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Selecting a hospital information system in a developing country: Assessment criteria and systems analysis

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Abstract

In the pursuit of better healthcare, developing countries are still in the process of digitalizing their information systems. This process is challenging and often expensive. In order to navigate swiftly among possible solutions, recommendations, and guidenceses, that can be used as a decision-making tool, are required.
In this thesis, the author explores available assessment criteria based on which he ought to define ones applicable specific to Tanzania hospitals. Specified assessment criteria are used to perform system analysis of the potential Open Source Hospital Information Systems, to select the most promising solution.

Preface

The research started on the 9th of September 2019 and finished on the 1st of March 2020. This study is carried to obtain the title of Master of Science in Computer Science and Engineering from the Technical University of Denmark. I would like to thank my supervisor - Kati Kuusinen, from DTU, for the support, direction, and guidance.

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CHAPTER 1

Introduction

1.1 Problem introduction

Managing a hospital institution is a complex set of tasks and processes. Due to the plethora of activities being performed in such an institution, there is a need to define the procedures for the work to be effective, as well as automate those processes that consume excessive amount of resources, are prone to human error, reduce time spent on patient treatment, or are expensive to run manually. Moreover, advanced electronic Hospital Information Systems allow analysing and improving the health care operations on hospital, regional and national level. Unfortunately, introducing such complex electronic systems is challenging and costly. Therefore hospital institutions in developing countries often do not have the required resources and knowledge for selecting, implementing and maintaining digital hospital information systems. To address these issues, the aim of this thesis was first to create an assessment criteria for selecting hospital information system and then use the criteria for evaluating a selected set of Open Source solutions. The criteria are based on literature review as well as qualitative content analysis of current digitalization state of healthcare in Tanzanian hospitals. The final goal is to perform systems analysis on the most prominent systems and select the most suitable one for the given purpose.

1.2 Hospital Information System

The quality of the healthcare industry is heavily dependent on the quality of Hospital Information System(HIS)[24]. Authors of study "Challenges to E-Healthcare Adoption in Developing Countries: A Case Study of Tanzania"[24] define Hospital Information System as a *"comprehensive and integrated information system designed to manage administrative, financial and clinical aspects of a hospital."*[24] It can come in two forms, either as a paper-based or digital. Digitalization of HIS is usually the first stage of electronic healthcare (e-healthcare). While developed countries have mostly digitalized their systems by now, developing countries are still in the process of migration. Poor quality of healthcare in developing countries is often caused by the issues connected with paper-based systems, including collecting, compiling, analyzing, reporting, and managing data. Those problems can lead to inaccurate, incomplete, and outdated information, without which management can not make informed decisions. Even though the advantage of e-healthcare versus paper-based systems is known, de-

veloping countries face challenges before implementation. Challenges vary from one nation to another and include lack of unique patient identifiers, lack of funding, low internet coverage, or lack of standards. Developing countries are looking for efficiency improvements in digital systems. It is estimated that 25% of the time of doctors and clinicians is spent on data collection[24]. Reducing that time would allow doctors to accommodate more time focusing on patients rather than updating data about them. Cost savings are also connected with e-healthcare. Radiology departments that have adopted digital systems can send digital x-ray results to healthcare providers' notebooks and devices. That removes responsibility from each clinic to poses its own x-ray devices. Access to information plays a significant role in the health condition of society. It is estimated that 75% of the poorest people live in rural areas[24]. Due to restricted access to information as well as limited access to healthcare professionalist, many people seek help only when their condition becomes severe. The internet might be one of the solutions, as it enables easier communication. It can simplify the process of receiving the first contact help before the condition turns to critical.

1.3 Open Source Software

Open Source software is continuously growing in popularity over the last ten years in both developing and developed countries. An excellent example of that theory might be an Open Source operating system Linux. In 1997 Linux had been used in 1% of the server operating systems, wherein 2007 its popularity had increased to 30% [3]. Open source used to be seen as not secure and unstandardized, as various developers from various backgrounds can work on the same product. Over the course of the last decade, those concerns turned out not to be valid anymore. As awareness and confidence grows, Open Source solution started being also adopted by government agencies in Brazil or South Africa[3]. The core principle of Open Source is not only to offer, whenever feasible, free software for users, but also to provide access to the source code. That does not necessarily mean that business can not make profit out of Open Source. Companies often would market them as distributions, and provide with terms of usage in the license notices. The most common one is GPL[16] (General Public License/GNU Public License). The Open Source model has exceptional qualities for clients and also developers. For the customer, it guarantees technology transparency and reduces or drops the cost of licensing. Developers on the other hand, can use various network of contributors and create a custom-made product for the given context.

Even though Open Source has no licensing fee, careful review of the total cost of ownership has to be considered. Often when businesses offer Open Source, they replace the licensing expense with the cost of service and maintenance. Thus it is not consistently true that Open Source is always an economically superior option.

CHAPTER 2

Related Work

2.1 Healthcare Digitalization in Developing Countries

Acknowledging the difficulties of digitalization of HIS[1] and necessity for a change, there has been number of research done in the domain. Both successful[3] and unsuccessful[20] digitalization cases can be used to draw conclusions of effective approach.

2.1.1 Hospital Information System in Limpopo

In 1994 project to install Hospital Information System was initiated to restructure health care institutions [20] in Limpopo (South Africa). Restructuration included putting more pressure on primary care and less on secondary and tertiary care. Limpopo province had 42 hospitals and has been one of the poorest in South Africa. The design of the system included the communication of data between the hospitals. Each hospital had its server where it would store all the local data as well as it would communicate with a central server and provide it with summary data on each patient encountered. The project started in 1997. The pilot system was launched in Mankweng Hospital in September 1998, and other hospitals supposed to receive a system within the next 18 months.

Sadly the project did not turn out to be a success. Among all the reasons for failure, the authors outline 3 categories:

- Infrastructure - e.g., power supply issues, or improper air conditioning for server rooms.
- Application - the system supposed to support too many functionalities with the initial release. Some modules were not delivered on time, causing few of hospitals to run a reduced version of the system in parallel with other systems (outside of the project). Some features were too advanced for the typical user, and staff never received proper training to utilize its functions adequatelym.
- Organization - due to malfunctions of computers, users developed antagonism for the system. Some had to wait 6 weeks for the support.

Even though users have been provided with training as to how to use the system, their awareness of the product was low. Due to that fact, they did not see the benefits

of extra work for benefits in the bigger picture. Misalignment of expectations between commissioners, developers, and users caused the end-product was not to be suitable to use in a real environment.

2.1.2 Mediboard Open source software package selected for the pilot project in Mali

In the introduction of new Hospital Information System in Mali[3], the first stage consisted of basics computer skills training. Many of the staff required to either update or obtain computer usage skills. The next step constituted the creation of an intranet for the purpose of information dissemination. The application has been installed on two Linux servers, one for the testing and validation of various modules other for production, which aligns with WHO recommendations[31]. Implementation has proceeded in a modular and incremental fashion. Before putting it to the production, each module has been introduced on the testing server. There it has been validated after thoughtful discussions with the users whether the module meets their requirements. After validation, training for the personnel has been planned. The module was introduced to production only when users felt confident with the usage of new functionalities. On top of that, users had a 24/7 support of technical team, in case any difficulties occurred. For the evaluation purposes, users have been asked following questions:

- Does the use of the system lead to a waste of time?
- Is the time spent using the system compatible with the tasks and the workload of the users?
- Do users prefer to enter their own medical data or delegate the task to a third party individual (e.g.,clerk)?
- Does the system increase the reliability of data?
- Does the use of the system add value to your work?
- Has the quality of your work improved with the use of the system?
- Has the system changed the way you work?
- Have you been sufficiently (or adequately) trained to use the system?
- Are you ready to continue the experience with the deployment of new features?
- Do you think the system must be expanded to the whole hospital?

The results were positive. The system met 32 of 36 functional requirements, which constitute to compatibility rate of 89%. 77% found system useful against 23% who did not. Regarding user-friendliness vast majority, 85% of people found new system

easy to use, against 15% who did not. Around 54% believed the system was quickly accessible, 31% found it acceptable, and 15% found the response time not fast enough. 61,5% claimed that the system saved their time, against 39,5% slowed them down. 100% of responders claimed that the system improved data quality as well as added additional value to their work. Mali project can be seen as a proof of confirmation that Open Source Hospital Information System may be the answer for the increasing needs of developing countries, despite shortage of resources and quality infrastructure. The risk of insufficient qualities compared to commercial products is no longer valid as these tools have the same functionalities and security risks. During the study authors noted barriers they had to overcome:

- resistance against change as digitalization is not part of the culture,
- lack of proper documentation,
- language barrier - most parts have been implemented in English with no translations,
- lack of single contact point in need of support,
- lack of financial support for maintenance of the system.

2.2 Evaluation criteria for the selection of Hospital Information Systems

In the emerging days of the IT systems, it does not come as a surprise that industries are looking for improvements in digitizing their systems. IT systems have plenty of advantages over the traditional pen and paper approach. One of the benefits would be access to the data. In traditional paper-based archival settings, information is not easily accessible. The amount of the data generated by a daily routine of the hospital makes it almost impossible to follow with a paper-based system, as the filters for extraction of information may vary. Without easy access to this information, policy-makers are left with no tools to make informed decisions about strategies they intend to formulate[1]. Flexible filters and on-demand possibility of extracting the data are not the only advantages. Using the paper-based system is much more pron to human errors. Since all the responsibilities of providing the data lie in the employees, that are mostly focused on their daily responsibilities and often regard providing information as less important, incorrect or missing data is much more common. Whilst using IT solution with simple form validation that would not allow proceeding further, solves such a problem.

Information management is not the only sector where HIS may turn out to be beneficial. Medication conflicts or improper dosage mistakes also could be reduced. Providing clearer data to health care professionals can help them take a more informative and accurate diagnosis.

All those benefits sadly comes with a price. Study shows that modern information systems are costly and constitute about 4,6% of the budget of health care institutions[34]. As the new system is introduced staff needs to adapt and familiarize themselves with it. If the system will not be designed with a low entry barrier, it is easy for users to grow reluctance to the IT system, causing difficulties for the adoption of innovation.

Due to the fact introduction of Hospital Information System is not a trivial task, there is a necessity for a well-thought decision process before implementation[1]. To be able to make an informed decision there is a need for defining evaluation criteria, that could be further used as a tool to navigate among possible solutions. Sadly, defining evaluation criteria for such a complex system as the Health Information System is always a big challenge[35].

It is important to understand that IT solution is just a part of the Information system of the given organization. Hence while defining criteria we can not focus only on a hardware and software part of the system. We need to take it as a whole, including the human factor that will interact with it. The success of the IT solution depends on a lot of factors among which one can distinguish: a match between the current business process and support of the IT solution, how the solution is being introduced to the organization and perceived advantages that it offers, training time, support possibilities and users motivation to learn. What would be considered as a reasonable first step of defining requirements is a challenge in itself. As HIS is a system that different stakeholder will interact with, each of them could have different conceptions and views of successful implementation, that can even lead to contradictions.

When reducing a possible number of evaluation criteria, it is far too easy to end up with an over-idealized picture of the outcome. Improvement and success of one department can cause malfunctions and distress of the other. Measuring the benefit of increased time effort for documentation purposes, without considering its completeness, can result in an unbalanced picture of benefits.

Not only measuring criteria are confusing[13]. Time-span over which the evaluation shall be made is also not obvious. Adoption of innovation takes time, hence it's not enough to measure effects soon after implementation. While users are getting knowedgle on how to use a new system, often the system undergoes modification to better fit its purpose. As the environment is constantly changing, the longer time-span, the more difficult it is to draw conclusions. On the other hand not allowing any modification of the system while performing evaluation is neither desired nor possible. As circumstances change rapidly, it is possible that by the end of the study, conclusions drawn from it may turn out to be obsolete, making results dependent on the point in time when the study starts.

In "Evaluation of health information systems, problems and challenges" study[34] authors took into consideration over 1500 citations on the evaluation of healthcare IT between 1967 and 1995, showed that many authors reported problems during the evaluation, such as:

- Unclear, conflicting or changing evaluation goals during the study.
- Large efforts needed for the preparation and execution of the study.
- Complex and sometimes contradictory results.
- Dependence of the evaluation results on the motivation and expectations of the users.
- Uncertainty whether results can be generalized to other environments.

2.2.1 Task-Technology Fit (TTF)

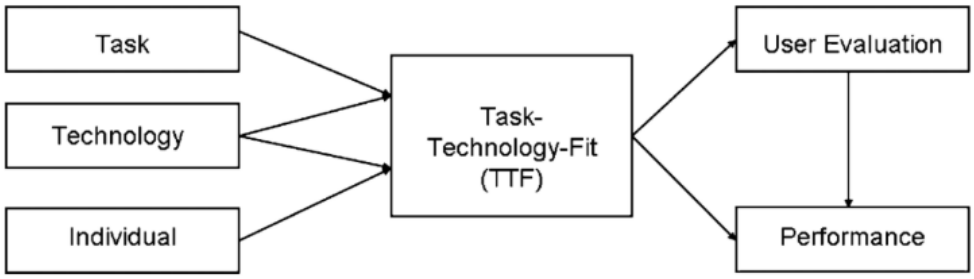

Figure 2.1: Task-Technology Fit[32].

TTF[32] takes into consideration aspects such as technology, user and complexity of the business processes that need to be supported by the IT solution and has been presented on figure 2.1. The framework puts a significant degree of importance on the fit between those three areas. Goodhue et al.[32] argue that Task-Technology Fit, or rather a task-individual-technology fit constitutes a degree of which technology functionality is matching task requirements and individual abilities. Task-Technology fit is defined as a degree of which technology capabilities align with task requirements. Task-Technology fit is grounded on the assumption that the IT solution is more likely to be used if the functions that are offered, support activities of the user. Users will choose tools and means that offer them the biggest efficiency benefits. When the IT system provides lesser benefits than competing systems, it will not be used. TTF focuses on the fit between user and technology, and between task and technology, it disregards fit between task and user, which can be a potential flaw of the framework.

2.2.2 Fit between Individuals, Task and Technology (FITT)

FITT model, presented on figure 2.1, is based on the idea that IT adoption in the hospital *"depends on the fit between attributes of the user (e.g. computer literacy, mo-*

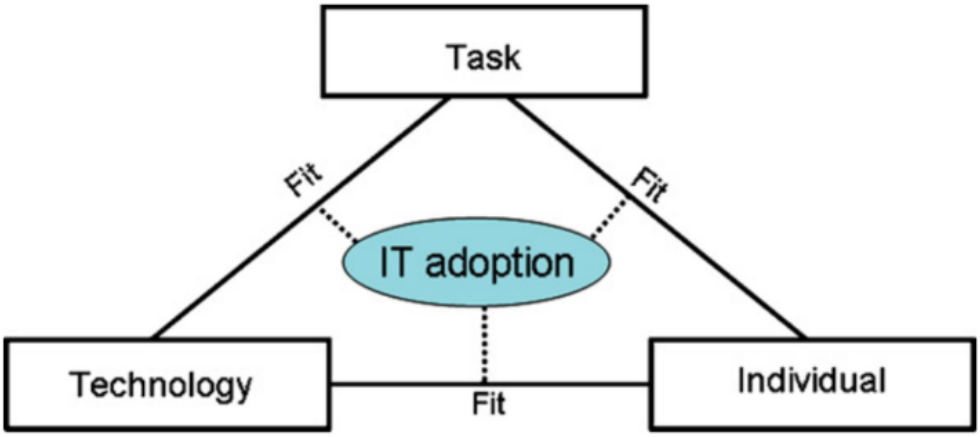

Figure 2.2: Fit between Individuals, Task and Technology[32].

tivation), of the attributes of the technology (e.g. usability, performance) and of the attributes of the clinical tasks and processes (e.g. task complexity)"[32]. Individual in that context is considered as an individual user or group of users, sharing the same role. Individual attributes include digital fluency, professionalism, and motivation. Technology is regarded as tools and it constitutes all the software, hardware and communications needed to achieve the given task. It also consists of stability, availability, usability, and functionality of the applications as well as tools and infrastructure. Task describes all the activities and business processes that the user is engaged with (e.g. patient admission, order entry, etc.) and technology supports. Its attributes consist of the interdependence of activities, complexity and business processes. Inadequate fit among the above attributes leads to problems during implementation and operation.

2.2.3 Technology-Organization-Environment(TOE)

TOE framework was introduced in 1990 by Tornatzky and Fleischer[1] and has been presented at figure 2.3. It can be described as an organizational level theory that foretells the technology adoption choice. It is characterized by three different contexts, technology, organization, and environment. TOE framework has been shown in previous studies to be broadly applicable and able to explain and predict over a variety of contexts. It has been applied and tested in both developed and developing countries. The success of implementation is determined by the technological context, the organizational context, and the environmental context. Framework describes in detail what given organization should consider when studying components that determine the success of acceptance. Technology context includes internal and

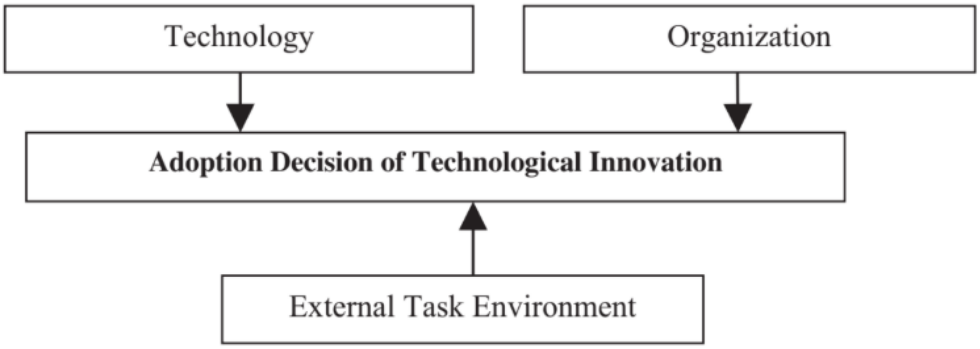

Figure 2.3: Technology-Organization-Environment[1].

external technologies used by hospitals to manage resources and processes. Organizational context includes characteristics and resources of the given institutions, such as size, management structure, and resources. Environmental context includes the structure of the industry, competitors, macroeconomic concept, and the regulatory environment.

2.2.4 Human-Organization-Technology fit (HOT)

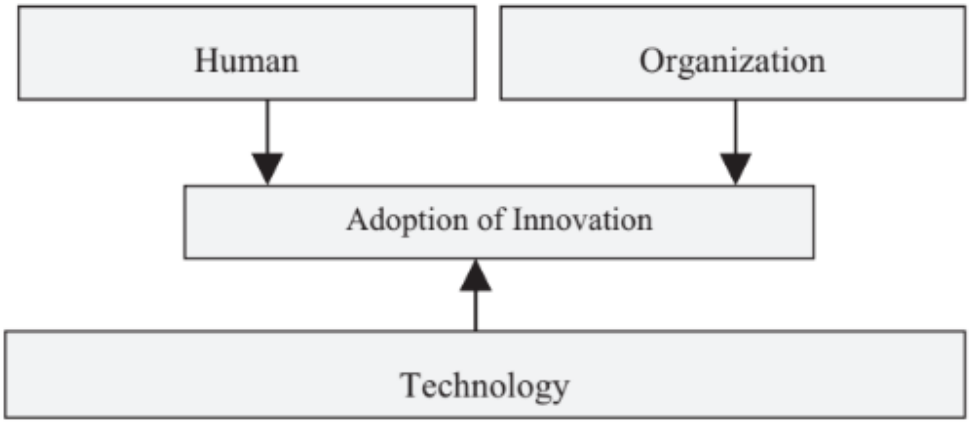

Figure 2.4: Human-Organization-Technology fit[1].

HOT-fit model[1] is based on the idea that the more fit between human, orga-

nization, and technology dimension, the bigger the potential of the system can be realized. It has been presented in figure 2.4. Most of the present evaluation criteria concentrate on technical aspects. HOT-fit model argues that human and organizational dimensions are equally important. A system that focuses on technical issues, but disregards its performance with a given user in the given settings, has lower chances of a successful adoption. The HOT-fit model has been designed to be used in a flexible manner, taking into consideration different settings, stakeholders' points of view, various phases of development, and evaluation methods. HOT-fit model is regarded as concentrated on the adoption of innovation in the healthcare information systems.

2.2.5 Human-Technology-Organization-Environment (HTOE)

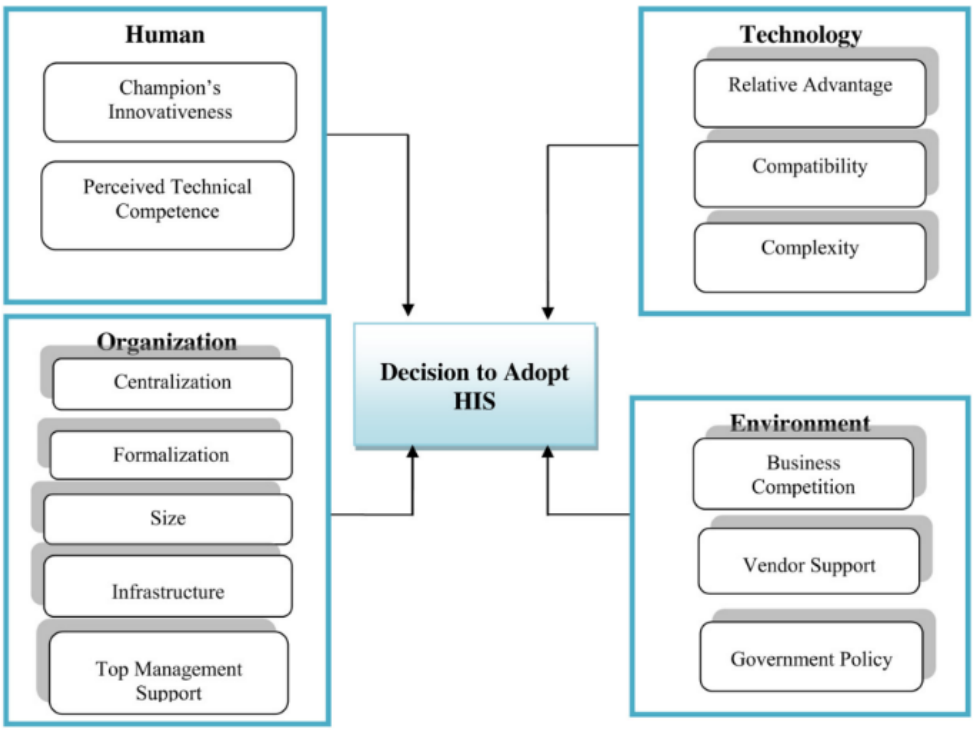

Figure 2.5: Human-Technology-Organization-Environment[1].

HTOE model[1] is presented at figure 2.5. It is a combination of the HOT-fit model and the TOE framework. TOE framework is an organization-level model focused on three distinct perspectives of a firm's context, including technological

context, organizational context, and environmental context. It has proven its sustainability in the healthcare industry examinations in understanding the technology innovation in the adoption phase. HOT-fit integrates human, organization, and technology, the aspects which can play a vital role, especially in the healthcare context. Combining the TOE framework with the HOT-fit model, where both of them are proven to be effective, results in HTOE dimensional model to determine the success of the adoption of HIS.

2.2.5.1 Human dimension[1]

Human resources are one of the most critical aspects of the given structure[1]. In the healthcare industry context, the performance Information System is heavily dependent on a user interaction. Hence their attitude towards innovation and willingness to learn new routines plays a vital role. Human dimensions in HTOE model consists of two segments.

2.2.5.2 Champion's innovativeness[1]

Leaders' attitude towards innovation has a significant impact on the effectiveness of adopting a new solution[1]. Employees often look for approval in the eyes of their direct superiors. It can be demonstrated that in the healthcare context, the individual who has a higher authority can have significant influence over the introduction of IS. Due to that, they are regarded as champions. When leaders express their reluctance towards innovation, employees that they manage also would. On the other hand, if important figures that hold a lot of decision power stay enthusiastic about the new Information System, employees would look up to them. As they view champions as more experienced individuals with bigger competences, they would be more eager to share their attitude, with the belief that they see a bigger picture.

2.2.5.3 Perceived technical competence[1]

When considering potential IT solutions, the staff's technological capabilities ought to be addressed[1]. The IT solution has match with the skills of the employees. Innovative solution that supports an extensive range of activities can turn into the counter intuitive system, that navigates through demands digital fluency. If the staff has adequate knowledge and appropriate abilities to adopt IT innovation technology, hospitals would have bigger chances for success in the process of adoption.

2.2.5.4 Technology dimension[1]

The technology dimension identifies aspects directly connected to the given solution[1] in the context of the HTOE framework. It is composed of three elements: relative advantage, compatibility, and complexity.

2.2.5.5 Relative advantage[1]

Relative advantage is the extent to which a new solution is regarded as better than its precursor[1]. If the innovation can lower hospital operational costs or improve operational benefits, it can significantly influence management to decide on a new solution.

2.2.5.6 Compatibility[1]

An important factor in the technological context is also system compatibility[1]. The system should be aligned with the activities performed by the hospital. The more similarities between current processes and flow supported by the system, the more intuitive interaction with the system will be, the less time staff has to spend in training. Hospital is a place where a lot of specialized equipment is being used. The system must allow for communication with other external and internal systems to exchange data. Hence the system should support common communication standards: Radiology Information System (RIS), Clinical Information System (CIS), Laboratory Information System (LIS), etc.

2.2.5.7 Complexity[1]

The complexity of the system has been identified as another crucial factor influencing adopting the decision[1]. Due to the number of activities performed at the hospital, it is far too easy to create a system that supports each case but disregards user interaction with it. Hence it is highly desirable to design the system considering aspects of user experience. If user-friendliness is ignored, it can play a crucial role in unsuccessful adoption. Especially in the context of Tanzania where human resources are insufficient alongside with their digital fluency, aspect of human interaction with the system plays a vital role.

2.2.5.8 Organization dimension[1]

Four factors have characterized organization dimension[1]: centralization and formalization, hospital size, IS infrastructure, and top management support.

2.2.5.9 Centralization and formalization[1]

It has been proven that strict centralization and formalization of the rules have a negative impact on innovation adoption[1]. Each hospital has different issues, and various cases that they handle. Hence it is often not feasible to impose strict rules that would fit all the circumstances. Hospitals have to have a certain degree of flexibility at their disposal as they know their challenges and needs best. Recommendations and guidelines might be beneficial as they can show a way for improvements, but they should stay as such, not becoming obligatory.

2.2.5.10 Hospital size[1]

The bigger the hospital is, the more resources it has. It should not come as a surprise then, that hospital size plays an essential role in innovation adoption[1].

2.2.5.11 IS infrastructure[1]

Information System infrastructure refers to the degree of capabilities of the institution to support flawless running of the desired system[1]. While introducing innovation, it has to be taken into consideration whether the infrastructure can support it. Power capacity, internet stability, and server rooms, are among other things that need to be matched for the particular solution. Especially in the Tanzania context, where IS infrastructure is not well developed, it can impose real restrictions over potential solutions. Costs of improving internet throughput, its stability or other aspects of the infrastructure are often too high for the hospitals.

2.2.5.12 Top management support[1]

Top management has to see added value clearly[1]. They are in power to make decisions regarding the direction of which the hospital will develop. If they know where the value is added, they can embrace those parts and identify and modify the aspects in which the system needs improvements.

2.2.5.13 Environment dimension[1]

The environmental dimension is characterized by business competition, vendor support, and government policy[1]. This context is focused around issues on the higher abstraction level around hospital administration and includes external circumstances of the healthcare industry.

2.2.5.14 Business competition[1]

IT solutions are becoming a general trend in improving services in various industries[1]. If every hospital is driven by development of its services, more new ideas would have the chance to be tested. Thanks to that, competition between healthcare institution drive innovation. Hospitals have the opportunity to plan their actions based on the success (or failure) of another institution.

2.2.5.15 Vendor support[1]

In the Tanzania context, where resources are limited, hospitals tend to accept a help wherever it is possible, including donations of equipment. That often leads to situations where there is a need for additional support from the vendor to integrate new systems. Taking into consideration the limited digital capabilities of employees,

chances for unintended actions that can lead to malfunctions of the system are probable. Hence efficient support of the system is required for its successful adoption[1].

2.2.5.16 Government policy[1]

Government policies can be a significant factor in innovation adoption[1]. As lawgivers pose a lot of power by the actions, they are entitled to increase resources of hospitals, or introduce guidelines and support for healthcare institutions in their attempts to adopt innovations. As they often are gathering data from each hospital, they have tools at their disposal to give informed recommendations.

2.3 Thesis Contribution

This thesis tries to reduce the gap between mapping existing theory on potential system implementations, to offer clear system recommendations in the specific context. Even though evaluation criteria can be used as a great tool in the decision-making process regarding which HIS to use, it can be challenging to do so[20]. This study can be used as a reference point on how to perform such an analysis in pursuit of the optimal solution in the given context, as well as obtain clear system recommendation in the specific Tanzania context.

CHAPTER 3

Research Method

For the purpose of consistent work, a clear definition of objectives is required. This Master thesis is focused on answering the question:

- What factors are most important when introducing a new health management system to a hospital in a developing country?

In the seek of possible solutions, existing evaluation frameworks and models had been explored. After careful examination of each, the most valuable factors in a given context will be extracted. These will be used as a base for system analysis and selection of the most prominent Hospital Management System.

In the period of 22.11 - 1.12.2019 the author visited Tanzania to conduct interviews with people involved in the digitization of healthcare in Tanzania. To use the data gathered during the on-site visit, qualitative content analysis has been undertaken. The methodology of extracting information has been based on the paper created by Mariette Bengtsson[9]. Krippendorff has defined content analysis as *"a research technique for making replicable and valid interfaces from text(or other meaningful matter) to the contexts of their use."*[19] The purpose of such is to reduce volumes of text collected, aggregate it into categories for better understanding. Content analysis can be segregated into three stages.

3.1 Planning

Every research study should start by defining what the researcher wants to find out, from whom, and how[9]. The author needs to decide whether he wants to use inductive or deductive reasoning before designing the study. Inductive reasoning[9] means that the author, based on the gathered information, creates theories. He carefully considers each piece of information, with no presumptions and speculations. Deductive reasoning is the opposite process. Here the author tries to validate his theories by testing principles and hypotheses. No matter which of the approaches the author decides to use, there is a need for a logical explanation of decisions taken to verify the credibility of the study. According to Mariette Bengtsson[9], five main points, as follows, need to be analysed:

- The aim - the first thing to consider during planning is the definition of the aim. It will determine the structure of research and its scope. The refined aim must

not be trivial. It should bring a certain degree of novelty and be precise about it. The author should be careful about defining the aim too broad. Even in a case where a vast amount of data is available, the author risks touching too many aspects without drawing concrete conclusions.

- The sample and units of analysis - The author needs to consider the sample size he/she wants to gather in order to answer research questions with an appropriate degree of certainty. The researcher needs to decide on the units of analysis. Decisions about which data can be aggregated and which should separately have to be made. For example, whether to segregate gathered data into age categories or aggregate data across generations. In this decision, the researcher should consider the aim of the study, considerative selection of units of analysis can navigate the focus of study. There are no generally accepted practices regarding the size of the unit of analysis, a number of sources, objects to study, or length of documented transcripts.
- The choice of data collection method - Even though there are no universal rules regarding the form of interviews, depth of it, or means of communication, a decision about the data collection method significantly affects the outcome of the study. A written form of an interview with specific questions can narrow down the scope of analysis but does not allow for flexibility as during open discussion, where the researcher can deepen selected aspects.
- The choice of analysis method - The purpose of data analysis is to draw realistic conclusions. Quantitative content analysis originates from media research, where qualitative content analysis comes from social research. Despite their roots, there are no preferences for usage influenced by the investigated domain. In quantitative content analysis, conclusions are drawn by assessing the frequency of occurrences. It is focussed more on summarization rather than going in detail with given subjects. In qualitative content analysis, data is segregated into themes and presented in words, that allows a more profound understanding of conclusions. The choice of analysis method is greatly influenced by the depth that the researcher is willing to work with. In consequence, it determines the number of participants needed and the process of data collection. Analysis can be either a manifest analysis or a latent. Manifest analysis focus is being put on the exact words that the interviewee used and their precise meaning. Latent analysis, on the other hand, is extended by the interpretive capabilities of the researcher. Here author focuses more on the meaning of the text rather than exact phrasings. Stress is being put on what the text is talking about rather than what words have been used.
- Practical implications - The researcher needs to respect the privacy expectation of informants. While conducting interviews author needs to explain the purpose and way how the collected data will be used. If participants want to remain anonymous, they need to be respected. Participants also need to be made aware of their right to withdraw their data with no consequences at any given time.

3.2 Data collection

The interviewee can communicate verbally or non-verbally with the author of the study[9]. Both means of communication could affect the message that is being sent and, therefore, the outcome of the study. The verbal or written questions must be formulated in an appropriate manner according to the method used by the researcher. Researcher must be aware that there might be a variety of factors that can affect miscommunication between the author of the study and interviewee. Often words that are used by the participant can mean something different to the author. Participants may also not tell the whole truth or telling what they think that the author wants to hear. They may have issues with expressing themselves (e.g. language barriers) or lack of communication skills. It is recommended to record by audio or video interviews, where the possibility exists. These recordings are often translated into the written form, which may result in biased text. While analyzing recording additional information can be brown by non-verbal communication (tone of voice, speed, pauses), but those elements may be challenging to put in writing.

3.3 Data analysis

Data analyzing part can be divided on four main stages[9]: the decontextualization, the recontextualization, the categorization, and the compilation. There might be a need for repeating some stages multiple times to validate the trustworthiness of analysis. No matter if it is manifest or latent analysis, stages are mostly the same regardless of interpretation. In the analysis processes, human mistakes is a factor that needs to be taken into consideration. It is the author's responsibility to assert the validity and trustworthiness of the study. In a qualitative study, validity means that results express a real state of the matter, and that same results would be drawn if the study were replicated. It is highly possible that different researchers would reach different conclusions from the same set of data. One way to increase validity is to use triangulation, where two researchers draw their conclusions separately and then discuss their findings.

3.3.1 Decontextualization

The first stage of data analysis is decontextualization[9]. Researcher needs to go through data and understand it as a whole. After that, the author starts the creation of meaning units. Meaning units are the smallest pieces of a text that consist of useful information for the researcher. They are usually related to each other and focused on answering the questions stated in the aim. Each meaning unit is labeled with a code that should relate to the context of itself. This process is called the "open coding process." During analysis, codes aid the classification of ideas around which the data can be assembled into blocks and patterns. The generation of codes should minimize cognitive transformation during the process of analysis in order to

ensure reliability. There are two methodologies for code generation: inductively or deductively. In deductive reasoning, the author creates a coding list upfront before starting to analyze. Where in inductive reasoning, a list of codes is being created during the analysis process and can be modified. Understanding of meaning units may seem evident at the beginning, but later can be unclear during the process. Hence it is recommended to perform the coding process multiple times, each time starting from a different point of the transcript. There exist internet tools that can help, although the author still has to decide on themes and what conclusion can be drawn from the results.

3.3.2 Recontextualization

After the creation of meaning units, the researcher needs to verify that all aspects of the content have been incorporated concerning the aim. Original text, with the final meaning units, is read one more time[9]. The author marks each meaning unit and reads the text that was left unmarked. The researcher goes through unmarked text and decides whether this text holds any additional value in relation to his aim. When unmarked text does not seem relevant, it should be excluded. For the researcher working on the data, everything may seem of significant importance, but it is crucial in this stage to build a distance towards the data to separate wheat from chaff.

3.3.3 Categorization

Before the author begins the creation of categories[9], meaning units must be compressed in a way that the number of words is reduced without losing the content of the unit. This process is vital when interviews collected data, and latent content analysis is to be performed. The purpose of the categorization process is to define themes and categories. Definition of these should assert that no data falls between two groups, nor fit into more than one. There are no specific recommendations on what strategy to use during categorization; besides that, all categories must be rooted in the data from which they originated. It is a common practice that the initial number of categories is later reduced. It is up to the researcher to decide when categorization is good enough and is greatly influenced by the aim of the study.

3.3.4 Compilation

The compilation stage starts when categories are established. Depending on the qualitative analyzing method researcher may relate to analyzing the process and conclusions drawn from it differently. The researcher decides between manifest and latent analysis, and the depth of analysis will significantly be influenced by the method of data collection. In the manifest analysis, the researcher goes through each category and themes in latent. In a manifest author often relates to the informant's words, going back to the original text. Thanks to this approach, he/she stays closer to their

true meaning. In the latent analysis, the researcher is invited to extend gathered data to enhance their hidden meaning. The researcher may present his/her findings in a graphical form of a table to give the reader a quick overview of the outcomes. To validate outcomes and ensure the validity of the study, the researcher can decide on presenting the findings to the informants. In such a case, time-delay between data collection and analysis may impose some risk. Interviews may change their opinions. Additionaly, they tend to deny less attractive aspects of their behavior. Another way to validate the study is to ask colleague, not involved in the study to read through original text and findings, and them reason with him/her whether the conclusions are reasonable.

3.4 Qualitative Content Analysis - methodology used

The author decided to use an inductive reasoning for the study. As the literature review did not provide enough information to justify the creation of theories solely based on them and use deductive reasoning as mentioned in section 3.1. Author has decided that listening to any input during data-collection with open-mind will give more value to the study. The data collection period lasted one week. Since it demanded personal visit in Tanzania, there has been a resource constraint affecting sample size. As a result, the author had an opportunity to include six organizations in research. For a data collection method, open-conversation has been used. Before each interview, questions to be asked have been defined, which later was extended by open conversation, in cases where it was beneficial. The open discussion allowed the author to elaborate on the parts where the interviewee could understand that author's words differently. This allowed minifying misunderstanding caused by language barrier, as interviews were not conducted in the mother tongue of participants. Not using the native language increases the chances of misconceptions. Hence latent analysis has been used to interpret results to avoid misinterpretation of meaning of the words used, that could have been imposed by manifest analysis. Summary of the outcomes is presented below.

CHAPTER 4

Results

4.1 Government requirements

As an attempt to participate in increasing digitization of healthcare Tanzanian Ministry of Health, Community Development, Gender, Elderly, and Children created a document called "Guidelines and Standards for Integrated Health Facility Electronic Management Systems"[18]. This document consists of almost a hundred pages and gives recommendations of what Health Information System should include. The document is a step in the right direction, HTOE framework presented on figure 2.5 refers to it as *centralization and formalization* claiming that Government policy can have a significant influence on the institution. As Government is an entity that has a broader overview of the matter, they can use that knowledge to extract practices that are working for hospitals, and based on them, make recommendations. It is important though that the recommendations are being treated as before-mentioned. The title uses the word "guidelines" not "rules," and the whole document should be treated as such. If the regulations imposed on the institution are too strict, Hospitals may not have enough flexibility to accommodate for their own, unique situation. Document created by the Government can be useful in seeking of best practices. One of the outcomes of qualitative content analysis, conducted in this thesis and presented at 4.1, says that knowledge about such a document is generally low among hospitals. The reason for that could be the fact that people with limited IT knowledge have a hard time understanding the material, where the knowledgeful audience can find it too restrictive.

4.2 Findings from the field study

The qualitative content analysis aimed to answer research question:

- What factors are most important when introducing a new health management system to a hospital in a developing country?

One of the Hospital Information System that is being used in Tanzania is CareMd. CareMd is an open-source system that has been created on top of Care2x (Open Source HIS that stopped being supported in 2015)[10]. Representatives from LUICO[21] that have been interviewed for the purpose of qualitative content analysis, presented

at figure 4.1, claims that success of the system comes from the fact that it provides a smooth barrier of entry for the staff, as its flow closely mirror hospital procedures that have been in place while using a paper-based system, they have been using before. What causes this system especially powerful is the possibility for extension. Its modularity allows to integrate only selected departments of hospitals and later extend for additional, once it turns effective. Currently, it is being used by about 30 hospitals in Tanzania.

The government of Tanzania is working on an improved version of GoT-HoMIS as presented in figure 4.1. It will come in three versions: light, standard, and specialized. They ought to be ready respectfully in: January 2020, the second quarter of 2020, and the end of 2020. While all public hospitals will be forced to use that system, private hospitals have complete flexibility in deciding which system they use. CSSC[12] representative claimed that it is hard to pick one system and declare it is universally the most suitable one, as circumstances and issues that hospitals are dealing with are different from one institution to another. Representatives of CSSC and APHFTA[2] said that hospitals see the value in digitalizing their systems, but often they lack resources or knowledge on how to do so. Human resources and digital literacy can also become an issue that needs to be considered while digitalizing. Students, as part of their education, tend to have ICT training, but sadly soon after graduation, they do not have the opportunity to put those skills to use. According to the APHTFA representative, due to that, when the hospital decides to digitalize their systems, ICT training is wholly forgotten. Hospitals are struggling with communicating the importance of valid data to their employees. Staff often sees collecting data solely for the purpose of reporting to the government. They are being trained on how to use the system, but not how to utilize it in the decision making process. The usage of Hospital Information System is expected to improve efficiency, which would reduce the demand on sacred human resources. It also would improve keeping track of patients across visits, allowing better treatment. Both CSSC and APHFTA are willing to coordinate the introduction of Hospital Information systems to hospitals that they are cooperating with. To do that, they need to have a proven and robust solution they can use.

Meaning unit	Code	Categories
30 hospitals using currently Care-MD. It is simpler, user-friendly, the flow of which they are used to is not altered, only now it is digital. Care-MD fits the real needs of users. GoT-HoMIS is fixed, it's not extensive. Care-MD is modular, can be extensible.	HIS options	HIS alternatives
Care-MD is open-source. The team of developers is less than five.	HIS options	
Currently, GoTHOMIS is used by 300 health facilities.	HIS options	
Working on an improved version of GoTHOMIS. Light version ought to be ready by January 2020, standard version by 2nd quarter of 2020 and specialized one will be ready by the end of 2020.	HIS options	
GoT-HoMIS has been build using care2X as a source of inspiration. Some hospitals in Arusha would like to go back to Care-MD, but establishment presures them to use GoT-HoMIS.	HIS options	
The approach that turned out to be effective is to customize the system to the hospital needs. Starting with a small module, and later extending the functionalities as the hospital grows.	HIS options	
Each institution has the flexibility in which system to use. It is impossible to choose one system and claim it being the best as circumstances differs from one institution to another.	Issues with HIS	Risks and benefits of HIS
Hospitals often lack resources to go digital.	Issues with HIS	
Students have their ICT training during university, but then after they go out to real life, it turns out that in the hospital there are virtually no computers. After that, they forget their training and need to be re-train in their usage of IT system skills.	Issues with HIS	
They had an issue with integrating laboratory machines, after two weeks from reporting the issue to the maintainer of the system, initial machines have been integrated.	Issues with HIS	

Figure 4.1: Qualitative Content Analysis part I.

Meaning unit	Code	Categories
Human resources are sometimes an issue in the hospitals - half of the people required are working. People are going from the private sector to public ones, hence the private sector has HR capacity issues. One reason could be that they find the public sector safer. One of the expectation from HIS is to reduce human resources required in hospitals.	Benefits of HIS	Risks and benefits of HIS
Usage of the system helped to control the number of patients being treated and admitted each day. There is a possibility to track the patient across visits.	Benefits of HIS	
Hospitals are moving to digital solutions by themselves, there is an initiative on the institution level.	Relative adventage	Perception on innovation
Hospitals do not see the importance and benefits of data. They see it as collecting data for government.	Relative adventage	
It is hard to get feedback from hospitals. Hospitals are being trained in how to utilize the system, but they can not see a bigger picture of using the tool, where it can be of help.	Relative adventage	
Digitalization is expected to reduce the workload and improve data quality by form validation. By using the Health Information System, the planning of resources and logistics around hospitals would be more manageable.	System expectation	
It is expected that Health Information System will be able to cover all activities of the hospital. The reason why the previous system did not succeed is that it was not covering all business cases of a hospital.	System expectation	
Umbrela organization that is working with around 900 facilities would be eager to coordinate the introduction of the IT system to those facilities if they would have a good, user-friendly solution.	System integration	
Hospitals do not know where to start digitalization. Umbrela organization wants to help with that, but they also need to know how can they guide.	System integration	

Figure 4.2: Qualitative Content Analysis part II.

4.3 Criteria of selection

Facing results from qualitative content analysis against existing evaluation frameworks in literature, the author has concluded that four factors play the most significant role in the selection of optimal Hospital Information System for the context of Tanzania hospitals. These factors are:

- Modularity
- User Friendliness
- Flexibility of data
- Community Support

4.3.1 Modularity

Carliss Y Baldwin defines Modularity as *"the degree to which a complex system can be broken apart into subunits (modules) which can be recombined in various ways"*. Before implementing enterprise-level applications, the decision has to be made about what would be the appropriate architectural design[8]. Far too often, too little attention is left for this activity, and the result is obese code-base, with each element of the code tightly coupled. This approach has its benefits. As a default practice, it allows saving resources on planning the design. Because the system is designed to support particular flows, implementing end-to-end tests is less challenging. Sadly those benefits come with downsides, as well. Due to the cross-referencing of each component of the system, it is impossible to derive separate modules that would be able to run independently. Introducing such a system is associated with a high entry-level complexity for the new users. It also requires the system to be deployed as a whole, even if most of the functionalities supported by the system will never be used. In the case of introducing such a solution to a new hospital, it is crucial to reduce the initial complexity barrier[3]. Thanks to the modular design of the system, only the required modules can be deployed. This will simplify the deployment process, as well as reduce entry-level complexity. The staff will only need to familiarize themselves with components that their work depends on.

Moreover, modularity allows for the natural expansion of the system. When the hospital will be contented with the HIS and decide to expand its scope for other departments, deployment would be simplified as there will only be a need for installation of additional modules. It also simplifies the maintenance and future development of the product. As each module has strictly defined responsibilities, modifying new code to add new features becomes less problematic for a developer, as it is clear from the beginning where new code shall live or where to look for a bug.

4.3.2 Usability

ISO 9241-11 defines usability as *"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."*[30]. When developing such a complex system as HIS, due to the enormous number of supported, constantly growing features, it is far too easy to focus on solving problems at hand, with no regard for usability.

When under-developed countries are considered, the usability of the system becomes an important factor. Even though most of the hospital employees had education in Information and communications technology (ICT), it is common that due to lack of practice, former students tend to forget their skills. Hospital is the place where experienced employees from the older generation meet younger. As the younger generation had ICT courses during their studies as well during the time they grew up computers became more and more common in the households, there tends to be big diversity in the skills of using computers among the staff from different generations. Due to that fact, HIS has to be intuitive and resistant to human errors, so even the less digitally fluent employees still can proceed with their daily responsibilities. Government requirements in those regards are that the average time for training the new employee should be less than a day[18]. The bigger the complexity of the system, the higher resistance among the employees in utilizing its functionalities.

Based on the APHFTA representative opinion, that has been presented at figure 4.2, employees of the hospitals nowadays often do not see the value in using the digital system. They often think that digitalization is just for the purpose of government control. Due to the fact that employees do not see the value in utilizing the data, they tend to do not put significant effort into the data they put into the system. Because of that analyzing the data is a difficult task, as there tends to be a lot of noise and missing data points. If the awareness of the staff about the benefits of the system will be low, the quality of the data will be an issue. One way to address this issue can be a visualization of the data. As graphs tend to be interpreted with fewer difficulties than numbers for the casual user, visualization can be used as a means to increase awareness of the data importance among the staff.

4.3.3 Flexibility of data

The research in this thesis is focused directly on the context of Tanzania hospitals, which constitutes around 270 hospitals[17]. Due to the sizes and geographical locations the cases that hospitals are facing differs, therfore there can not be one rigid solution that would fulfill all the needs. Hence the data that system operates on needs to have a certain degree of flexibility to allow different hospitals to modify the collected data. It needs to be opened in the manner of allowing administrators to flexibly modify datasets in the forms. As the life of the hospital goes on, cases that it handles differ. Furthermore, the geographical location may play a role in it. When one region has a higher numbers of HIV infected, the other could be struggling with a child mortality rate. For the purpose of being able to use the data in the decision-

making process, for the two cases mentioned, different set of evidence needs to be considered. Even though the flexibility of data is a desirable trait, what needs to be mentioned is that not all users shall have such an opportunity. Each modification to data-sets, and in consequences to the form, shall be considerable and well-thought decision. Given each user, such flexibility could easily result in an over-complicated form that would go against the user-friendliness aspect of the system. Additionally, it would affect storing immense amounts of fruitless data, causing noise and extensive resources required to support such. Each system shall support the data-set required from the government, for reporting purposes.

4.3.4 Community Support

Life of a hospital institution is full of unexpected changes and continues developments. Especially in the circumstances of developing countries, where resources are limited and hospitals often are depended on donations. Due to that fact, hospital institutions can not be choosy and for the greater good are willing to accept equipment that may not be entirely compatible with their systems. Such a case is one of the examples where community support plays a vital role.

When dealing with a complex IT system, it is always desirable to be prepared for its unexpected behaviors. Bugs in code, inappropriate usage by users or wrong configuration of the components, all those factors can result in the necessity of assisting the user to help him/her continue with his/her daily responsibilities. Even though it is recommended that each hospital has in-house IT specialists that shall be the initial line of support[18], community support plays a vital role in more complex cases.

The more active the community around the project, the more efficient help in solving issues at hand. If the project is constantly developed and improved, there is an indication that eventual bugs will not be present in the system forever.

CHAPTER 5

Open Source Solutions System Analysis Using Created Assessment Criteria

To select the most prominent HIS extensive internet research has been conducted. In this thesis focus is being put on Open Source solution, hence only these has been considered. As analyzing every system would not be feasible for the purpose of this thesis, the author focused on five systems that he has found most promising.

5.1 OpenClinic

OpenClinic[23] is a system that, by design, has been focused on limited resource hospitals. The initial work on a project started in 1990. In 2004 project have been redesigned and reprogrammed to Java programming language. It has more than five hundreds of implementations, including Africa. It supports several aspects of data management, including:

- Administrative patient record management.
- Financial patient record management.
- The electronic health record.
- Health insurance management.
- Cash and payment management.
- Pharmacy stock management.
- Laboratory management.

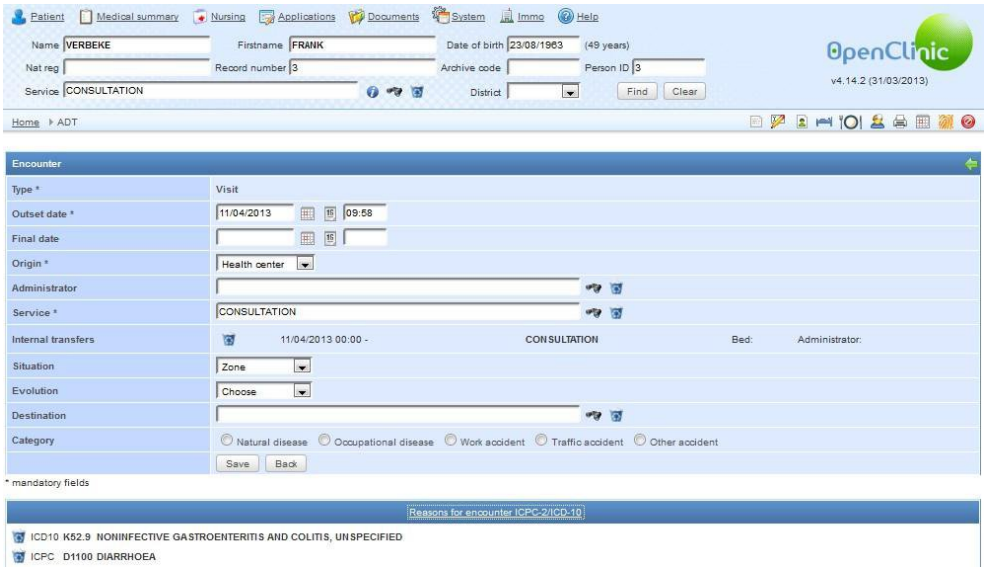

Figure 5.1: OpenClinic.

- Radiology management.
- Statistics and epidemiology.

It supports client-server architecture with the client connecting to the server using a web interface.

5.1.1 Modularity

Open-Clinic comes as a complete solution and, as such, is intended to be used[22]. It can be customized to the particular needs of hospitals, but that customization requires modifications in the source code. Documentation does not specify explicitly which Java classes are responsible for what functionalities, hence modifying source code without introducing new bugs may turn out to be a challenging task.

5.1.2 Usability

Open-Clinic uses a web interface[22]. Users are connecting to the server by a web browser, causing interaction with the software more natural. Views tend to be filled with an immense amount of data that can confuse the user. Due to that fact, in the thesis author opinion, interaction with the application does not have a natural feel to

it. Complex views can cause improper user interaction with the system and prolong the time necessary for training.

5.1.3 Flexibility of Data

Open-Clinic defines common patient-demographic data elements (such as Name, Date of birth, National ID number, Gender)[22]. There exists an option of adding any number of missing data fields, allowing a certain degree of flexibility. Sadly administrator does not have complete control over data-structure, as predefined data can not be modified.

5.1.4 Community Support

Unfortunately Open-Clinic does not have an active community[23]. There is no publicly available information about options for contribution to the project. In the moment of writing this, the last commit is older than six months. In a section of tickets, there are questions older than a year that remain unanswered. Even though the source code is publicly available, it is expected that hospitals could meet significant initial barrier involved with a lack of help from the community.

5.1.5 Summary

Open-Clinic started as a great project, with a lot of potential. There are evidences in literature that the project has been successfully implemented in multiple locations[33]. Sadly Open-Clinic did not age well. Nowadays solution looks obsolete. The community around the project seems nonexistent, with no clear indication of what potential contributors could help with. Hospitals that would decide on introducing this solution in their clinics would be forced to hire external help for that purpose.

5.2 Open Hospital

Open Hospital[14] is a free and open-source software supported and developed with basic principle for helping digitalization of healthcare in developing countries. The system enables the user to keep track of patient data, visits, hospitalizations, medicines, and lab results for better daily management. Used for the first time in the St. Luke Hospital in Uganda, it has rapidly grown in popularity. Currently, it is operational in 23 institutions across 13 countries, and it is estimated that it served more than 425 thousand of patients. It is implemented using Java programming language and being delivered as a stand-alone application that does not require installation on local machines. Each stand-alone application acts as a client. The server is a MySQL database server that each client connects to.

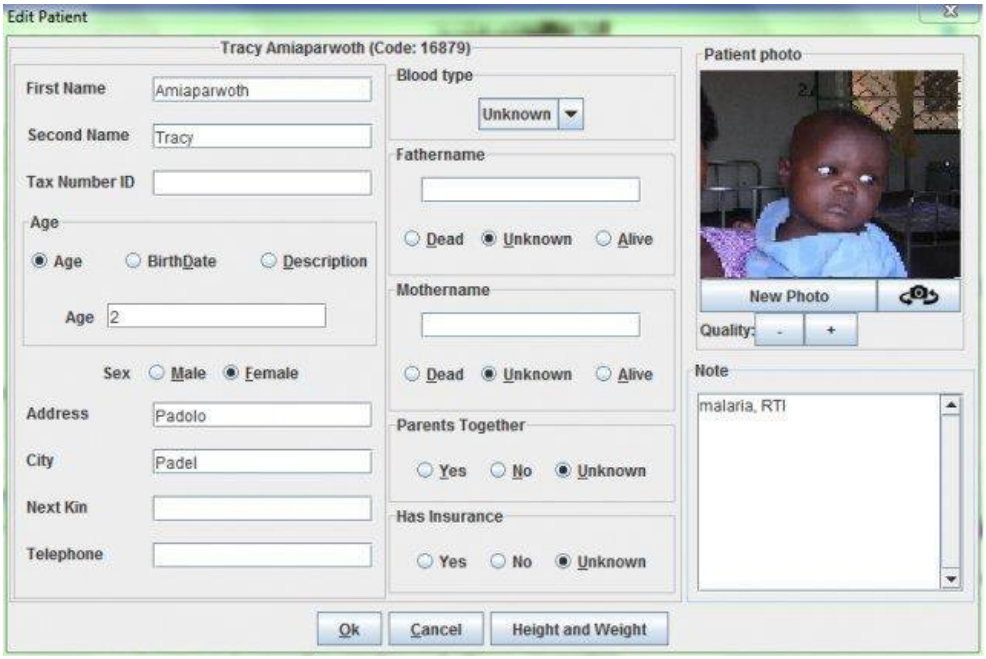

Figure 5.2: OpenHospital.

5.2.1 Modularity

Open Hospital has been designed in a modular manner[15]. It allows introducing new solution gradually, expanding functionalities over other departments of a hospital.

5.2.2 Usability

Open Hospital is being used as a stand-alone application[15]. Due to that, users are not interacting with it through the web browser interface, which can cause a bit of confusion initially. It provides a well-designed user manual with screenshots and descriptions of each action, which can be valuable during the training as well as a reference point while using. Developers of the system found the right balance between offering too much information on one view and directing the user to another.

5.2.3 Flexibility of Data

Administrators of Open Hospital have the possibility to define and modify all types of data that system the system uses[22]. That accounts for a significant degree of

flexibility that can be customized according to the needs.

5.2.4 Community Support

Open Hospital invites for cooperation potential contributors with call to action available on their website. Their repository is available at the GitHub platform[25]. Currently, the project has around 20 contributors and offers clear guidelines on contribution rules publicly available on the Jira platform. Using Jira currently handled tickets are visible, which allows keeping track of the progress of the project. Tickets are being up to date, and there are no obsolete, unanswered threads.

5.2.5 Summary

Open Hospital[14] is a strong candidate to consider when looking for a new Hospital Information System. It has a simple installation process with well-documented steps to follow. It is continuously developed and well maintained, allowing hospitals for a certain degree of flexibility to suit the solution according to their individual needs.

5.3 OpenMRS

OpenMRS[26] is a community-driven Hospital Information System. The community's mission is to improve healthcare in developing countries, where resources are limited. It was implemented in 2004, and currently, it is being used all over the world, including South Africa, Kenya, and Tanzania. OpenMRS supports client-based application with three loosely coupled layers: Data Model, Application Programming Interface, and Front-end Web application.

5.3.1 Modularity

OpenMRS comes with out of the box support for supporting core functionalities of hospital institutions by default modules. These modules can be modified according to the hospital's particular needs. Developers can implement modules on their own, or use one of the ones already published. Complete lists of modules with their description can be found online[28].

5.3.2 Usability

One of the core ideas of OpenMRS is to allow users with no programming experience to fully benefit from the usage of the system[26]. A Client-side of application is web-based, hence users can use standards they are familiar with daily. By the author of this thesis view, User Interface is simple, and each view has only necessary pieces of

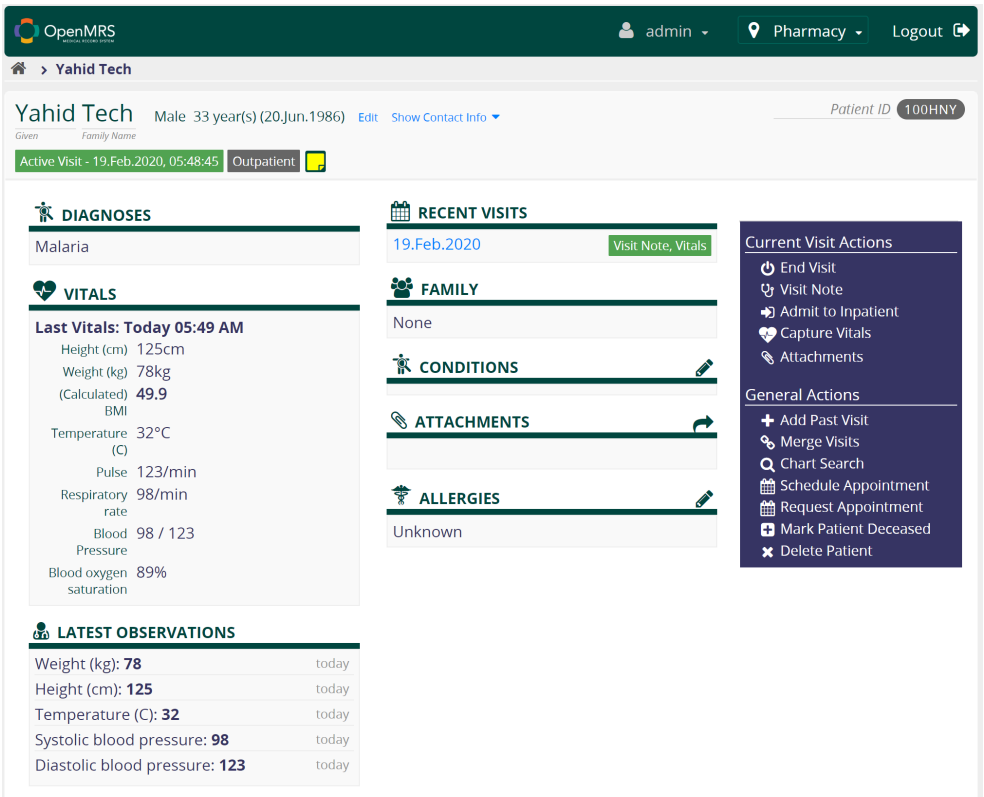

Figure 5.3: OpenMRS.

information visible. That makes navigation through the application straight forward, reducing the training time among staff and a mistake rate.

5.3.3 Flexibility of Data

OpenMRS is a highly customizable system[27]. It uses an HTML Form Entry Module to synchronize data with the server. Thanks to that module, administrators have complete control over what data will be collected, making a system highly customizable and flexible.

5.3.4 Community Support

OpenMRS is a community-driven product, and evidence of that are clear. There are multiple ways to contribute to the product. Instructions on how to help are available

on the official website of the project[26]. Users looking for support have various channels of communication, including mailing lists, Internet Relay Chat (IRC), online form, or wiki forum. The community is very active, and there are no obsolete threads with no responses. OpenMRS core module has over 300 contributors. Source code is available at a GitHub platform[29], with clear instructions or how to get started and possibilities to help.

5.3.5 Summary

OpenMRS[26] is a scalable, community-driven product with big potential and easily accessible information. It has been designed with intention of helping resource-restricted hospitals. What makes it unique is the community support gathered around the product. It is constantly developed with publicly available road-map of product. Users that are struggling with issues can use various forms of support and judging by the current activity on the forum, they can count on getting answers without immense delay.

5.4 Bahami

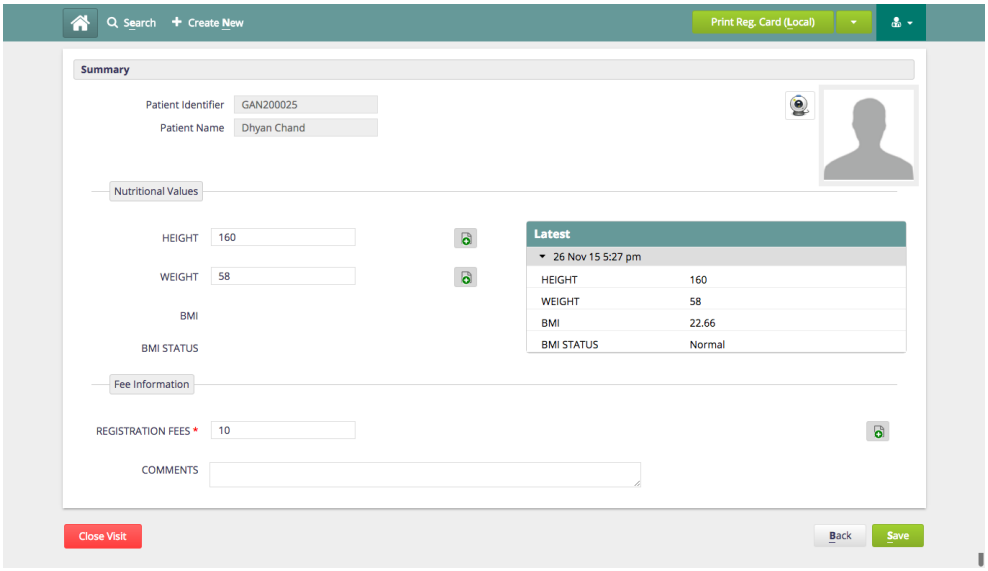

Figure 5.4: Bahami.

Bahami[4] is a system that has been designed for people with a low digital literacy. Bahami project started in 2013 by a company called ThoughtWorks as a medium to fulfill its mission of social and economic justice. It 2017, ownership of the project was moved to the Bahami coalition. Bahami coalition is a group of organizations supporting the project in various ways, including users, developers, or organizations offering different services connected with Bahami. Bahami is a system that has been built on top of various other solutions. On a back-end, it uses OpenMRS implemented in Java and Spring and using MySQL, while using JavaScript and AngularJS on the front-end.

5.4.1 Modularity

Bahami[4] is aimed to be a generic system that can be further customizable according to the particular hospital needs. Customization can occur on a file configuration level, rather than modifying the source code, which allows a lesser barrier of entry for modifications. As on a back-end, it uses OpenMRS[5], and there is a possibility of extending functionalities by additional modules as well as defining custom ones.

5.4.2 Usability

As previously mentioned, the core principle of Bahami is to be easily understood by people with a low digital literacy. This approach resulted in a simple and clear User Interface, in the thesis author opinion. Navigation through the options feels very natural. Bahami is a web-based solution, hence users are accessing client application through their standard web browser.

5.4.3 Flexibility of Data

Bahami[4] is a flexible solution easily customizable, where administrators can define any given set of field data, to fit the system to its unique needs.

5.4.4 Community Support

Bahami is open to potential contributors. Information on how to contribute can be found on their website[7]. Source code is available on the GitHub platform[6], with around 100 contributors working on it. Users can ask questions regarding the malfunctions of the product using an online forum and expect an answer within a few days. For the more sophisticated and dedicated help, hospitals can decide to use services one of the implementation partners, which list is available on the website.

5.4.5 Summary

Bahami[4] is a system that takes good parts of various available solutions, and compose them all in one fully functional Hospital Information System. It is easily extendable and easy to use. It has well-described documentation for both users and administrators of the system that can be referenced. It uses the wiki as a knowledge center, where plenty of useful information can be found (including road-map). Although at the moment of writing, some of the parts are out-dated (e.g., road-map finished in August 2019).

5.5 CareMd

CareMd[11] is an open-source system that has been implemented on top of Care2x. It has been developed by developers from Tanzania, with particular Tanzanian context in mind. Therefore Tanzanian hospitals, migrating from paper-based to digital system might find it attractive, as it offers a low entry barrier. Its code is available on GitHub[11]. Sadly CareMd, even though being open-source, does not have any community around a product. In result it is hard to find publicly available information, without personal interaction with authors of the system.

5.5.1 Modularity

LUICO representatives, whose opinion has been presented in figure 4.1, CareMd is a modular system that allows gradual expansion of the system for additional departments.

5.5.2 Usability

There is very little data publicly available to determine usability of the system.

5.5.3 Flexibility of Data

There is too little data publicly available to determine degree of flexibility of the system.

5.5.4 Community Support

Unfortunately CareMd, even though being open-source, does not have any community around a product. There are two contributors involved in the development of the product on GitHub[11]. Beside publicly available code at GitHub, there is hardly any publicly available information about the product. Hospitals deciding on using CareMd needs to use an external provider for deployment and maintenance, or any IT support of the system.

5.5.5 Summary

There is a limited data publicly available to provide comprehensive system analysis of the CareMd. That being said, this points out big flaw of the system - lack of community. Even though system is Open Source, it is still completely depended on the work of a few individuals, and hospitals willing to try out this solution have no means to do this by themselves.

5.6 Hospital Information System of Choice

Based on the criteria defined in previous chapter, the author has decided that the most suitable Open Source HIS in Tanzania Context will be OpenMRS[26]. The Author of this thesis sees a great value in community activity. Thanks to it, the user can always count on response when in need of the support. By the vast number of available modules OpenMRS is a highly customizable system. If hospital has particularly unique needs, it is opened for implementing additional modules. Usability of the system makes user navigate through the system intuitively, reducing the time necessary for training.

CHAPTER 6

OpenMRS

After choosing OpenMRS the optimal HIS in the given context, the author of this thesis has decided to investigate solution from the potential hospital perspective. The author examined in detail process of initial integration and made trial registration of the patient, to verify credibility of the solution.

OpenMRS can be downloaded from http://download.openmrs.org. It comes in two versions Standalone or Enterprise. OpenMRS requires Java 6 to be installed, and Java 8 or higher is recommended to be able to use all features of OpenMRS[27]. OpenMRS Standalone has simplified installation choice. It allows exploring initial system options with minimal time spent on configuration and includes initial sample data. OpenMRS Standalone is recommended to be used in an organization that handles less than 10,000 patient records[27]. If in doubt about amounts of data to be processed, the Standalone version should be installed, as migrating data to Enterprise version is supported.

The installation of OpenMRS Standalone is straight forward. After downloading, extract files, run openmrs-standalone.jar, and proceed with instructions. During the installation, there is a step to specify whether demo data should be installed. This is recommended if the purpose of the installation is a trial run of the system.

Default login credentials are for Username: **admin** and Password: **Admin123**. They should be changed immediately in My profile section. OpenMRS is accessible by any web browser. Due to that, the first view that any user sees after accessing the system is the login screen, presented on figure 6.1. Below username and password, the user needs to choose a location for the current session that he/she operates on. Once the user is logged in, modules that can be accessed are displayed, as presented on figure 6.2. On top of the screen, the user can see the role that he/she is being logged in as well as the username. From this view, the user can navigate to any of the modules that are displayed.

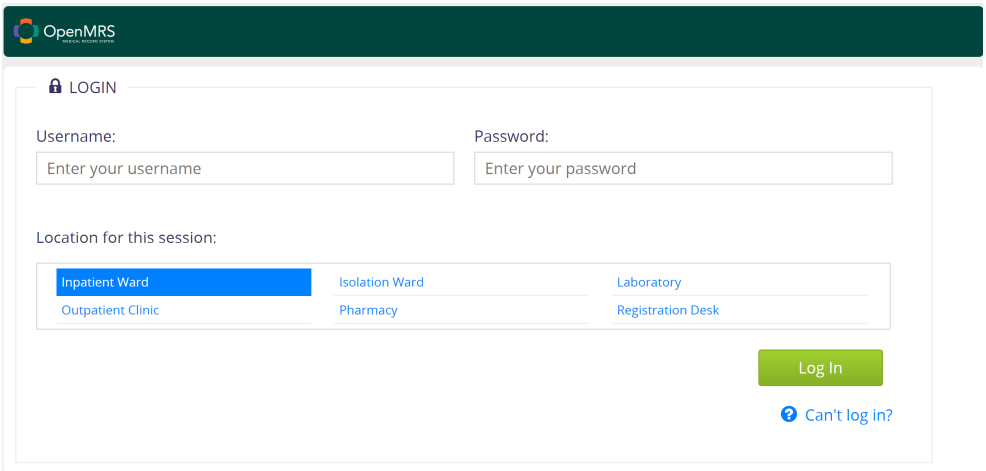

Figure 6.1: Login.

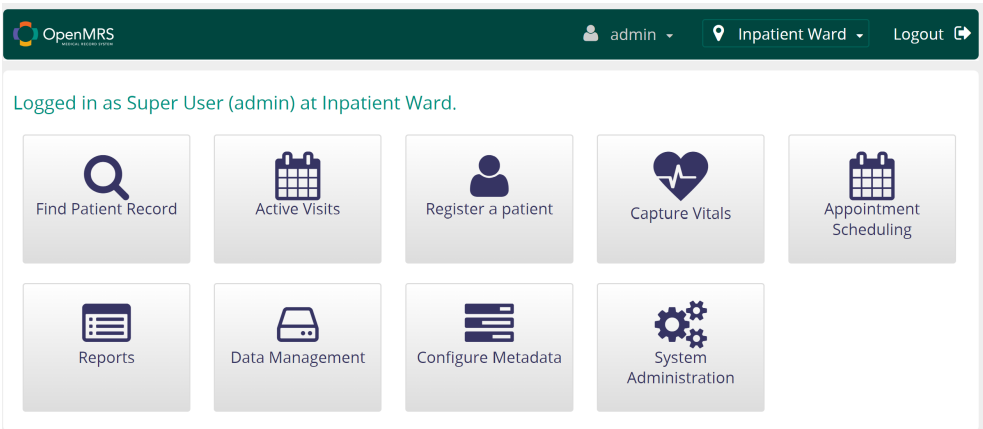

Figure 6.2: Home.

On the new patient encounter, the first step is to provide a personal information about the patient, shown on figure 6.3. In case when such activity is impossible, the opportunity of registering an unidentified patient exists. After the creation, each pa-

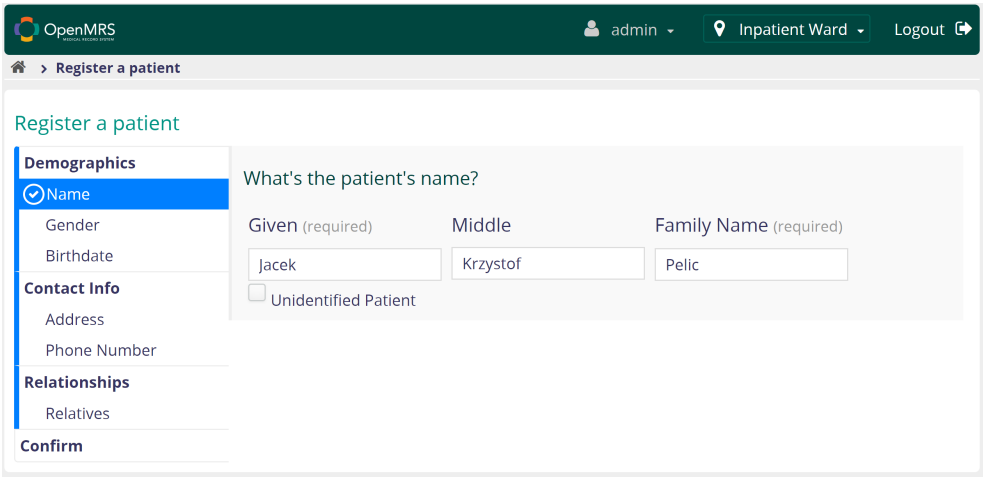

Figure 6.3: Patient Registration.

tient receives a unique identifier visible on the upper right corner of the screen. On the right-hand, quick actions are accessible. One of the options is to ”start visit,” where capturing a patient vitals is possible, presented on figure 6.4. After recording any data regarding the patient, an overview of patient data can be accessed by clicking at the name of the patient. The administration panel offers rich possibilities of customization of the system. From this view, presented on figure 6.5, administrators can add more modules, either provided by the community or own implementations. Administrators also can customize forms, changing data that users should provide, manage users, and perform system maintenance.

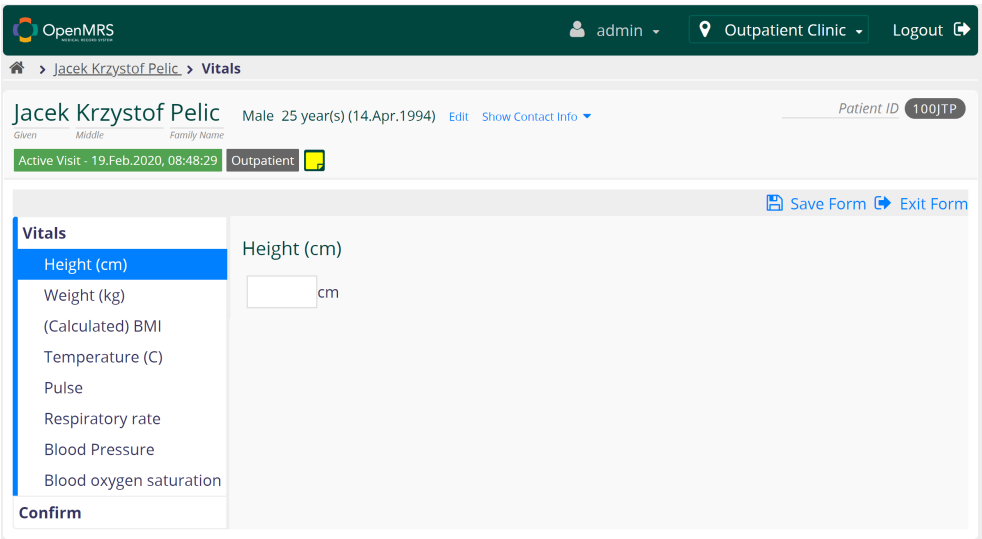

Figure 6.4: Patient Vitals.

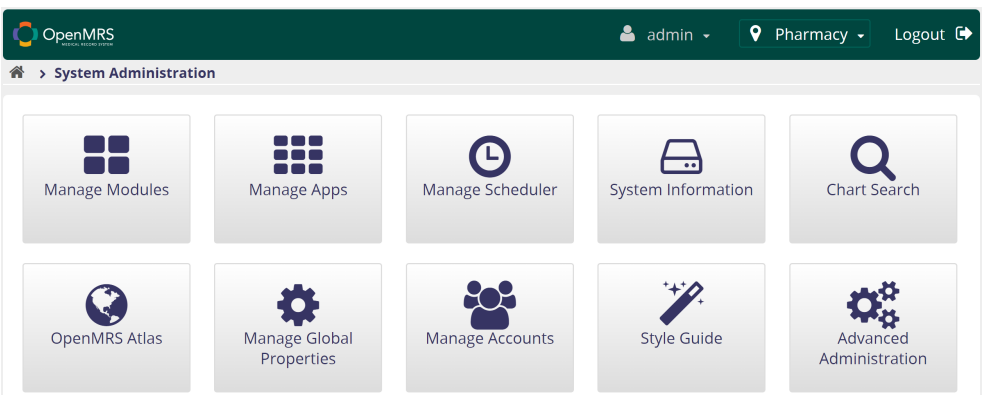

Figure 6.5: Administration.

CHAPTER 7

Discussion

The results align with what has been concluded so far from the scientific world. In developing countries, paper-based systems are still popular. Hospitals see the value of digitalization their systems to increase the performance and reduce the resources required to run a hospital, what has been concluded by Qualitative Content Analysis presented it figure 4.1. Often they struggle with weak infrastructure to do so or knowledge how to. Luckily CSSC or APHTFA, working with hospitals are willing to coordinate the process of digitalization the healthcare, although they also need to be equipped with decision tools.

Introduction of digital Hospital Information System is a complex and challenging operation. Due to the plethora of activities that such a system should handle, there is a need for implementation of a well-thought strategy of deployment. Choosing an appropriate system is burdensome, as there are no universal ground truths. The situation of each hospital differs, and what holds in one scenario may not in the other. Thus it is impossible to enforce a rigid set of rules that each hospital ought to follow.

Acknowledging that the task is not trivial, general recommendations can be of much value. This thesis identified four factors that can be used in choosing the appropriate system. These factors are:

- Modularity - It has been proven that what increases the chances of success is the incremental integration of departments.
- User Friendliness - Especially in the areas with low digital literacy, the system has to be intuitive for the users.
- Flexibility of data - Acknowledging that differences in hospital circumstances differ, the system also has to support a certain degree of flexibility.
- Community support - As Open Source Software can be a more affordable solution than the commercial, the support of such a system can be an issue. To account for that fact, an active community ready to help with various bugs and issues is of great importance.

While there exists plenty of research in the theory of defining criteria of selection for Hospital Information Systems, a little work has been done in taking those to practice and cross-examine available Open Source solutions. This thesis is an attempt to go one step further and deliver concrete system recommendations in the given context.

What deserves to be noted is the fact that data collection period, for the purpose of qualitative content analysis, lasted for a week. Since the data collection demanded in-person visit in Tanzania, there have been limitations as to the number of organizations involved in the dialogue on the matter. Thus it may pose a threat to the generalizability of the outcomes, and larger sample size could be used to assert credibility.

The purpose of this thesis was to answer the question.

- What factors are most important when introducing a new health management system to a hospital in a developing country?

In this thesis author has concluded that the most important factors in the Tanzania context are:

- Modularity
- Usability
- Flexibility of Data
- Community Support

Using these criteria, in the author of this thesis opinion, can be used as a decision tool in the selection of Health Information System among possible solutions.

CHAPTER 8

Summary

This thesis started with a literature review in order to understand the current state of healthcare digitalization in developing countries. After acknowledging the issues sourced from literature, potential ways of optimal evaluation systems have been considered. For better understanding of the Tanzania context, a document "Guidelines and Standards for Integrated Health Facility Electronic Management Systems" issued by the Ministry of Health, Community Development, Gender, Elderly and Children has been carefully studied. During the data-collection period, it became apparent that the document did not hold much value. The government is working on the Health Information System for the hospitals, and public hospitals ought to use it. Thus they will not be beneficiaries of the results of this work. Private hospitals, though, still have the autonomy to choose whatever system they find suitable.

After facing results from qualitative content analysis with a literature review, the assumption of not being feasible to use one rigid solution for all the circumstances has been confirmed. Having that in mind, four factors that had been established by both literature review and results of qualitative content analysis has been concluded: modularity, user-friendliness, the flexibility of data and community support. Based on those four determinants, system analysis of the Open Source solution has been performed, and the most prominent solution has been selected. To verify the credibility of the study, OpenMRS has been tested using a cloud-based testing platform.

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