) will be the alternative with the highest score.

MEEDS DSS Consistency check

The accuracy of decisions in AHP is verified by calculating the Consistency Index (*CI*) [59], this calculation was performed for each matrix to ensure consistency in the evaluations.

CI was obtained by first computing the scalar x as the average of the elements of the vector whose j^{th} element is the j^{th} element of the vector $A \times w$ to the corresponding element of the vector w.

$$\mathrm{CI} = \mathrm{x} - \mathrm{m} / \mathrm{m} - 1$$

A perfectly consistent decision maker should always obtain $CI = 0$, when $CI > 0.10$, the decision index is inconsistent. We propose a formula for ensuring highly consistent decisions. (see section 3.4.3).

Proposed formulae to improve consistency ratio

As part of using AHP, a pairwise comparison of the selected criteria was performed. To improve the consistency index (ci), A distance calculator and relative importance equation were developed to populate the criteria comparison matrix (M). Relative importance calculator

Distance Calculator. $d_{jk} = k^{th} - j^{th}$

Relative Importance. $rm_{jk} = d_{jk} + 1$

Boundaries:

Where d_{jk} ***is*** < 0:

Then d_{jk} is negated ($-rm_{jk}$) and rm_{jk} is inversed ($1/rm_{jk}$)

Example 1:

if $d_{jk} = -1$

$rm_{jk} = 1/(-(-d_{jk}) + 1)$

$rm_{jk} = 1/ (d_{jk}+1)$

$rm_{jk} = 1/ (1+1) == ½$

Example 2:

If $d_{jk} = 0$

$rm_{jk} = 1$

Example 3:

If $d_{jk} = 1$

$rm_{jk} = 1 + 1 = 2$

Below is an illustration of the matrix that has been populated by the formula above.

Criteria	1st K	2nd K	3rd K	4th K	5th K	6th K	7th K	8th K

J^{1st}	1	2	3	4	5	6	7	8
J^{2nd}	½	1	2	3	4	5	6	7
J^{3rd}	1/3	1/2	1	2	3	4	5	6
J^{4th}	¼	1/3	1/2	1	2	3	4	5
J^{5th}	1/5	1/4	1/3	1/2	1	2	3	4
J^{6th}	1/6	1/5	1/4	1/3	1/2	1	2	3
J^{7th}	1/7	1/6	1/5	1/4	1/3	1/2	1	2
J^{8th}	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1

Figure 4: Illustration of pair wise comparison matrix

When this equation was applied there was a significant improvement in the consistency ratio. This offers a great possibility for open data to be added without manually working out the pairwise matrix. This system is not only applying AHP but also improving how AHP can be automated and applied in systems where the data being used as criteria is dynamic

AHP Decision Code Snippet

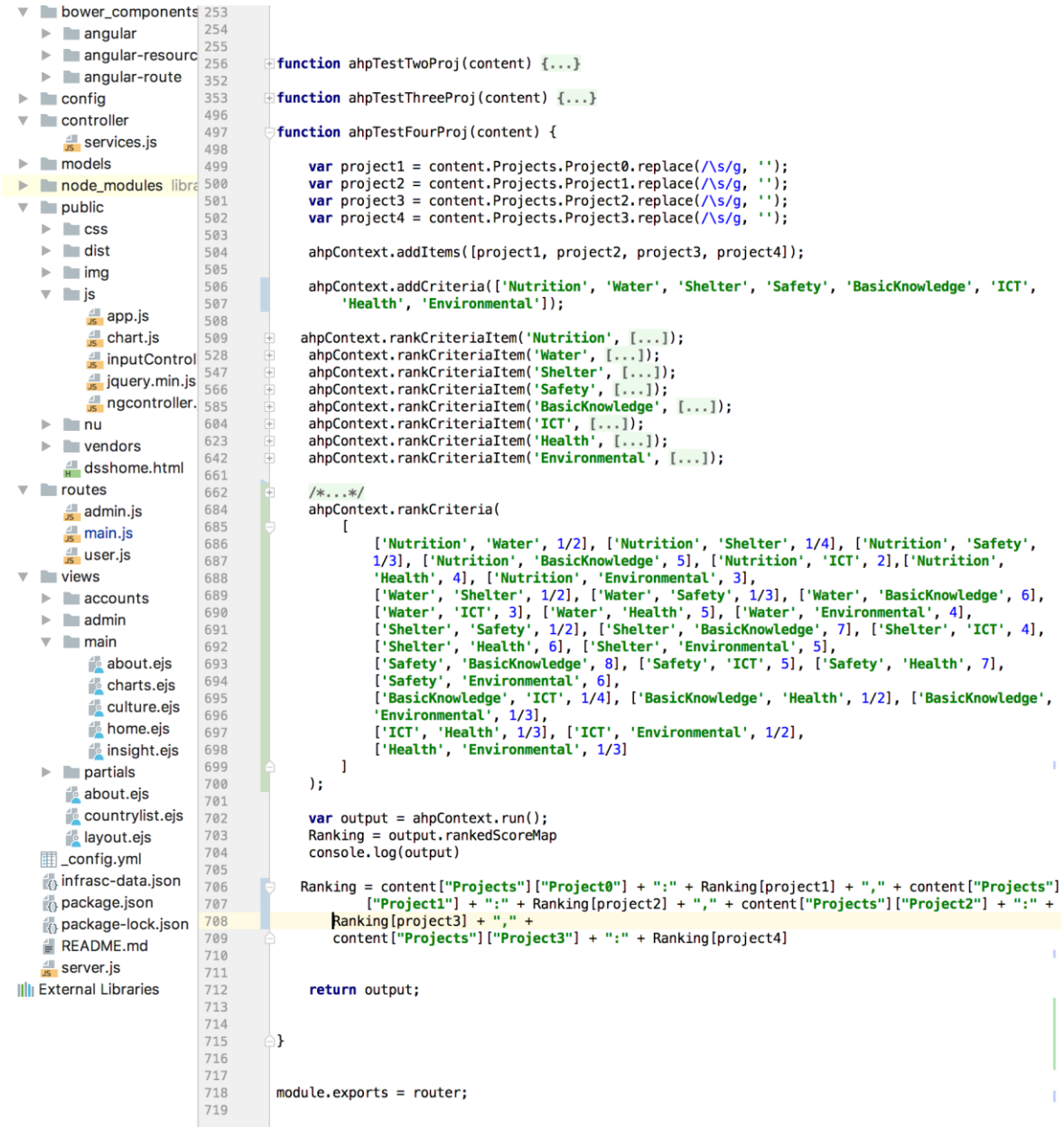

Figure 5: Code snippet of ahp implemetation of 4 projects

Needs Prioritization Algorithm Code Snippet

```
input: countryCode
process:
  get list_country_spi_socre from db
  unsorted_spi_score_list = spi_score ..."has size 8"
  sorted_spiscore_list = []

  while unsorted_spi_score_list.size > 0
   least_score = find_least_element(unsorted_spi_score_list)
   unsorted_spi_score_list.pop(least_score)
   sorted_spiscore_list.push(least_score)
  end

exit_process

output = sorted_spiscore_list
```

Figure 6: Needs prioritization algorithm

AHP Excel Views

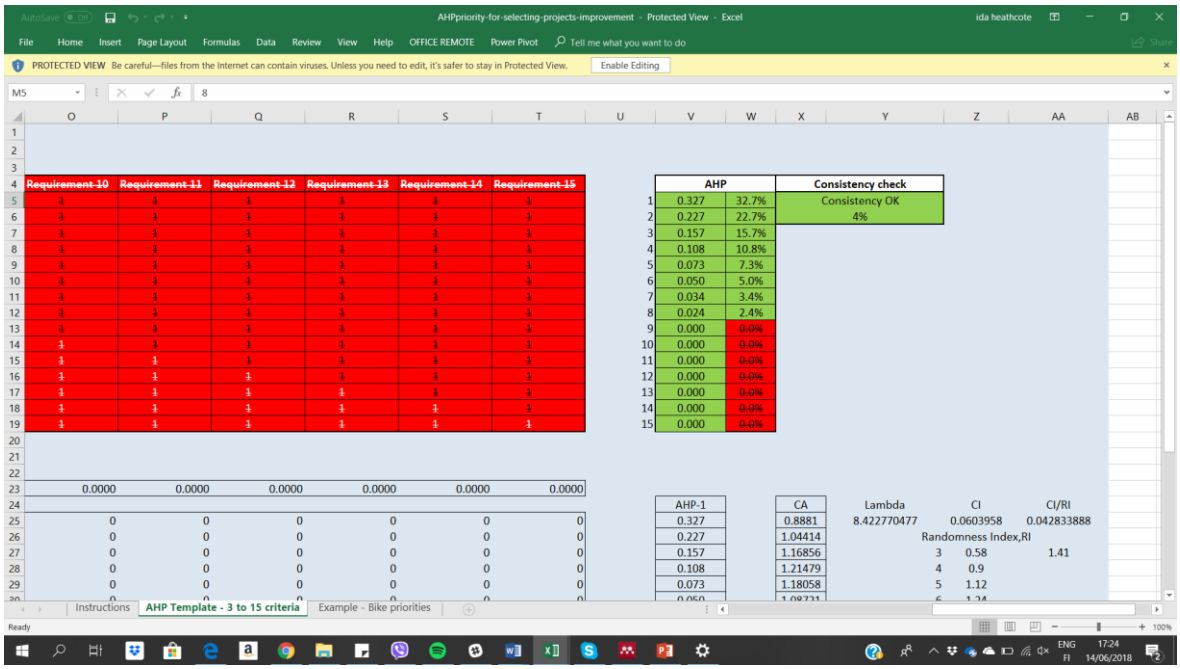

Figure 7: Excel validation of consistency ratio improvement after using the formulars relative importance formula and distance calculator

APPENDIX 2

Desktop and Mobile input views

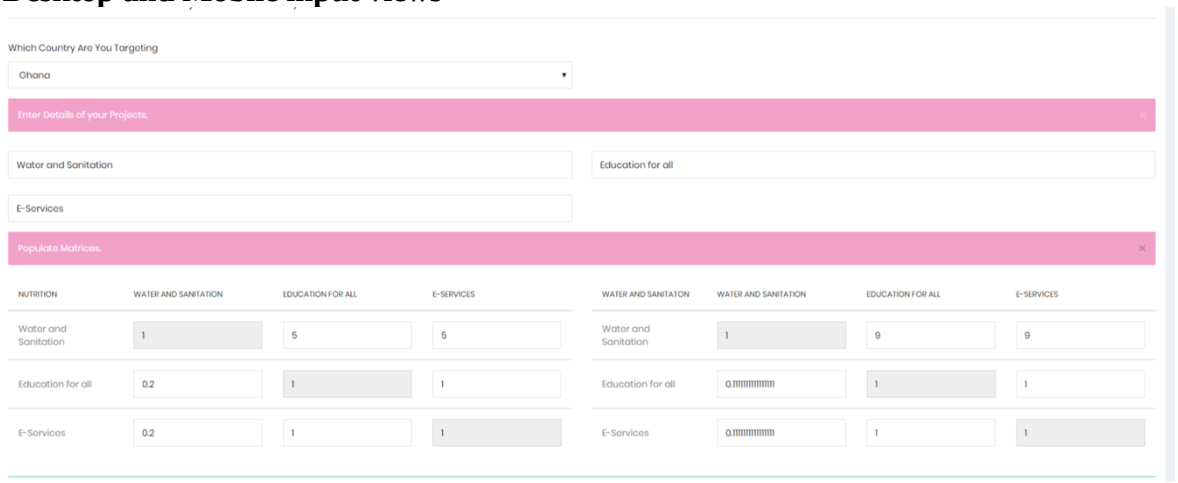

Figure 8: Desktop screenshot for project creation

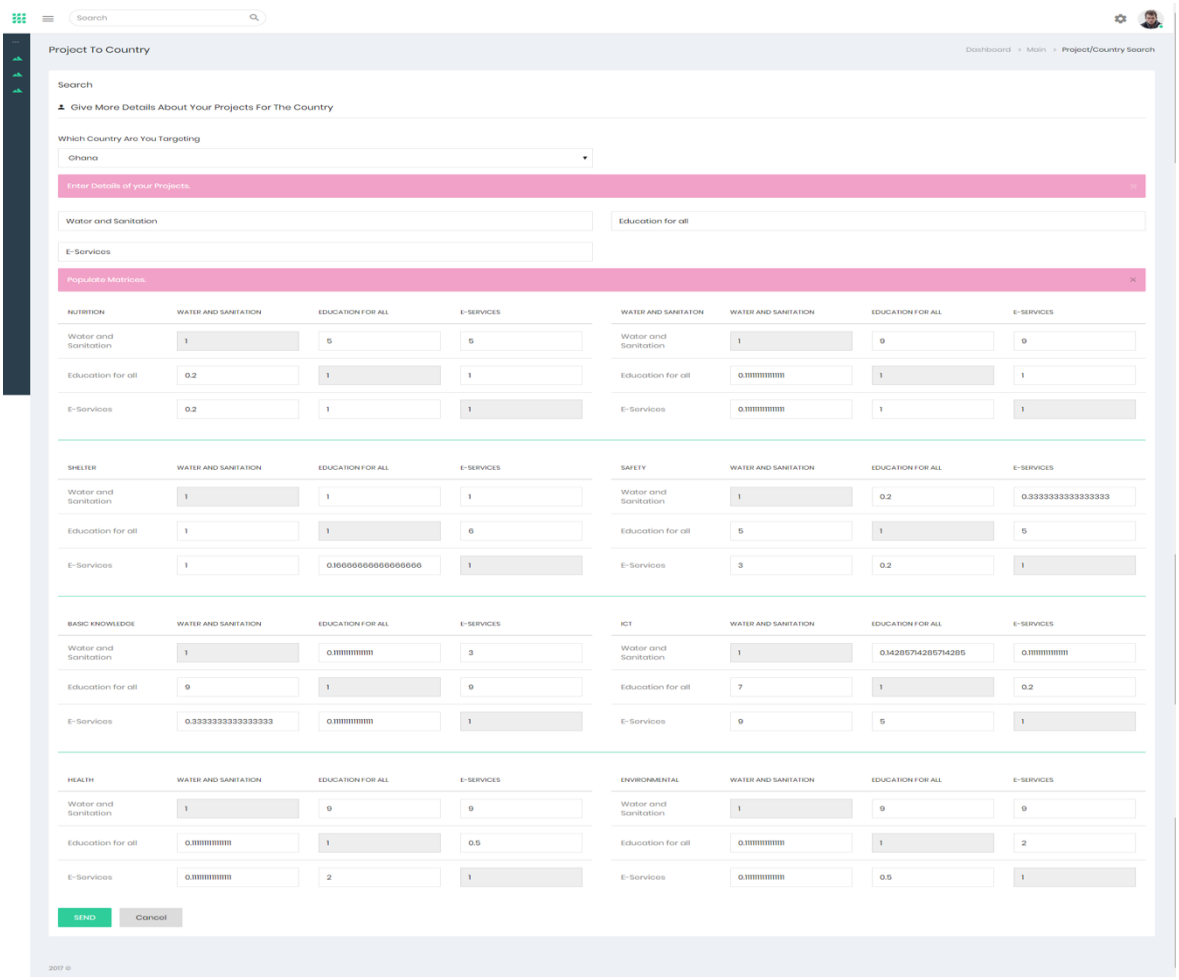

Figure 9: Desktop screenshots for matrix population

Mobile input views

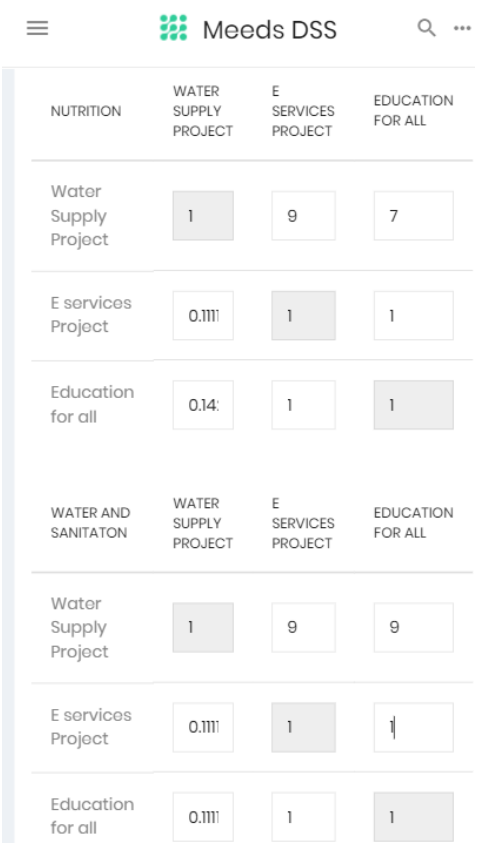

Figure 10: Mobile screenshot of matrix population

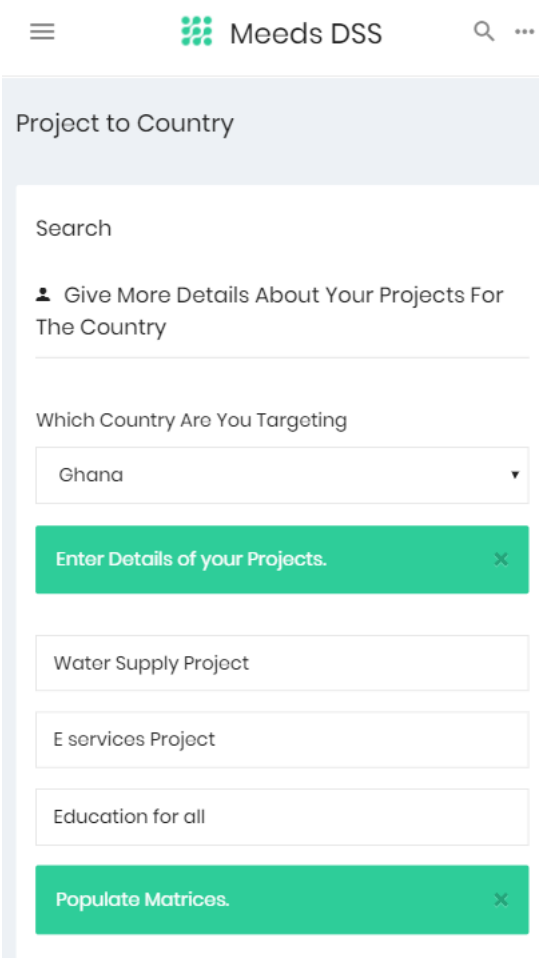

Figure 11: Mobile screenshots of results page

APPENDIX 3

Results views

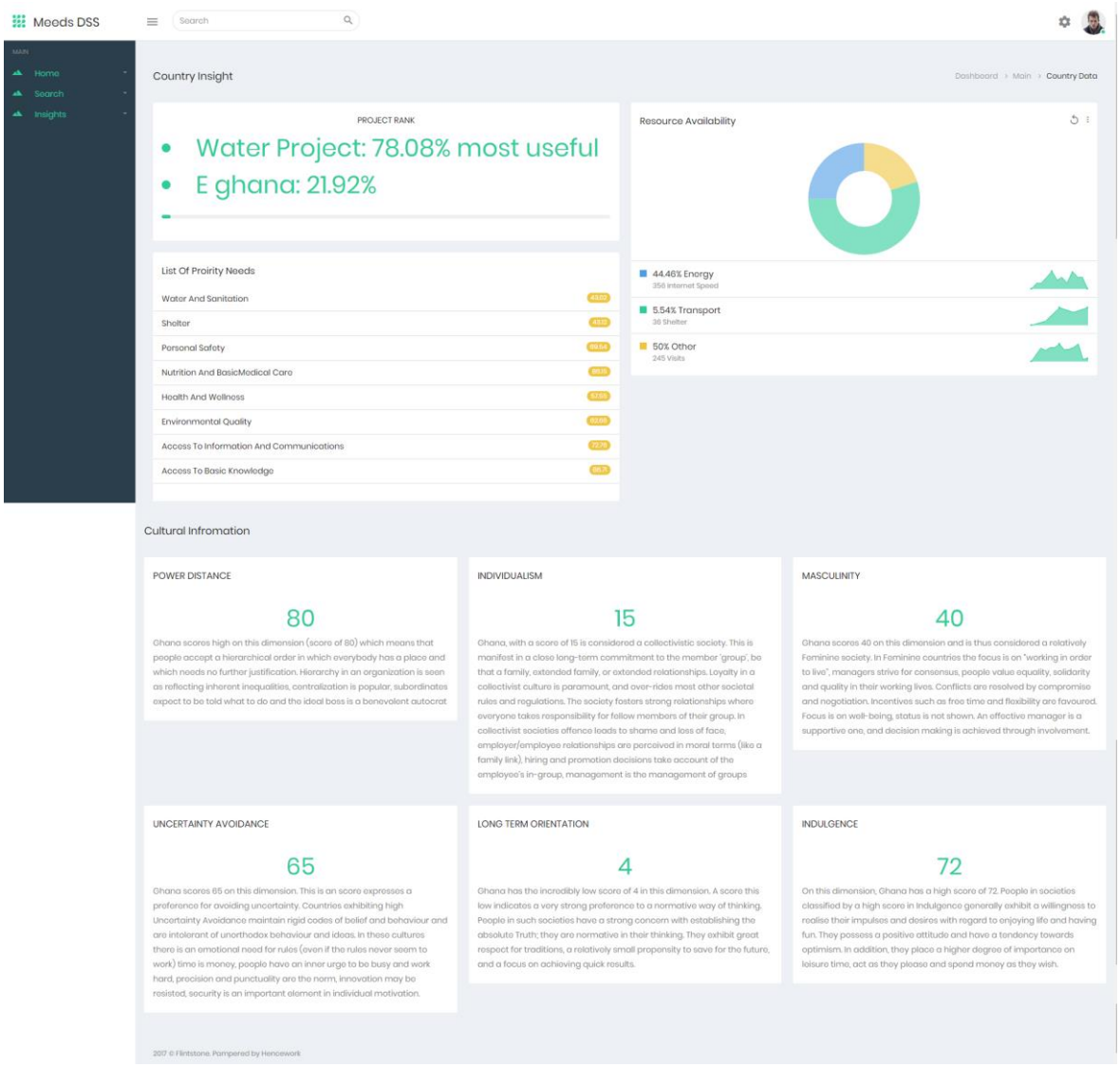

Figure 12: Desktop page for showing results depicting other important information of a country(Ghana)

Mobile result views

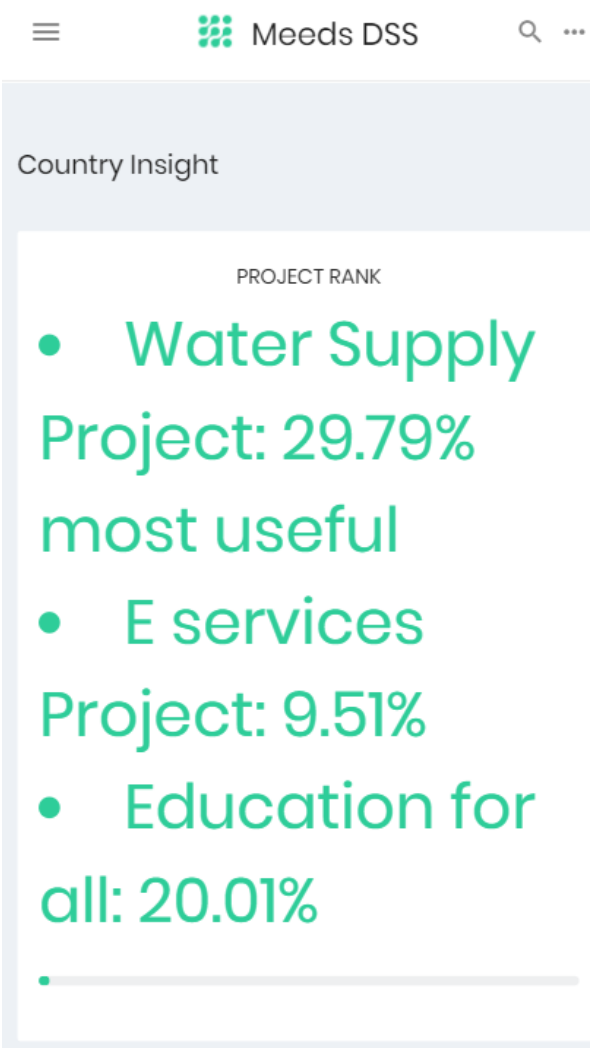

Figure 13: Mobile view needs prioritaization