

UNIVERSITY OF KWAZULU-NATAL

**A FRAMEWORK FOR IOT IMPLEMENTATION IN THE PUBLIC HEALTHCARE  
SYSTEM IN ZIMBABWE**

*By*

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Master of Commerce in Information Systems & Technology**

**School of Management, IT and Governance**

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2019

## DECLARATION

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I, **Kudakwashe Antony Motsi** declare that

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## ABSTRACT

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The study's main objective was to ascertain the viability of implementing a "best practices" implementation of an Internet of Things (IoT) intervention in the public healthcare system in Zimbabwe. The motivation for conducting this study is that currently, Zimbabwe is faced with a huge challenge to meet the healthcare requirements of its citizens. A major source of the problem lies in a lack of coordination between the various healthcare professionals and health management systems that are meant to ensure the optimum availability of expertise and infrastructure so that health related challenges are effectively countered.

An efficient healthcare system will enhance the affordability and access to medical healthcare for many Africans who are in dire need of such services. This can only be achieved if there is an identification of critical areas of healthcare delivery where a technological intervention would provide a new enhanced dimension for the delivery of a quality healthcare service for the citizens of Zimbabwe. Currently, the technological systems are being used in an ad hoc manner with no structured mechanisms for ensuring a coherent, systemic approach to healthcare delivery.

The current study was designed to obtain knowledge of the effectiveness of the current IoT setup that is used in the Zimbabwean healthcare sector. The empirical evidence obtained in the current study was used to initiate the synthesis of a framework based on IoT technology to enhance healthcare service delivery in the public healthcare system in Zimbabwe. The empirical phase of the study

consisted of a qualitative phase where phenomenology was used to obtain insights from medical healthcare professionals into the healthcare system in Zimbabwe. The qualitative phase was followed up by a quantitative phase where the “best practices” framework was presented to a cohort of healthcare professionals for validation by ascertaining the behavioural intention to use the framework. The outcome of the validation phase indicated that 81% of the respondents indicated a high level of acceptance of the proposed framework. Minor changes to the framework were suggested by the study’s respondents and these were incorporated into a refined version of the “best practices” framework for IoT implementation in Zimbabwe.

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## LIST OF ABBREVIATIONS

6LoWPAN	IPVv6 over Low Power Area Network
ADSL	Asymmetric digital subscriber line
BI	Behavioural Intention
C	Compatibility
CHV	Chikungunya Virus
CSF	Critical Success Factors
DICOM	Digital Imaging Communication-in
DOI	Diffusion of Innovation
HDP	Health Device Protocol
HL7	Health Level-7
IoT	Internet of Things
IOT	Internet of Things
IS	Information Systems
IT	Information Technology
ITTA	IoT Technology Transformation Alignment
O	Observability
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
RA	Relative Advantage
RFID	Radio Frequency Identification
TAM	Technology Acceptance Model
WCDMA	Wideband Code Division Multiplexing Access
WLAN	Wireless Local Area Network
XML	Extensible Mark-up Language

YDDAPY	Data Aggregation & Pre-processing Module
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# CHAPTER 1: INTRODUCTION

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## 1.1 Background and Rationale for the Study

The study aimed to make an incursion into the implementation of the public healthcare system in Zimbabwe with the objective of evaluating healthcare professionals' perceptions of the current status of the public healthcare system in Zimbabwe. The intention was to identify critical areas of healthcare delivery where a technological intervention would be provide a new enhanced dimension for the delivery of a quality healthcare service for the citizens of Zimbabwe. It is suggested by Coovadia et al. (2009) that most mortality conditions faced in Africa could be better managed if nations could come up with a common agenda to strategize and build models to leverage innovative technologies to enhance the efficiency of healthcare systems. According to WHO, African healthcare sectors are mainly affected by a number of factors that include extreme inequalities, socio-political / economic instabilities, low ratio of patient to doctor/ nurse ratio, lack or no strategy towards better healthcare innovations and the availability of only a few privately owned healthcare organisations (WHO, 2017).

According to UNDP (2013), Africa consists of most of the poorest countries in the world. As a consequence, most African governments struggle to provide basic needs to its people (such as food, water, health, shelter, education and sanitation among others), resulting in technology innovations to take a “back seat” as a priority. Most countries in Sub-Saharan Africa are affected by diseases, harsh climatic conditions and food security. In terms of Information and Communications Technology indicators across the world, 41% of household have access to the Internet, while Africa is lagging far behind with only 7% that have access (Pushak and Briceño-Garmendia, 2011).

From a broader perspective, these challenges provide an opportunity for the advent of government controlled technological interventions that enable better healthcare services. This can be achieved by establishing a collaborative environment between healthcare professionals and IT professionals with the main beneficiaries being the citizens of a society that are in need of medical healthcare services that are convenient to access and abides by the highest quality standards. According to Magnussen et al. (2004), a renewed approach to healthcare should be centred on informatics, hospital decentralised models promoting home care centric solutions and optimised data management.

The drastic changes that are happening to the African consumer user behaviour towards the appreciation, acceptance and adoption in technology has indicated that there are potential opportunities for a market that is ready to engage in technology that is perceived to solve their day to day problems. According to Asongu (2018), the use and access of mobile telephony in sub-Saharan Africa has drastically improved and the indications are that this trend will continue unabated for the years to come. Observations with regards to the problems faced in healthcare systems in Africa coupled with the rising usage of the internet and smart phones indicate an opportunity to merge the domains of healthcare and smart technology to solve the problems being faced by the African healthcare sector (Asongu, 2018). According to Masinde (2014), although cellular penetration is higher than 63% and this may still be lower than in the developed countries, mobile broadband costs less than half of fixed broadband in Africa. This may explain how African countries may leapfrog development through Internet connectivity using mobile phones, a phenomenon that is unlike other developed countries that have built landline infrastructure and then migrated on to mobile. Innovative utility applications have converted mobile phones in Africa into Automatic Teller Machines (ATMs), clinical officers, agricultural extension officers, tutors and landlines. This growing unique cultural aspect to mobile usage in Africa is what makes it possible to have phone access levels

that are much greater than the cell-phone penetration levels. This culture of sharing is being leveraged by creating successful innovative solutions to problems facing communities in Africa (Asongu, 2018).

Ben-Zeev et al. (2013) suggest that technology innovation should be followed by technology adoption / adaptation otherwise the efforts of the innovation become pointless. Furthermore Ben-Zeev et al. (2013), suggest that African countries should not simply rely on importing the IoT technology from western countries and adopting it. Rather, Africans should be in a culture to innovate their own relevant technology. It is preferable to adopt the innovation route because IoT has great potential in solving many unique problems facing Africa especially in the area of environment management, healthcare and security. As explained above, considering that Africa has very unique opportunities and challenges, only home-grown solutions built by or in consultation with the rest of Africa, will succeed (Ben-Zeev et al., 2013).

However the use of technology in the medical field has its own challenges. According to Wager et al. (2017), the health care industry is one of the most information intensive and technologically advanced in the common society. Despite the need for administrative and clinical information to facilitate the delivery of high-quality and cost-effective services, most organizations still function using paper-based or otherwise have insufficient information systems (Wager et al., 2017). There are many reasons why this situation exists, not the least of which is that the health care industry is complex, both overall and in many of its functions (Dlodlo, 2013). Complexity and the structure of health care organizations, both individually and as a group, make it very challenging to implement health care information systems and IT effectively. This complexity poses challenges for both the purchasers and vendors of health care information systems and related IT products and services (Wager et al., 2017). Among

some challenges of using information technologies in healthcare the rise and impact of cyber-attacks that threaten investment of technologies such as the case when the “WannaCry Ransomware” virus attacked Britain’s National Health Service (NHS). It was reported that computers, MRI scanners, blood-storage refrigerators and operating room equipment were affected and in many instances, these vital healthcare devices were rendered to be dysfunctional (Ehrenfeld, 2017).

There are numerous other challenges that may affect implementation of technology in healthcare systems. According to Wager et al. (2017), the health care industry consists of large numbers of very small organizations of where the majority of physicians practice in one- or two-physician offices. The small size of these organizations makes it difficult for software and hardware vendors to make a profit from them, where the vendors cannot charge much for their applications making it difficult for them to recover the costs of selling to small organizations and providing support to them. As a result most major vendors often avoid small organizations (Wager et al., 2017).

So far in Zimbabwe there are very few case studies of IoT usage as yet. However, one of the exceptions is the case study by Bennet et al. (2019) who used RFID technology for the remote monitoring of livestock. In a similar study, Gunda et al. (2012) investigated the use of RFID technology to assess the viability of using electronic toll gates to help in the collection of toll fees. In both these studies, it has become apparent that the minimalist technology infrastructure required to implement RFID technology ensured that using such technology in Zimbabwe was highly viable. The technology itself is quite simple and essentially consists of a remote sensor made up of an integrated circuit of basic processing and an antenna to transmit data from an RFID tag. In the context of the healthcare system, RFID tags can be used to collect vital medical data from a patient such as body temperature, blood pressure and



heart rate and transmit this data to a centralised software application that sends this information to a healthcare professional in real time.

According to a global study by Isma'ili et al. (2017), detecting mechanisms are one of the key areas that have been proposed for the efficient use of IoT in healthcare. As an example, ambient sensors may be used to monitor the health of patients who are “home bound” because of health issues. Low-energy wireless connectivity can be used even in remote areas in Africa due to the cheap cost that is conventionally associated with installation. However, the drawback could be in the availability of the network capacity to make these solutions feasible. Around the world wearable sensors have started to be used in the healthcare industry. Therefore there is an opportunity for such medical monitoring devices, in combination with ambient sensors and body detecting mechanisms, to easily monitor and track the health of the patients even in African remote areas. This will cut several indirect and direct costs, such as reactivity time and patient’s mobility to the hospital to get treatment. In addition, these technologies can provide the patient with immediate and accurate access to health monitoring services even in remote areas (Isma'ili et al., 2017). According to Ben-Zeev et al. (2013), IoT opens up opportunities to African problems therefore, it is key to incorporate some implicit elements of cultural transfers and mutual learning. However, according to Ben-Zeev et al. (2013), the baseline challenges of IoT such as security, standardisation and integration of the ‘things’ remain a common problem that require solutions emanating from the academic sector.

The study’s empirical phase was designed to obtain knowledge of the effectiveness of the current IoT setup that is used in the Zimbabwean healthcare sector and use this empirical evidence to identify and propose a framework that encompasses an improvement and enhancement of the current practice. The synthesis phase of the study entails the development of an IoT “best practices” framework for the public healthcare sector in Zimbabwe. This best

practices framework was then validated by subjecting it to a mini-adoption study where the respondents in the study consisted of healthcare professionals in Zimbabwe who are familiar with the implementation of RFID technology to enable the delivery of quality healthcare.

## **1.2 The Internet of Things (IoT) Intervention in Healthcare Systems**

Healthcare access is one of the most essential human rights that each nation, government and intergovernmental organisations aim to observe and promote. Two international organisations that are sensitive to world health issues are the United Nations (UN) and the World Health Organisation (WHO, 2017). A core function of these organisations is to stimulate funding and engage in process innovation that enhance the efficiency of the global healthcare ecosystem. A sad indictment of the healthcare system in many African countries is the inability of these systems to handle the scourge of health-related challenges resulting in numerous fatalities that may have been avoided. A major source of the problem lies in a lack of coordination between the various healthcare professionals and health management systems that will ensure the optimum availability of expertise and infrastructure so that health related challenges are effectively countered. An efficient healthcare system will enhance the affordability and access to medical healthcare for many Africans who are in dire need of such services. According to Rose et al. (2015), by 2020, there will be almost 100 billion internet-connected medical monitoring devices because of the perceived value these technologies currently add and will add to human lives in the near future. Luqman and Van Belle (2017), further suggest that in Africa, IoT is predicted to reach mainstream adoption by 2020 and have a major disruptive impact on communities and local businesses. South Africa in particular is reserved for significant benefits from the IoT in terms of addressing the country's socio-economic needs (Luqman and Van Belle, 2017).

An elucidation of Internet of Things (IoT) technology is provided by Gubbi et al. (2013), suggests that IoT entails an interconnection of sensory medical monitoring devices. These devices act as remote data sources that enables the sharing of information across a technological platform that is universally accessible by applications that rely on real time data to provide innovative solutions to problems as they occur. According to Ward (2013), the emergence and applied use of the IoT has created a new dimension for the use of technology,

enabling a huge potential to transform the medical field. According to Rohokale et al. (2011), an IoT intervention has the potential to promote ubiquitous access to healthcare thereby serving as a viable solution to alleviate the healthcare crisis in Africa. An immediate possibility is the use of IoT technology to engage in remote monitoring of patients thereby generating 'big data' that enables the use of techniques such as big data analytics to create early warning systems that identify health related threats to a community well in advance of a disaster actually occurring. Currently the implementation of the IoT in Africa faces challenges because of the low internet penetration rate and poor internet connectivity. However, the much improved technology infrastructure in many African countries has provided a viable platform for these countries to benefit from an IoT strategy.

According to Kulkarni and Sathe (2014), IoT applications in healthcare can be categorized into four domains namely; enterprise, personal healthcare, utilities and mobile. Personal healthcare IoT is at the scale of an individual, enterprise IoT at the scale of a community, utility IoT at a national or regional scale and mobile IoT which is spread across other domains due to nature of connectivity and scale. The categorization depends on the type of coverage scales heterogeneity, network availability, impact, user involvement and repeatability. The main contributor of IoT can be attributed to the growth of smart phones and tablets which act as an agent to link patients with doctors in the IoT world, also with an ability to deeply change the delivery of health services (Hughes, 2017). IoT has dynamic capabilities to associate humans, smart medical monitoring devices, machines and dynamic systems which gives effective healthcare (Kulkarni and Sathe, 2014). Smart, connected systems can evaluate patient conditions from many perspectives. They can assist "intelligent hospital decisions", in real time and save lives. However, there is also the prospect that the system may generate inaccuracies with regards to healthcare reporting. For example, if there is a lack of proper infrastructure, reading errors from any specific device may go unverified resulting in too many false alarms that cause a lack of confidence in the IoT based system. There is still a need for medical staff intervention and monitoring to ensure the integrity of the system (Kulkarni and Sathe, 2014).

The current study has a plan to mitigate the chance of errors by establishing a set of critical success factors for the optimal use of an IoT strategy to enhance the healthcare infrastructure in Zimbabwe.

### **1.3 Research Problem**

According to Murugadoss et al. (2019), the healthcare sector is the most important sector for supporting any social and economic setting in today's modern system. In the context of the Zimbabwe, Mudadigwa (2016) warned that the health sector in the country is deteriorating at an alarming rate with some hospitals having a highly abnormal patient-doctor ratio of 1:12,000 compared to the 1:200 prescribed by the United Nations. According to Zim Health (2017), Zimbabwe has been facing a huge human resources capacity constraint in the public health sector that severely constrain efforts to provide a quality healthcare service in the country.

The challenges faced in the healthcare sector have a few similarities to the general industrial sector where there has been a slight improvement as a result of the intervention of technologically based systems. Over the years, industries have been "disrupted" by greater use of technology that provide an easier way to interface with customers, capture information, process and store information so that accurate results can be provided in a timely manner (Rohokale et al., 2011). Currently the emergence of technological solutions such as IoT , Big Data and Artificial intelligence provide a major opportunity for investigations on how these technologies may be used especially in the disadvantaged communities, in order to mitigate the challenges they face (Murugadoss et al., 2019). Particularly, societies in environments with disadvantaged backgrounds such as those on the African continent need to leverage on the capabilities of technologies such as IoT that provide solutions to the challenges experienced such as in the healthcare sector where there is a lack of doctors, medical equipment, unavailability of hospitals and lack of access to general healthcare facilities (Dlodlo, 2013).

Based on the preceding argument, the current study has been undertaken with the intention of exploring the viability of using technology in the form of the IoT in the healthcare sector. The study's main outcome was to propose an IoT based solution that could connect all the available necessary medical resources to perform remote monitoring, diagnosing and

reporting of the status of Zimbabwean patients to medical experts so that a medical intervention can be initiated timeously and efficiently.

#### **1.4 Justification for the Study**

The study is designed to make a contribution to the current body of knowledge on the use of a technologically enabled intervention to improve the quality of healthcare services. In the context of the African continent and specifically, the case of the Zimbabwean Public Healthcare sector, such a study will make a vital contribution towards an improvement in the quality of healthcare services. The researcher has also realised that there is an opportunity to leverage the willingness of vital stakeholders such as medical professionals and technology experts to develop a solution in the Zimbabwean context that also has a relevance to the African continent and possibly to the global domain as well.

#### **1.5 Research Questions**

**Main Research Question:** How can experiential knowledge of Zimbabwean healthcare professionals be leveraged to develop a “best practices” framework for the implementation of IoT technology to enhance healthcare services in Zimbabwe and what is the intention to adopt such a proposed framework?

- What are the perceptions of Zimbabwean healthcare professionals of the current implementation of IoT technology as an enabler to provide quality healthcare in the public healthcare system in Zimbabwe?
- How can the experience of current usage of IoT technology by IT healthcare professionals in Zimbabwe be leveraged to develop a “best practices” framework for the implementation of IoT technology to enhance the delivery of public healthcare services in Zimbabwe?
- What is the behavioural intention of medical healthcare professionals in Zimbabwe *to adopt a best practices framework* for the implementation of an IoT strategy to enhance the quality of healthcare service delivery in Zimbabwe?

#### **1.6 Main Research Objectives**

The study’s main objective was to *propose a framework for the implementation of an IoT based framework to enhance medical healthcare in Zimbabwe*. This objective will be achieved by structuring the study according to the following sub objectives:

- Determine the perceptions of healthcare professionals towards the current implementation of IoT technology to enhance public healthcare service delivery in Zimbabwe.
- Develop a best “*practices framework*” based on IoT technology to enhance public healthcare service delivery in Zimbabwe.
- Determine the intention of medical healthcare professionals to adopt the proposed best practices IoT based framework to enhance public healthcare service delivery.

### **1.7 Limitations of the study**

The “cutting edge” nature of the topic makes it difficult for the researcher to establish a solid theoretical and literary grounding for the discussion that will unfold in the thesis. There have been very few academic resources that attest to the use of IoT technology in the healthcare sector. These factors may render much of the discussion to be not academically relevant because of the greater focus on practical elements that are introduced in the synthesis phase of the study. This limitation has been somewhat minimised by the researcher by making academic references to the use of IoT not just in the health sector, but in society in general. The other limitations of the study pertain to the empirical phase of the study. The confinement of this phase to the case of the Zimbabwean Public Healthcare sector compromises the generalisability of the study’s main outcomes. At this stage, this limitation is somewhat neutralised by the researcher’s immediate intention to provide a solution that is applicable to the Zimbabwean context. It should be noted however, that the Zimbabwean economic and healthcare situation is concordant with many countries on the African continent thereby increasing the study’s realm of applicability. Also, the validation phase of the study required respondents who are healthcare experts and also have knowledge of the use of technology. Finding such an audience was not easy. The researcher did however minimise this shortcoming by leveraging personal working experience and knowledge within the Zimbabwean Public Healthcare sector to identify and “recruit” the most appropriately qualified individuals to provide input into the study.

## 1.8 Outline of the Study

**Chapter One-Introduction.** Provides an introduction and overview of the study mainly focusing on “demystifying” the study’s importance and relevance. This chapter also presents the study’s main research questions, objectives and limitations. The chapter also provides an outline of the sections that are covered in the rest of the paper as indicated below.

**Chapter Two- Literature Review and Theoretical Framework.** The study’s literature review is presented in Chapter Two. The literature review provides an academic foundation that introduces IoT technology and provides a critical review of its use in society and the medical healthcare sector. There is also a discussion of similar IoT based healthcare interventions that have been implemented in other countries in the world.

The Theoretical Framework discussion entails a critical justification of the researcher’s choice of theoretical models to underpin the main phases of the study. This discussion is centered on the use of phenomenology to underpin the qualitative phase of the study and a combination of technology acceptance models (Diffusion of Innovation and Technology Acceptance theory) to underpin the quantitative component of the study.

**Chapter Three: Research Methodology.** This chapter discusses the research methods used to craft the design of the study. The research methodology is driven by the Sequential Exploratory Research design framework proposed by Cresswell (2013). The study’s research design is based on a qualitative 1<sup>st</sup> phase that leads to a 2<sup>nd</sup> phase where the researcher synthesises a solution and a final phase where the solution is subjected to a quantitative validation phase.

**Chapter Four: Qualitative Analysis and Presentation.** The detailed qualitative analysis conducted in the study warranted the allocation of an entire chapter for this phase. The researcher discusses the intensive use of qualitative data analysis techniques such as thematic analysis in conjunction with the advanced use of qualitative data analysis software to aggregate the qualitative data collected. This phase of the study provides clear guidelines for the study’s next phase which entailed the development of a technology based solution.

The technologically-oriented, IoT based solution which was the current study’s main output is also presented in this chapter.

**Chapter Five: Quantitative Analysis and Presentation.** This chapter entails a quantitative validation of the solution proposed in Chapter 4. Technology Acceptance theory is used as the underpinning theory behind the development of a survey based instrument that formed the main area of discussion in this chapter. The researcher conducted tests of correlation and significance to ascertain the validity of the responses received.

**Chapter Six: Conclusion and Recommendations.** This chapter provides a reaffirmation of the study's main research questions and an explanation of how these questions have been answered. There is also a discussion of areas of improvement where the validity of the study could be enhanced as well as a discussion of areas of future research into the use of IoT technology in the healthcare sector.



## **CHAPTER TWO: LITERATURE REVIEW & THEORETICAL FRAMEWORK**

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### **2.1 Introduction**

According to Boote and Beile (2005), an in-depth, sophisticated literature review is the basis and stimulus for extensive and useful research. The complex nature of scholastic research requires such thorough and sophisticated reviews. Creswell and Creswell (2017), suggest that the literature review should meet three criteria: to critically analyse the study to the ongoing arguments in the literature, to present results of similar studies and to provide a framework for comparing the results of the study with other studies. Therefore according to Bloch and Richins (1983), there is an imperative to sequentially aligning the literature review, the research objectives and the theoretical framework so that they are coherent with the study's hypotheses and findings.

Therefore in order to develop a collective understanding, the current chapter provides an elaborated "view" of the need for the study as well as the current state of IoT implementation. A critical review of the advantages and disadvantages of implementing an IoT based intervention is discussed. The study's main theoretical frameworks are presented and critically analysed in the latter sections of the current chapter.

### **2.2 The Need for a Technical Healthcare Solution in African Countries**

According to Rohokale et al. (2011), the death rates due to the absence of timely available medical treatments are high in developing countries particularly in Africa, as compared to developed countries where efficient response systems ensure that emergency services are always available thereby minimizing the mortality rates that arise out of emergency situations. A viable solution in African countries is to leverage internet based technology for better health monitoring and control of patients with infectious diseases as well as the monitoring of vital medical indicators (Rohokale et al., 2011). In Zimbabwe, according to Muza (2019), the Crude Death Rate (CDR) of the year 2012 preceding the census was 10.2 deaths per 1000 population. The trend shows that this rate is higher than

the 1992 rate of 9.5 but lower than the 2002 rate of 17.2. These facts present a cold and stark reminder that some sort of urgent intervention is required.

According to the WHO (2017), due to challenges faced in Africa, there is a need to transform the public health system to an integrated and comprehensive national service. Essential facets of primary healthcare are not yet in place and there is a significant human resources catastrophe facing the health sector in these countries. Certain viruses like Human Immunodeficiency Virus have contributed to and have hastened these challenges (Vashi et al., 2017)

In a survey to determine the e-health readiness of hospitals in the North West province of South Africa, Dlodlo (2013) concluded that urban hospitals in South Africa have better access to medical technology as opposed to rural hospitals. One of the main reasons for this phenomenon is the reliability of the internet connection where the discernible trend is that there is greater reliability in urban hospitals. However in rural hospitals, the connectivity and speed of internet services are affected by the interruption of the electricity power supply and poor telephone lines. The average ratio of machine to doctors in rural hospitals is 1:3 whereas it is 1:2 in urban hospitals. Alarmingly however, technology is not used in a sophisticated manner in the urban areas. Medical staff use technology mainly for sending emails, for revenue collection and capturing patients' demographic information. There is no indication that technology is used for advanced functions such as e-consultation, patient e-health record systems, e-referrals, e-training and e-prescription in both rural and urban hospitals in South Africa. Furthermore the IT systems are not integrated to work together across and within hospitals to allow healthcare professionals to gain benefits of e-health solutions and applications. Dlodlo (2013), concludes that these findings indicate that throughout South Africa and other African countries, the e-health maturity curve is close to the zero level with little prospect of getting any better (Dlodlo, 2013).

### **2.2.1 ICT Infrastructure in Zimbabwe**

According to Gwaka et al. (2018), in spite of Zimbabwe's economic and political situation, it has sustained parity with other Sub-Saharan African countries averages for many ICT indicators. As of the first quarter 2018, Zimbabwe's mobile penetration was at 84.6%.

However the mobile penetration rate lagged due to continuing network underinvestment as a result of the country's economic situation. But the telecommunications market more than doubled in 2016, stimulating mobile subscriptions to 24 per 100 people thereby reducing the gap between Zimbabwe and the rest of Sub-Saharan Africa. Despite reforms that were put in place, the level of competition in the telecommunications industry in Zimbabwe remains low. There are only four Internet service providers. These are Econet, Telone, Telecel and Netone and only Telone is a fixed-line operator. Currently the Econet wireless infrastructure dominates the mobile market with a 84.2% market share as of the fourth quarter of 2017. The fixed operator Telone and Net-One (its mobile subsidiary) are state owned (Mpondi, 2018).

According to Kaira et al. (2017) fixed broadband access in Zimbabwe is expensive, and is almost twice as much as the other Sub-Saharan countries. Internet-access penetration in Zimbabwe is at an average level in the Southern African region. There is no full official data on the number of Internet users in Zimbabwe(Kaira et al., 2017). However, the Zimbabwe All Media and Products and Services Survey found that 22 percent of urban dwellers aged 15 years and older used the Internet in mid-2016. This totals around 645,000 people or 5.1 of the total population. According to Mpondi (2018), in 2017 a total of 15 220 000 Terabyte of data was used in Zimbabwe. In Mpondi (2018) it is also mentioned that international connectivity is a challenge in Zimbabwe mainly because of its landlocked situation and the only way this can be circumvented is via the use of satellite technology. In terms of infrastructure development, activities are under way to build national fibre networks to obtain cross-border connectivity to an undersea fibre cable. Telone is building a fibre-optic cable from Harare to one of Zimbabwe's main cities; Mutare, which is located at Zimbabwe's eastern border where it is intended to connect to a submarine cable in Mozambique (Mpondi, 2018). Also, Econet is building a nationwide fibre-optic cable backbone with branches planned for connection to the undersea fibre systems in South Africa and Mozambique. If these initiatives achieve completion, they would create sources of international bandwidth and would also enable a reduction in the retail broadband prices and bandwidth costs. Wireless broadband shall also create greater competition with Econet having launched WiMAX and 3G networks while Telone and Powertel have installed CMDA 2000-based high-speed wireless networks (Mpondi, 2018). Mobile telecommunications is the best hope for extending connectivity to most

Zimbabweans (Kaira et al., 2017). Telecel reports its network has coverage of 68 percent across the country, while Econet state that almost all rural and most urban areas have been covered. According to Mpondi (2018), Zimbabwe is thus close to reaching its technology infrastructure coverage gap, which has been calculated in 2015 to be at 13 percent. The coverage gap represents the fraction of the population living in areas that may not be commercially worthwhile and require some level of open investment or subsidy (Mpondi, 2018).

According to Tsokota and von Solms (2013), in Zimbabwe there is a lack of institutional ICT policies and standards that guide ICT integration among systems. It is however, quite vague as to how the ICT software and hardware are being utilised in businesses. Some organisations supplement the use of technology through traditional methods such as physical paper files for data capturing or storage in an attempt to be operational. With the exception of a few services, currently most businesses in Zimbabwe use paper for data collection and data storage and there is very little evidence of automation. These traditional paper based techniques are cumbersome, costly to the economy and creates opportunities for corruption and general dissatisfaction with the level of efficiency that can be delivered. These challenges have resulted in information redundancy, duplication and poor system synchronisation. The slow internet speeds in Zimbabwe have resulted in a considerable loss of opportunities for the full benefits of utilisation of ICT. In Zimbabwe most organisations use computers mainly for accessing the internet, data collection and storage and internet usage is still largely restricted to faxes, email usage, searching for suppliers and visiting suppliers' websites and in a few cases it is used to make online payments (Tsokota and von Solms, 2013). Hence, it has become apparent that there is limited utilisation and an ineffectual use of technology in Zimbabwe. However, there has been an intensive growth in the use of the mobile money service by all the three Zimbabwean mobile service providers for transferring, receiving and paying of services using mobile phones. This service does have its limitations because mobile money transfer are not used for international business and online payments (Tsokota and von Solms, 2013). If robust ICT policies could be implemented that enable digitising all sectors of the economy the weak ICT utilisation would be eradicated and increase the opportunities especially in the healthcare sector and generally to the economy as a whole (Tsokota and von Solms, 2013).

### **2.2.2 Healthcare system in Zimbabwe**

According to Zim Health (2017), the public health system is the largest provider of healthcare services in Zimbabwe, complemented by missionary hospitals and healthcare delivered by non-governmental organizations (NGOs). Mudadigwa (2016), explains that citizens travel long distances to access healthcare in hospitals and clinics despite constitutional provisions that obligate the government to provide this basic right to its citizens. Zimbabwe is facing serious socio-economic complications, a situation that has resulted in various challenges in health institutions, including a critical shortage of doctors and nurses. According to Mudadigwa (2016), there are clear indications that the health sector in the country is deteriorating at alarming rates with some hospitals having an exceptional patient-doctor ratio of 1:12,000 compared to the 1:200 prescribed by the United Nations. According to Zim Health (2017), Zimbabwe has been facing a huge human resources capacity constraint in the public health sector. Replacing doctors who have left the system and administering to the needs of the doctors and nurses currently in the system has been difficult. WHO (2017), suggest that the situation reached breaking point in 2008 when the health practitioners engaged in prolonged industrial action, which resulted in very limited services being offered in communities and health facilities. The retention program introduced in 2009 partially resolved the human resources issue, however only for the lower level practitioners; there is still a shortage of highly experienced and qualified technical staff as of 2017 (WHO, 2017). The ramifications from these challenges were confirmed when there was a major outbreak of cholera in 2009, where 98,591 cases were reported and documented and this catastrophe resulted in 4288 documented deaths (WHO, 2017).

According to Zim Health (2017), Zimbabwe faces political instability and economic decline that have resulted in a reduction in healthcare budgets, affecting medical provisions at all levels. In the past five years, there has been an approximate 40% drop in healthcare coverage. Firstly, the chronic malnutrition limited the life prospects of more than one third of the Zimbabwean children. Secondly; the country continues to experience a heavy problem of preventable diseases such as malaria, HIV infection, tuberculosis, diarrhoeal diseases, vaccine-preventable diseases and health issues affecting pregnant women. The child mortality rate stands at 1:11 meaning that one in every 11 children dies before his or her fifth birthday

suggesting that 35,500 Zimbabwean children under the age of five die every year (Zim Health, 2017). In addition to skills gap, also the health sector faces other challenges such as eroded infrastructure with old and obsolete equipment in hospitals such as dysfunctional laundry machines, hospital equipment and sanitary; and a lack of commodities and essential medicines (Zim Health, 2017). The deteriorating health-care services in Zimbabwe's coincided with a fall in demand for services, following the introduction of consultation fees. These fees, which are applied in an ad hoc way and so differ per service providers. According to UNICEF (2011), this acts as a barrier to access basic health services for many of the most vulnerable public in Zimbabwe.

Combining these challenges, the health-sector needs a prompt recovery plan that reverses the decline in the performance of the country's healthcare system, especially as it impacts on universal access to primary healthcare for vulnerable citizens. The strategy for recovery includes tackling all levels of health that includes the financial requirements as well as enhancing access to basic medical essential medicines and equipment; taking initiatives to retain and attract health workers in the public health sector; and setting foundations for an investment policy to fund the development and rehabilitation of the health-services infrastructure (Zim Health, 2017).

### **2.2.3 IoT Technology in Healthcare as a Possible Solution**

While the intervention of IoT may not necessarily be seen as a panacea to the healthcare crisis in Zimbabwe and Africa in general, it provides an opportunity for the medical fraternity to leverage technological innovations such as IoT to explore the possibility that such an intervention will alleviate many of the operational aspects of the crisis. According to Ullah et al. (2016), the primary aim of IoT technology is to extend the applicability of the Internet to include remote control communication so that constant connectivity and data sharing will enable the provision of a dynamic response to healthcare related issues. IoT also enables healthcare service providers to personalize patient care by enabling business analytics, making it possible to capture massive amounts of patients' data (Lee and Lee, 2015).

Prior studies on IoT involvement in healthcare have been focused on the technical aspects of IoT implementation. However, limited studies have addressed the critical socio-

technical factors that need to be considered to enable the chances of success of IoT implementation for medical healthcare in an African environment. From a technical perspective, there are studies that have simulated the implementation IoTs in a healthcare system. Such as an example of an IoT based study is that by Jara et al. (2013) where a remote monitoring system was proposed to enhance the provision of healthcare services by integrating the system with the hospital information system using supporting infrastructure such as integration platforms and knowledge management systems.

According to an experimental study by Sood and Mahajan (2017), a solution of using IoT was developed and deployed to solve the medical crisis caused by the Chikungunya Virus (CHV), to assist the mainly affected areas in countries such as Brazil, Kenya, Bolivia and Columbia. This vector borne disease spread quickly in geographically affected areas. An IoT assisted fog health monitoring system was used to identify infected users from CHV in an early phase of their illness so that the outbreak of CHV could be controlled. The use of Fog computing provided many benefits such as low latency, location awareness, high mobility, minimum response time enhanced service quality and notification service itself at the edge of the network. The experimental results indicated that it was far more advantageous to use the combination of IoT actuators, fog computing and cloud computing services together for achieving high quality of service and network bandwidth efficiency, minimum response time in the generation of real time notification as compared to a cloud only model (Sood and Mahajan, 2017).

A study by Dlodlo (2013), evaluated challenges that faced the health sector in South Africa, were there was a shortage of health professionals, poor communication, inefficient health record management between the various health entities, and poor disease control and surveillance. Dlodlo (2013) reports on possible applications of IoT technologies that could contribute to an efficient health sector, by impacting on the challenges recognised. Suggested in this paper was that IoT technology may have a positive impact on diseases or conditions such as chronic medication, oral health, baby care, the aged, telemedicine, disease surveillance, occupational health management, sport and fitness, heart disease, emergency services, community home-based care, mental health, nutrition and diabetes management.

The Dlodlo (2013) study provided an academic justification for the use of IoT technology as a possible contributor towards enabling sustainable health service delivery for South Africa.

A practical case study was conducted by Hughes (2017), in the Kikwit province of Congo to monitor blood transfusion temperatures using IoT technologies. Due to limited infrastructure and the unreliable electricity access, a low cost networking infrastructure was installed. The network provided long range geographic coverage to enable the implementation of the IoT based intervention. From a technical specifications perspective, LoRa radio technology was used to enable IoT based monitoring of vital patient health indicators such as blood pressure and heart rate. This kind of monitoring was now made possible in an environment where there was previously little or no existing infrastructure. A Multitech Conduit MTCDT-H5 gateway equipped with the LoRa mCard were used to provision the base station infrastructure. In order to enable the gateway to operate continuously without being affected by power outages an independent 150 W solar panel with a 100Ah battery was installed. For the sensing medical monitoring devices, microchip RN2483 LoRa were connected to a PnP board that allowed up to 3 sensors to be connected; a solution of low power and long range operation that was compatible to the LoRa radio technology was used. Results of this pilot indicated several limitations to the project. These challenges included a lack of networking experience, the informatics literacy of local people hindered sufficient transferral of knowledge and skills to allow local actors to enable continuity in applying the technology. The local health practitioners had little experience with the use of computers that immensely impacted the adoption scale. Hughes (2017) made a suggestion of using education as a tool to obviate the information literacy problem. The educations should include training on networking and emerging IoT technologies and their local applications as part of informatics courses for medical students in local universities. This intervention will address the need to foster local IoT innovation and experimentation. Results of this study also indicated that the effective range of the PnP –medical monitoring devices are not consistent with covering the intended radius of the LoRa gateway. This attributed to interferences in the operational environment. (Hughes, 2017).

An investigation by Luqman and Van Belle (2017), explores the human factors that influence the adoption of IoT-based services in the informal settlements of Cape Town. The



objective of the study was to identify the human factors that are likely to influence the adoption of IoT-based services in informal settlements in the City of Cape Town in South Africa. The outcome of the study will be pivotal in assisting policy makers to understand the influence of IoT technology in enhancing healthcare service delivery especially in situations where there is a lack of proper technological infrastructure. The study leveraged a qualitative research approach and used interviews as the source of primary data and thematic analysis as the main strategy for data aggregation, analysis and interpretation. Three services were used in this study as tangible examples of an IoT-based service. The first service was an early fire detection and warning system; all residents interviewed were well aware of the shack fires that often occur in informal residences. The second service was a technology of detecting and warning if there was water contamination at the water source (which is typically a communal tap). This service was a vital resource to the citizens considering that not all residents were educated of potential waterborne diseases. The third service was a technology of detecting and warning citizens of crime related activity in a particular area; several residents expressed concern over their security. Five themes emerged in this study. These were: Affordability of technology adoption; Care for the community; Scepticism in either the technology or service use; Basic needs and fulfilment and concern for physical safety and security. The findings indicated that having basic needs satisfied plays a key role in the adoption of each of the three services described. Respondents indicated that they would not use the service because they would rather first need to buy food if such as service came with a cost, therefore linking basic needs to affordability. Another factor that came out as a key role is factor of safety and security. Inhabitants live in fear of the crime around them and any early warning detection system was welcomed as a positive intervention. It should be noted that the qualitative nature of the study resulted in a lack of generalisability because of the small sample size. A further theme named “Ubuntu”, reflecting a spirit of community cohesion also emerged from the study. There is likely higher chances of adoption IoT or any technology if it benefits the community as a whole rather than targeting individuals. As an example, a device could be engineered to be installed outside or in an area that warns multiple residents. The last finding was, understanding how the informal settlement community leadership influences the residents’ adoption of technologies or technology-enabled services would also be a recommendation for future research. However barely any resistance to the IoT-based technologies was encountered

in this study and much of the reluctance to adoption could be “smoothened” over time with support and education. Luqman and Van Belle (2017) suggests that it is clear that the physical environment and complex human dynamics in which IoT-based services would be deployed needs to be taken into account (Luqman and Van Belle, 2017).

Blaya et al. (2010), suggests that despite major improvements in the use of technology in recent years, most large e-health implementations have little or no evaluation data. According to Blaya et al. (2010) most studies have been limited; focusing on progression indicators rather than patient outcomes, or on the attitudes of users and patients; and has been performed mainly by academic groups. This creates a challenge when it comes to obtaining a true evaluation of an e-health intervention. A possible solution is to mandate IoT service providers to include an assessment or evaluation option for the users of electronic health systems. Considering that the evaluations are important indicators of healthcare success, an evaluation option becomes a necessity in all IoT healthcare devices (Blaya et al., 2010).

Another useful study was conducted by Prakashan et al. (2017), who discovered the potential of rolling out IoT health services in undeveloped regions in the rural areas of India. This study makes a reference to the feasibility of implementing an IoT intervention in the villages of India. The study makes specific reference to the infrastructure requirements and roles that will ensure the success of IoT in alleviating the healthcare crisis in rural India. Two major requirements that have been identified for the successful deployment of IoT in healthcare systems in rural India is the need for a reliable *technology infrastructure* based on internet connectivity as well as the *acceptance* by healthcare professionals that an IoT intervention will be beneficial to the healthcare systems in India (Prakashan et al., 2017).

According to Isma'ili et al. (2017), the two main hindrances that may affect IoT acceptability are privacy and security. The extent of these issues can be very critical especially envisioned to issues like hacking patients' database. Privacy and security are predominantly critical in wearable healthcare medical monitoring devices, and IoT needs to be extremely protected against privacy breaches and malicious attacks that may cause detriment to the users. Project owners and African governments need to understand what the challenges are

evolving from the IoT and how they should strategize to design their infrastructure to tackle these challenges (Isma'ili et al., 2017).

According to Mukhopadhyay and Suryadevara (2014), 92% of IoT users have worries about security. Cybercrime is costing approximately US \$ 445 million each year. This number potentially may be much higher due to the connectivity of a vast volume of medical monitoring devices in IoT (Mukhopadhyay and Suryadevara, 2014). A Gartner report stated that IoT is one of the most trending technologies in recent years and institutes need to have a clear IoT strategy for their adoption. Garrity (2015), raised the concern of standardisation mainly due to the anticipated increase in competition and offerings among IoT merchants. The availability of economical, sufficient and internet infrastructure bandwidth for implementing IoT solutions is essential (Zander et al., 2015). Governments in Africa must be able to provide necessary infrastructure to support the creation of IoT solutions.

RFID technology is an example of the IoT enabling technologies. Bardaki et al. (2012), argued in their study that there is need for enhancement of RFID technology to achieve successful IoT deployment. This would illustrate that it is vital to enrol not only successful IoT technologies but also to improve other collaborative technologies that provision the IoT project deployment. Another hindrance is that wearable medical monitoring devices have been crafted and intended for consumers and this, in some sectors such as health care, makes it difficult for such medical monitoring devices to get regulatory approval. System developers somehow knowingly avoid seeking regulatory approval due to the anticipated length and expense of such process. Identifying and understanding the challenges specific to African countries will be vital in crafting strategies to implement IoT in healthcare. They will be the key drivers towards overcoming the huddles and to provide efficient IoT technological solutions (Bardaki et al., 2012).

Currently, academics have emphasised the theoretically viability of the use of IoT technology in Africa as such by Isma'ili et al. (2017), however there is a dearth of knowledge on the identification of critical factors that influence the success of technology interventions in the healthcare sector in Africa. The decision to limit the study to Zimbabwe was based on the operational and logistical impediments of extending the study to a representative sample of African countries. It is envisaged that the results of the study is a critical resource to inform

the adoption of an IoT strategy to enhance healthcare service delivery specifically in Zimbabwe, but also broadly to countries on the African continent. A significant outcome from the study is that there will be an identification of solutions that are centred on IoT technology that will alleviate the inefficiencies and bottlenecks that currently plague healthcare service delivery in Zimbabwe.

### 2.3 IoT Evolution and Architecture

According to Chase (2013), Internet of Things (IoT) is defined as connecting technological things/devices to the Internet. The definition also alludes to use of an internet connection to deliver an element of useful remote control or monitoring of those things/devices. Lee and Lee (2015) are of the opinion that this definition is limited were it references only part of the IoT basic function. He distinguishes this general definition by highlighting that the IoT evolution graduated to become the Internet of Everything or the Industrial Internet. The IoT of Everything is a new technology paradigm that is envisioned as a global network of devices and machines capable of interacting with each other. Therefore based on Lee and Lee (2015)'s explanation, the real value of the IoT for enterprises shall be wholly recognized when connected devices are able to communicate with each other and integrate with humans, vendor managed inventory systems, business intelligence applications and business analytics (Lee and Lee, 2015). Rivera and van der Meulen (2014), comment on a forecast that was reported by the Gartner report that IoT is one of the most important areas of future technology and is gaining vast attention from a wide range of industries. The article by Lee and Lee (2015) further gives a statistic that IoT shall reach 26 billion units by 2020 , up from 0.9 billion in 2009, and will impact the information available to supply chain partners and how the supply chain operates. The evolution of IoT technology is traced in Table 1 where the actual technology used and the area of applicability of IoT devices is presented.

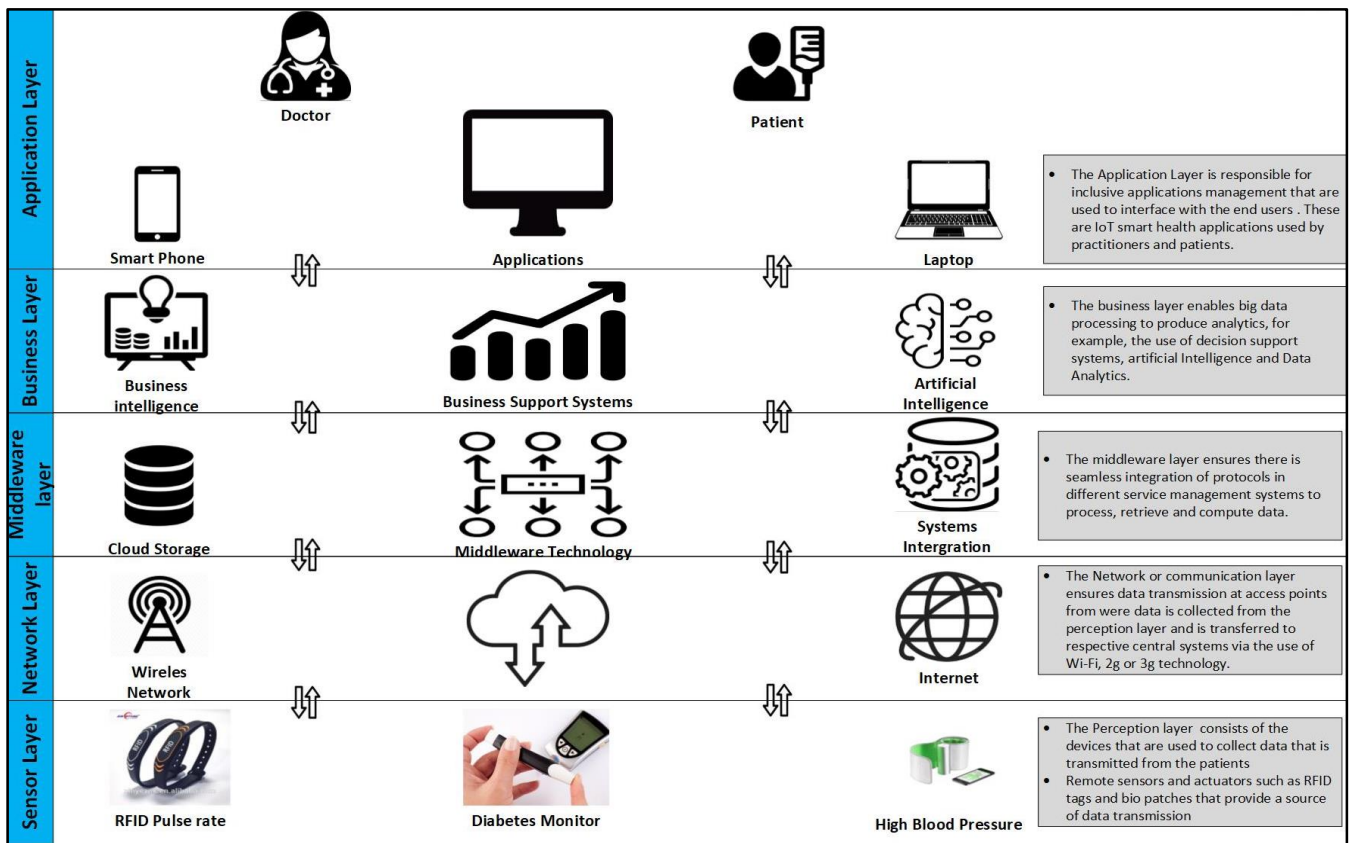
**Table 1 – The History and Evolution of IoT**

	<b>Before 2010</b>	<b>2010 — 2015</b>	<b>2015 — 2020</b>	<b>Beyond 2020</b>
Network	Sensor networks	<ul style="list-style-type: none"> <li>Sensor network location transparency</li> </ul>	<ul style="list-style-type: none"> <li>Network context awareness</li> </ul>	<ul style="list-style-type: none"> <li>Self-learning, self-repairing networks</li> <li>Network cognition</li> </ul>

		<ul style="list-style-type: none"> <li>• Self-aware and self-organizing networks</li> <li>• Hybrid networking technologies</li> <li>• Delay tolerant networks</li> <li>• Storage networks and power networks</li> </ul>		
Software and Algorithms	<ul style="list-style-type: none"> <li>• Relational database integration</li> <li>• IoT-oriented RDBMS</li> <li>• Event-based platforms</li> <li>• Sensor middleware Sensor Networks Middleware Proximity / Localization algorithms</li> </ul>	<ul style="list-style-type: none"> <li>• Large-scale, open semantic software modules</li> <li>• Next generation IoT-based social software</li> <li>• Next generation IoT-based enterprise application</li> <li>• Composed algorithms</li> </ul>	<ul style="list-style-type: none"> <li>• Things-to-Things collaboration environments</li> <li>• Distributed intelligence, problem solving</li> <li>• Goal-oriented software</li> </ul>	<ul style="list-style-type: none"> <li>• User-oriented software</li> <li>• The invisible IoT</li> <li>• Easy-to-deploy IoT software</li> <li>• Things-to-Humans collaboration IoT 4AI</li> </ul>
Hardware	<ul style="list-style-type: none"> <li>• RFID tags and some sensors</li> <li>• Sensors built into mobile devices NFC in mobile phones</li> <li>• Smaller and cheaper MEMs technology</li> </ul>	<ul style="list-style-type: none"> <li>• Multiprotocol, multi standards readers</li> <li>• More sensors and actuators</li> <li>• Secure, low-cost tags (e.g., Silent Tags)</li> </ul>	<ul style="list-style-type: none"> <li>• Smart sensors (biochemical)</li> <li>• More sensors and actuators (tiny sensors)</li> </ul>	<ul style="list-style-type: none"> <li>• Nano technology and new materials</li> </ul>
Data Processing	<ul style="list-style-type: none"> <li>• Serial data processing</li> <li>• Quality of services Parallel data processing</li> </ul>	<ul style="list-style-type: none"> <li>• Energy, frequency spectrum-aware data processing</li> <li>• Data processing context adaptable</li> </ul>	<ul style="list-style-type: none"> <li>• Context-aware at a processing and data responses</li> </ul>	<ul style="list-style-type: none"> <li>• Cognitive processing and optimization</li> </ul>

## 2.4 The IoT in healthcare Architecture

The basic IoT architecture presented in Ullah et al. (2016), consists of 5 main layers that are presented in accordance with the Open Systems Internet (OSI) model that enables internet based connectivity on multiple platforms. Figure 1 illustrates the 5 layers.



**Figure 1- IoT In Healthcare Architecture Ullah et al. (2016)**

As illustrated in Figure 1, the first layer is named the Perception layer. This layer is responsible for collecting data in its raw format, which is then transmitted to the receiver. Examples of these remote sensors include RFID tags or bio patches. The second layer is the network or communication layer. This layer ensures end to end transmission of data from the access points. Examples of network layer technologies include LoRa wireless technology, WiFi or 4G technology. The third layer is the middleware layer. This layer is responsible to ensure seamless integration of different protocols and platforms. The fourth layer is the business layer which is responsible of sorting, preparation of analytics whether in the cloud or on a server. Examples of the business layer technology includes artificial intelligence algorithms or decision support systems. The final layer is the application layer. This layer includes the applications that are used to interface with the end users. Examples of application layers are

the IoT smart applications built for the patients and doctors on Android operating system platforms or on Windows operating systems platforms (Ullah et al., 2016).

## 2.5 The Theoretical Framework

The study was underpinned by a conceptual model of combining the technology acceptance theory, diffusion innovation theory and a technology infrastructure viability analysis. According to Ward (2013), the uniqueness of this combination is that three of the models have similar components, but each has a different emphasis. Although their complexity has been amplified over recent years, their predictive power is still maintained. The conceptual model has been designed so that a greater understanding of the subjects in review can be optimally analysed.

### 2.5.1 The Technology Acceptance Model (TAM)

TAM has been proposed by Davis (1985), and it provides an indicator of the main drivers that influence user acceptance of technology based innovations (illustrated in Figure 2). This theory enables system designers and implementers to evaluate proposed new systems prior to these systems being used in a fully-fledged manner. Davis (1985), asserts that the overall attitude towards using a given system is hypothesized to be a major determinant of whether a person actually continues using the system or not.

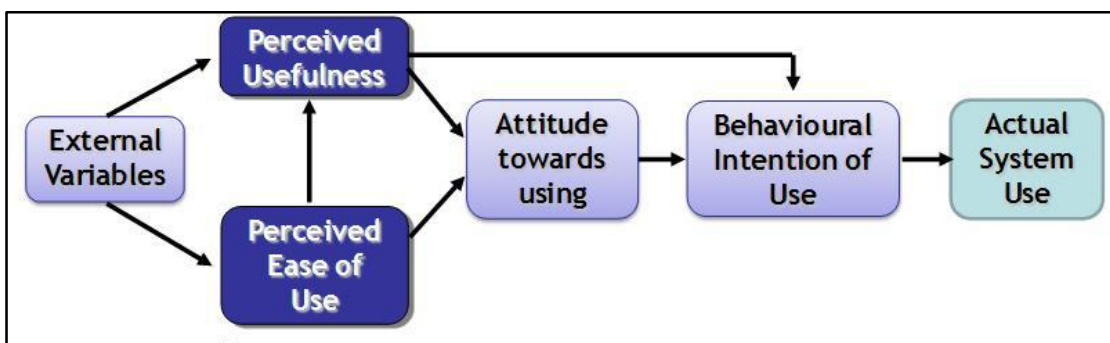


Figure 2-The Technology Acceptance Model as proposed in Davis (1985)

As indicated in Figure 2 the TAM constructs consists of “Attitude towards using” as a function of two major factors underpinning TAM, Perceived Usefulness (Thangaraj et al.), and Perceived Ease of Use (PEOU). PU is the degree to which an individual believes that using a particular system would enhance his or her job performance and PEOU is the degree to which a person believes that using a particular system would be free from effort (Davis, 1985). Davis suggests that PEOU influences PU which directly influences the intention to adopt and actually use a system. According to Venkatesh et al. (2003), TAM informs an individual’s decision to either adopt or reject a technology.

In this study, the TAM model was also chosen based on the impact it had on similar studies that were once conducted. An example is a study that was conducted by Hu et al. (1999). The objective of the research work was to examine the applicability of the TAM in elucidating physicians’ decisions to accept telemedicine technology in the health-care context. The results suggested that TAM was able to provide a reasonable depiction of physicians’ intention to use telemedicine technology. The user group, the technology and the organizational context were all new to IT adoption research. The study addressed a practical investigation of a technology management system that resulted in millions of dollars invested by healthcare organizations in developing and implementing telemedicine programs in recent years. The TAM model’s overall fit, explanatory power, and the individual causal links that it postulates were evaluated by examining the acceptance of telemedicine technology among physicians practicing at public tertiary hospitals in Hong Kong (Hu et al., 1999).

According to Bradley (2009), the major limitation of the TAM study, is the self-reported usage component, this means that the TAM theory does not explain how the actual system usage is really influenced, but relies on the research subject to indicate system usage. Lee et al. (2003), also concurs that the Self-reported usage is the most commonly reported limitation of the TAM theory. Instead of the model measuring actual usage, the study has to depend mainly on self-reported use, thereby assuming that self-reported usage successfully reflects actual usage. However, self-reported usage is known to be subject to the most common method bias, which exaggerates and distorts the relationship between dependent and independent variables. The other most mentioned limitation of the using the TAM theory is the tendency to examine only one information system with the same group of subjects on a single task at a



single point of time, thus levitating the generalization problem of any single study. The use of a homogenous set of subjects also weakens generalizability of the findings. Considering the user's intention and perception can change over time, it is important to measure these quantities at numerous points of time. The cross-sectional study's major weakness is that it cannot deduce the causality of the research results. The majority of the studies with lower variance explanations do not consider external variables other than original TAM variables. A few explanations of variance are referred to as a major problem of TAM studies. Other suggested limitations of TAM studies includes single measurement scales, relatively short exposure to the technology before testing, and self-selection biases of the subjects (Lee et al., 2003).

Therefore a better approach would have been to employ an independent measure of actual use. In the context of the current study, the issues of current usage of IoT does not create too much of a controversy because currently there are aspects of IoT technology that is used in public hospitals in Zimbabwe. These include heart rate and blood pressure monitors. The usage of this type of technology is however not widespread.

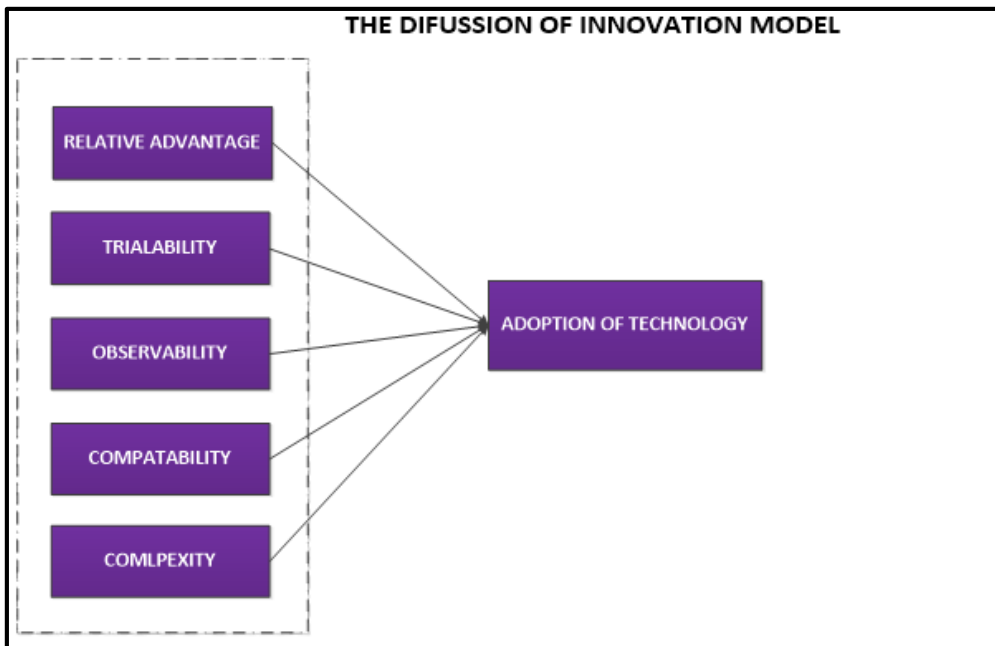
### **2.5.2 Diffusion of Innovation (DOI) Theory**

DOI theory has been pioneered by Rogers (1995), and explains how innovations are adopted in a society. He defines an innovation as an idea, behaviour, or object that is perceived as new by its audience. According to Rogers (1995), the adoption of an innovation is reliant on specific characteristics of the innovation that determine whether potential adopters of the innovation adopt the innovation immediately, at a later stage or not at all. These characteristics of the innovation are illustrated in Figure 2.

According to Rogers et al. (2005), diffusion occurs in multifarious systems where networks connecting system members are multiple, overlapping and complex. Diffusion occurs mostly in heterogeneous zones, such as transitional spaces where adequate differentiation among network members comes to obtain a particular idea or solution. Such heterogeneous connections, which comprise the innovation-diffusion system, occur among innovators and other engaged members of target populations who, in Rogers's original formulation, are called

“cosmopolites.” Cosmopolites are locally networked system members with heterogeneous weak ties to outside systems (Rogers et al., 2005).

As indicated in the Figure 3, there are five attributes that make up the Diffusion of Innovation theory. These are Relative advantage, Compatibility, Complexity, Trialability and Observability.



**Figure 3 - Diffusion of Innovation Model (Rogers (1995))**

Relative advantage is a reference to the perceived technical superiority that an innovation introduces so that it is an improvement over a previously used technology/innovation. Compatibility is the capacity for the innovation to be aligned with existing human skills, values, and work practices of potential adopters. Complexity ascertains whether an innovation is relatively challenging to understand and use. Trialability measures if the innovation can be experimented with on a trial basis without excessive effort and cost and without incurring too much of an influence to the domain of use; it may be implemented in parts and still provide a net positive benefit or its implementation may be reversed without incurring too much damage within the context of use. Observability is a reference to the benefits and results of the innovation`s use which can be simply communicated and

experiential to others. Rogers argues that diffusion of innovation explains the process that occurs as people adopt a new idea, product, practice or philosophy.

Lyytinen and Damsgaard (2001), Identifies six limitations of the DOI theory. Stating that technologies are discrete packages developed by independent and neutral innovators Therefore, technologies diffuse in a homogenous fixed social ether called diffusion arena, which is separate from the innovation locale; Diffusion rate is a function of push and pull forces; Adoption decisions are dependent on available information, preference functions and adopter's properties; Diffusion traverses through distinct stages, which exhibit little or no feedback and Time scales are relatively short and the diffusion history is not important.

The first limitation as stated by Lyytinen and Damsgaard (2001) is that the DOI it does not consider that technologies are not discrete packages. DOI research associates an innovation with unique and measurable features (Hai, 1998, Rogers et al., 2005). With this type of definition, numerous difficulties emerge. Firstly, it is not clear whether the feature list is complete and covers all features that affect adopter's behaviour. For example, why technical style or elegance does not appear in the lists though studies in the history of technology demonstrate the opposing (Hughes, 1987). Secondly, why all technological innovations should be categorised with the same set of attributes. Thirdly, what characters play these different characteristics at different stages of diffusion? For example, compatibility may mean different things for the late and early adopters. Fourthly, the assumption disregards the socially constructed nature of big technological systems (Lyytinen and Damsgaard, 2001).

The second limitation as identified by Lyytinen and Damsgaard (2001), is that the DOI does not consider that technologies do not diffuse in a homogenous and fixed social ether. In the DOI theory, interactions between technology, adopters and suppliers are expected to occur in a relatively homogeneous space. The assumption is that the technology diffuses in this ether through the effects of these three "forces". With complex technologies however, the diffusion arenas are neither fixed nor homogeneous, instead, institutional measures technological, business context and economic constraints restructure these arenas. Therefore, in analysing complex systems' diffusion it was found essential to use institutional concepts to dynamically draw the boundaries of the diffusion space to understand what the studied processes were like. The institutional perspective helps focus on regimes and institutional measures that are

involved in defaming the mandate and scope for the diffusion course. Powerful institutional changes can fundamentally affect the speed and progression of any diffusion process by restructuring its boundaries, redefining involved entities and changing incentives (Lyytinen and Damsgaard, 2001).

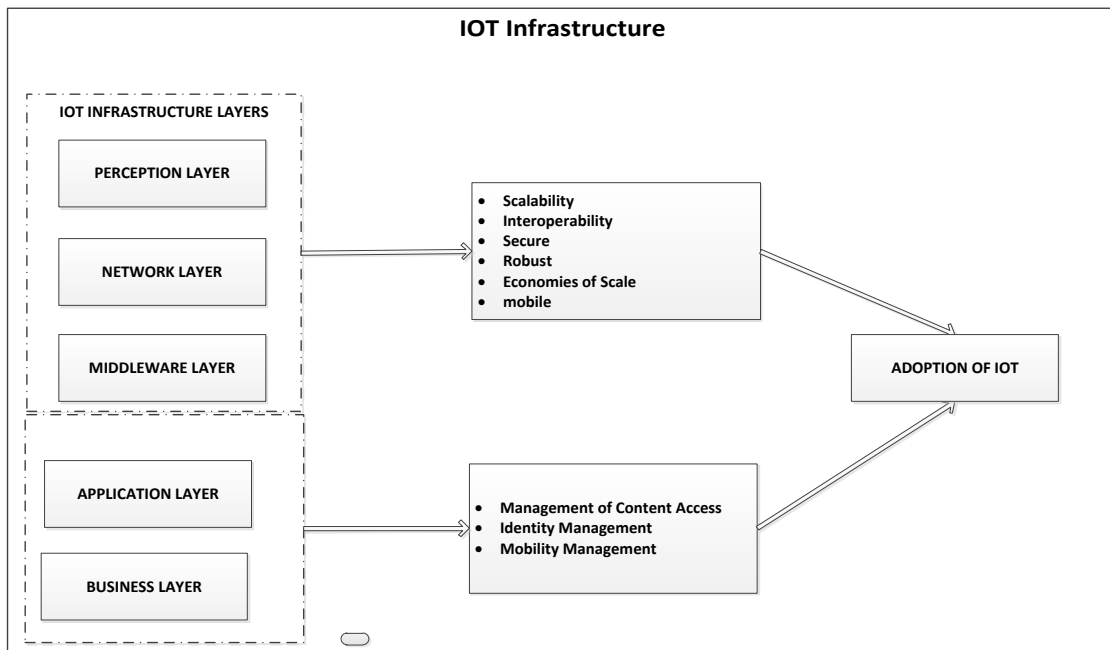
Lastly among other limitations is that diffusion rate is not solely a function of push and pull forces. The DOI theory integrates two additional modes of explanation: the demand-pull and the supply-push theories (King et al., 1994). Supply-push theories estimate that specific functions of the innovation cause the technology diffusion like its functionality, or the values that enable its use. The demand-pull theories explain a technology systems diffusion by a growing demand for organizational coordination. Companies need to improve their internal operations, and change their market position by relating technical knowledge (Porter, 2008). Several IS studies have considered both forces simultaneously, unfortunately the predictive power of the theory has been low and the results confounding (Hai, 1998)

Given these limitations Lyytinen and Damsgaard (2001), believes that armed with theoretical guidelines listed below, DOI researchers will have a upper likelihood of providing faithful explanations of the diffusion of networked and complex innovations. As a way forward it is necessary to consider the following issues while studying multifaceted networked technologies. First, to pursue to understand the networked, local complex, and learning rigorous features of technology. Secondly, seeking to understand the vital role of market making and formal structures in shaping the diffusion arena. Thirdly to focus on essential process features and all key players in the diffusion arena. Forth, to develop a multi-layered theories of diffusion that factor out structures between different layers and locales. Lastly, to use other theoretical perspectives that help cover analysis beyond questions of efficient choice.

### **2.5.3 Technological Infrastructure**

The final construct in the conceptual model is the critical role of the technological infrastructure. According to Vashi et al. (2017), IoT technology architecture consists of 5 main layers just like the Open Systems Interconnection (OSI) model. To determine the success of the adoption of an IoT in the medical healthcare sector, it is essential to ensure that the technological infrastructure that enables implementation of IoTs are available to enable the

deployment of the IoT strategy. Figure 4 illustrates the key elements that define the general architecture and characteristics of a typical IoT device.



**Figure 4-The IoT Infrastructure Architecture (Ullah et al., 2016)**

As shown in Figure 4, the IoT model consists of the Perception layer, Network layer / Communication Layer, Middleware layer, Application layer and the Business layer. In these layers are technologies, hardware, software and protocols that create a technological ecosystem which enables the existence of the IoT functional architecture. Ullah et al. (2016), provide details of the six technology layers as required for the deployment of an IoT strategy in the medical healthcare sector. These are:

- The Perception layer that consists of the medical monitoring devices that are used to collect data that has been transmitted from the patients
- Remote sensors and actuators such as RFID tags and bio patches that provide a source of data transmission
- The Network or communication layer ensures data security at access points where data is collected from the perception layer and is transferred to respective central systems via the use of Wi-Fi, 2g or 3g technology.

- The middleware layer ensures a seamless integration of protocols and different service management systems to process, retrieve and compute data.
- The Application Layer is responsible for inclusive applications management based on the processed information in the Middleware layer. These are IoT smart health applications used by practitioners and patients.
- The last layer is the business layer; after data has been gathered information is now fused to produce analytics, for example, the use of decision support systems is used at this stage.

According to Jara et al. (2013), from a hypothetical perspective the perception layer, middleware layer and the network layer should ensure that the IoT infrastructure is scalable, interoperable, secure, robust, enhances economies of scale and mobility. The compatibility of technologies used in the lower two layers would enable greater chances of success to ensure ubiquitous integration in the health care systems (Jara et al., 2013). On the other hand, the application and business layers should ensure consistency in robust management of content access (security related), identity management and mobility management to enable greater success chances of the supported infrastructure.

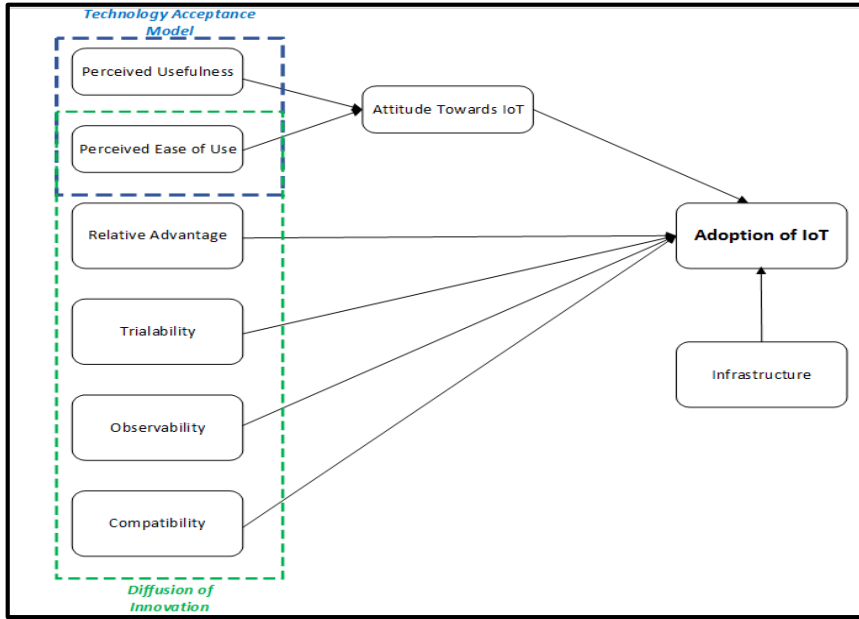
Ray (2017), identified key hindrances that may affect the implementation of an IoT healthcare system. The first challenge is to do with standardization, considering that IoT based e-health care solutions are still in the emerging stages of development, current solutions do not conform to regulations and specific rules. This includes interoperability issues that need to be taken immediately by researchers by collaborating together for example. The second challenge that may affect IoT rollout in healthcare is the quality of service. As e-health care services require reliability, rigorous and maintainability of the system hence it should be secured that no connection, delay or data loss occurs hereby improving the quality of service. In case the case of system failure it has to be ensure that redundant services should promptly be availed to avoid disruption. The third hindrance involves issues to do with ecological aspects. Full-fledged IoT e-health care services shall need a solution such as low cost bio medical sensors that can be easily worn or implanted into human body. The challenge is without a regulatory effect, companies that manufacture may end up risking end users as the race towards creating cheaper products. Ray (2017), suggests that the regulatory bodies such as World Healthcare Organisation and governments should provide policies and guidelines of

manufacturing of sensors, disposal practices, and usage pattern. Therefore IoT can be a positively disruptive for providing e-health care solutions by incorporating its technologies. Wearable medical monitoring devices and Internet of Things clouds shall become a trend of future innovations in the health sector in coming years will severely impact upon the healthcare perceptions making it safer, smarter, usable, and economic for everyone. It is of key essence that research be done to evaluate on IoT architectures beneficial for dissemination of seamless and smart e-health care services (Ray, 2017).

#### **2.5.4 The Conceptual Framework**

The study was underpinned by a conceptual model by combining the technology acceptance theory, diffusion innovation theory and a technology infrastructure viability analysis. A significant outcome of this study is the suggestion that technology adoption needs to be studied from the perspectives of the technology as well as the social context in which the technology will be used. Further insight is provided by Sanson-Fisher (2004) who used the DOI model to understand why some clinical innovations are adopted swiftly and others tend to meet a lot of resistance. Some clinical behaviours may be adopted relatively easily because of the nature of the behaviour itself, while others may involve a complex interplay between social systems, communication style and the decision-making process.

The afore-mentioned cases provide an argument for the adoption of a theoretical model that has sufficient capacity to integrate the social and technical aspects of the adoption of innovation in the medical field. Both the technical and social dimensions of technology adoption in the medical field are prevalent in TAM and DOI theory. However, to supplement for the lack of representation from the technical dimension of the study, a specific reference to the technical infrastructure is incorporated into a conceptual model that is envisaged to be an ideal fit for the study's purpose. This conceptual model that will underpin the study's empirical phase is presented in Figure 5.



**Figure 5- The Conceptual Framework**

Figure 5 indicates the study’s proposed conceptual framework of the combination of 3 constructs that are designed to measure the social and the technical capacities of the study. Based on the arguments illustrated the individually the separate theoretical models lack full representation to explain the predictive power of the study’s objective. However synthesised they offer a stronger robust framework to determine the study’s key questions. The TAM theory attempts to determine social factors that influence user adoption. Whereas the DOI attempts to predict key factors that influence adoptability of an innovation. The Technical Infrastructure attempts to examine the feasibility of a technology operating in a particular environment given its architecture.

## 2.6 Conclusion

The current chapter consists of an exploration of existing literature that served the foundation from which a critical analysis is conducted of the relevance and justification of using IoT in the healthcare system in Zimbabwe. The literature also managed to illustrate the technical viability and the challenging aspects of implementing an IoT infrastructure to support the healthcare ecosystem in Zimbabwe. The chapter also provided an elucidation of previous, similar studies that were carried out by various researchers that has enabled an



understanding of the key elements that need considerations when building IoT based systems on the African continent. The chapter is concluded with a conceptual framework that consists of an assimilation of constructs from the Technology Acceptance Model, Diffusion of Innovation Theory and the Technical Infrastructure Viability Theory. The conceptual model derived in this chapter will be used as the model that will underpin the empirical validation phase of the current study.

## CHAPTER THREE: RESEARCH METHODOLOGY

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### 3.1 Introduction

The research questions and research problem guiding the current study were designed so that it leverages recognised technology adoption theoretical models to enable a meaningful understanding of critical issues that influence the implementation of an IoT Strategy in the healthcare sector in Zimbabwe. According to Creswell and Creswell (2017), there are many research designs, but each has an alignment with a specific research paradigm. There are 3 main research paradigms that are quantitative, qualitative and mixed methods. Qualitative Research is mainly exploratory research. It is used to gain an understanding of underlying reasons, opinions, and motivations. Providing insights into a problem to develop ideas or hypotheses for potential quantitative research to uncover trends in thought and opinions, and dive deeper into the problem. Qualitative data collection methods vary using unstructured or semi-structured techniques. Whereas quantitative research is used to quantify the problem by way of generating numerical data or data that can be transformed into usable statistics. It is used to quantify, opinions, attitudes, behaviours, and other defined variables and generalize results from a larger sample population (Sekaran and Bougie, 2016). According to Creswell and Creswell (2017), mixed methods research is a reference to a research design where quantitative and qualitative data collection and analysis techniques are used for different phases of a study. The phases of such a study are done either concurrently or sequentially. The current design strategy was guided by the researcher's intuition and worldview perspective. The qualitative phase of this study was exploratory and was not bound to any specific theory. However, the study made use of phenomenology as a theoretical basis where healthcare professionals related their experience of the phenomenon of healthcare service delivery in Zimbabwe to identify problem areas that may be resolved via an IoT intervention. Using the specifications listed above, the most appropriate research design identified for the current study is the Sequential Exploratory Design suggested by (Creswell and Creswell, 2017). The sequential exploratory design was conducted in two phases where priority was attached to the first phase of the study. The first phase consists of a qualitative data collection and analysis phase. The outcome of this phase was that the researcher will obtain a clearer

understanding of the problems faced by healthcare professionals in Zimbabwe as well as knowledge of the potential areas where an IoT intervention may obviate some of these problems. This knowledge culminated in a synthesis component of the study where a framework for the implementation of an IoT intervention in the public healthcare sector in Zimbabwe was proposed. The final and 3<sup>rd</sup> phase of the study was a quantitative verification of the proposed framework for the perceptions of the implementation of an IoT intervention in the medical healthcare system in Zimbabwe. This phase of the study was guided by a conceptual theoretical framework illustrated in Figure 5.

### **3.2 Research Paradigms**

Lincoln and Guba (1989) define a paradigm as a set of beliefs which represent a worldview that define from the nature of the world or reality, the researcher's position in it, the perspective of a researcher and the possible relationships to the world or parts thereof .

According to Lincoln and Guba (1989), a paradigm comprises of four elements. These are ontology, methodology, axiology and epistemology. Johnson and Onwuegbuzie (2004) argue that it is important to have a firm understanding of these elements because they comprise the basic assumptions, beliefs, norms and values that each paradigm holds. The understanding the research upholds will be guided by the beliefs, norms, assumptions and values of the paradigm. It is therefore key to distinguish what each of these elements mean. Ontology narrates to the nature and form of reality and what can be known about it, whereby epistemology focuses on the nature of relationship between the researcher and participants (Turner and Laird, 2012).

Guba and Lincoln (1994) distinguishes the existence of a multitude of paradigms ranging from positivism through to post positivism, critical and constructivism theories. The aim of the positivist and post positivist paradigms are mainly explanatory whilst critical theory aims to provide critique and constructivism and transformation seeks to provide reconstruction and understanding in the area of inquiry (Lincoln and Guba, 1989).

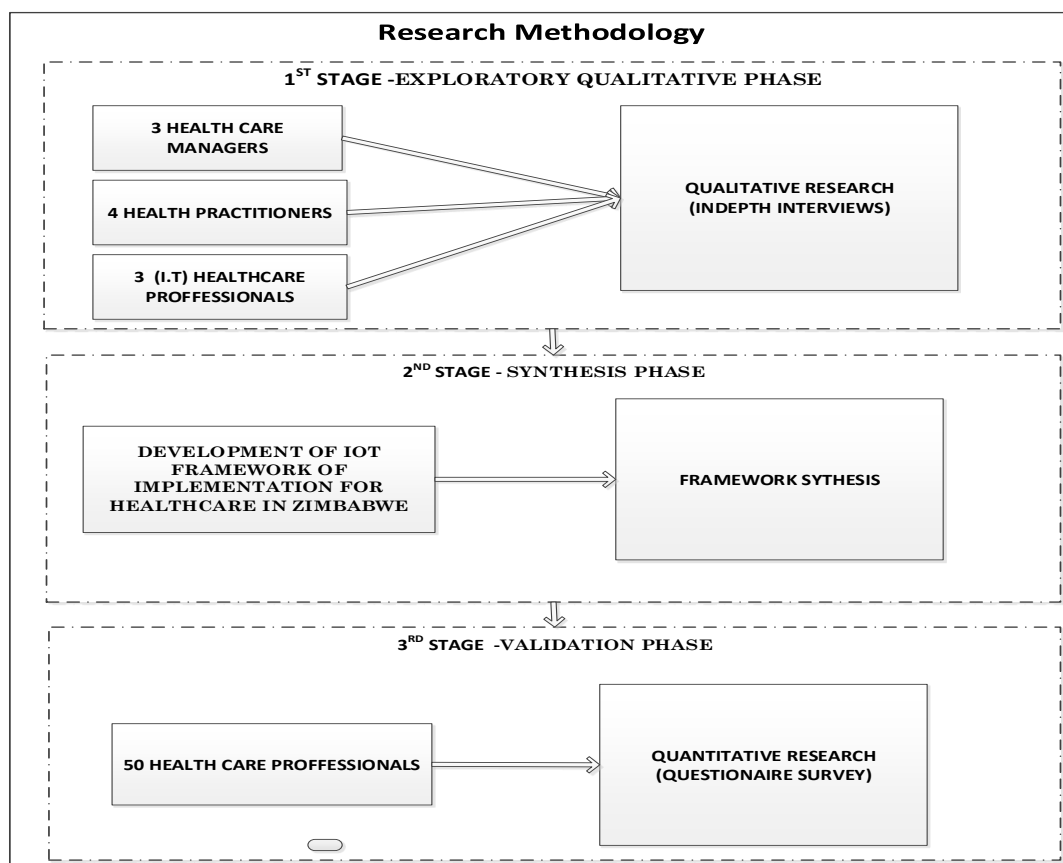
According to Johnson and Onwuegbuzie (2004), the pragmatic paradigm was subjected by philosophers who debated that it is not possible to acquire the 'truth' about the real world exclusively by virtue of a single scientific method as encouraged by the Positivist

paradigm, nor was it possible to determine social reality as constructed under the interpretivist paradigm (Johnson and Onwuegbuzie, 2004).

In the current study the researcher holds a worldview that a multi-method approach is ideal for providing knowledge on a phenomenon that has not been extensively researched. This approach provides the researcher with the flexibility of using different methods to uncover accurate knowledge about IoT implementation as a resource for enhancing healthcare. The preference for a pluralistic approach aligns with the philosophy of Pragmatic Realism where the researcher explores the topic of contention with “real world” entities who are part of the problem domain. In the current study, these real world entities are represented by the medical practitioners and technologists who ply their trade in the domain of general healthcare and medical technology.

### **3.3 Research Design**

The Sequential Exploratory design adopted in the current study is illustrated in Figure 6



**Figure 6- The Research Design**

As indicated in Figure 6, the research questions were guided by following a research plan that entails the following deliverables:

The setting up of in-depth interviews with 7 healthcare professionals (3 healthcare managers and 4 healthcare practitioners) who are the critical role players in the public healthcare system in Zimbabwe. The cohort of 7 interviewees comprised of 3 healthcare managers and 4 medical practitioners who have at least 5 years of experience of working in the public health department in Zimbabwe. The objective of this exercise was to collect data to enable the answering of the following research question: What are the perceptions of healthcare professionals of the implementation of an Internet of Things (IoT) Strategy in Zimbabwe? This perception-oriented phase of the study alluded to the challenges and advantages of implementing an IoT based intervention to enable better healthcare.

The setting up of in-depth interviews with a cohort of 3 IT professionals who are currently engaged in providing technology support for the public healthcare sector in Zimbabwe. The objective of this exercise was to collect data to enable the answering of the following research question: How will the technical infrastructure requirements influence the adoption of an IoT approach in the medical healthcare sector Zimbabwe?

The synthesis phase of the study (also referred to as the 2nd phase) entails the development of a framework of implementation for the deployment of IoT technology in the healthcare sector in Zimbabwe

The validation phase (also referred to as the 3rd phase) of the study was to collect empirical evidence attesting to the validity of the proposed framework. The objective of this exercise was to leverage the academic constructs of technology adoption theory found in the study's conceptual framework to answer the following research sub question: What is the intention of medical healthcare professionals in Zimbabwe to adopt a framework for the implementation of an IoT strategy to enhance the quality of healthcare service delivery in Zimbabwe?

### **3.3.1 A Qualitative Phenomenological First Phase**

The 1st phase of the study was conducted as a phenomenological study that is qualitative and driven by data collection that consisted of semi-structured interviews. Kafle (2013) explains that phenomenology is a term that refers to a research philosophy as well as research methodology. From a philosophical perspective, phenomenology is aligned to a constructivist theory of learning where it is advocated that people construct knowledge on the basis of reflection and experience of their "life world" (Langdrige, 2008). From a research methodological orientation, Leedy and Ormrod (2005) suggests that a phenomenological approach is used to understand people's perceptions of life situations by virtue of their prolonged experience of these situations. A significant objective of the study was to ascertain the perceptions of healthcare professionals in Zimbabwe of the phenomenon of using RFID technology (a subset of IoT technology) to enhance medical healthcare services in Zimbabwe.

### **3.3.2 A Quantitative Adoption Based Third Phase**

The 3rd phase of the study was the quantitative and was underpinned by the dissemination of questionnaires that were aligned to the conceptual framework underpinning the study. It is envisaged that the sample set for this phase of the study consisted of 50 healthcare professionals who provided an indication of their acceptance of the proposed framework for the implementation of an IoT strategy in the healthcare sector in Zimbabwe. The sample for this phase of the study was selected purposively based on the requirement that all respondents must have at least 3 years of experience as a professional worker in the public healthcare sector in Zimbabwe.

### **3.4 Research approach**

The study leveraged both the qualitative and quantitative research methodologies with the aim of exploring current practice to identify problems (qualitative) and ascertaining the viability of a proposed solution (quantitative). This methodological approach resonates with an established methodology of research suggested by Creswell referred to a Sequential Exploratory Research. This approach requires using qualitative data to understand the problem and to obtain insight into a possible solution and finally making use of quantitative research to ascertain acceptance and intention to adopt the proposed solution.

According to Saunders (2011), there are two main forms of research approaches; quantitative and qualitative methods. Of which the methodology was determined by the type of data collected, it is also partially determined by the data collection method, presentation and analysis. Quantitative research makes use of samples of subjects to measure variables and describe relationships between variables by using effect statistics for instance correlations, relative frequencies, or differences between the statistics; they place a lot of value on the testing of theory. In contrast, qualitative research is used predominantly as a synonym for any data collection technique (such as interviews and questionnaires, observation and participant observation, official documentation and manuscripts, and the researcher's views and responses) or data analysis procedure (such as categorising knowledge claims,

investigation approaches, and data collection methods) that generates or use non-numerical data.

### **3.5 The Study's Target Population**

According to Hair (2007), a target population “is a group of elements (objects or people) from which the analysis data is to be acquired to meet the objectives of the study” . The target population for the study was identified as healthcare professionals (Healthcare Managers, Medical Practitioners and Information Technology Professionals practicing in the medical field) in the Zimbabwean healthcare ecosystem.

#### **3.5.1 Sampling Strategies**

Sampling is a process of selecting a subset of the full population. The subset must be representative of the actual population from which it was selected to enable the researcher to obtain information about the subject that is of interest in the study. According to Saunders (2011), a purposive sampling method uses the information that the researcher has about the population of concern and the purpose of the study. This information will assist in selection of the study's sample.

According to Dobson et al. (2017), sampling seldom effects in a completely accurate estimate of the population, but a larger sample size minimises variation and increases the possibility estimate that is reasonably accurate that would likely to produce a more accurate estimate. Researchers can be biased when choosing samples to measure or count, selecting the largest, healthiest, or most noticeable. For example, estimating the population size of a variable of interest on the in the easiest region to pick a sample a researcher may prioritise to select samples in regions where the sample is mostly rich of his finding interest instead of including the entire population as a probability. To obtain a more accurate estimate of population size, samples must occur in areas with an equal representation of numbers of the entire population. Random sampling reduces bias by warranting that all individuals under investigation have an equal chance of being sampled. Random number generators, can facilitate the random selection of areas to be sampled. They produce a list of random numbers that can be used to select individuals or areas to sample (Dobson et al., 2017).



The study's sample was selected purposively based on the requirement that the all members of the sample must be experienced healthcare professionals who are employed as healthcare professionals in the Zimbabwean public healthcare system. The imposition of the experience factor will enable the acquisition of meaningful data thereby upholding within the healthcare system that is aligned towards ensuring that the objectives of the study are successfully achieved. In order to entrench the sample's validity, a further criterion imposed by the researcher is that the healthcare practitioners that constitute the sample must have at least 3 years of experience working in the public healthcare system in Zimbabwe. The population of the sample were health care professionals operating in the public sector in Harare, Zimbabwe.

### **3.5.2 Sample size**

According to Singh and Masuku (2014), a sample size should be carefully fixed so that it will be adequate to depict a valid and generalized conclusion. The fixation of the acceptable sample size requires specific information about the problems under investigation from the population under study. In addition, the sub classifications of sample require for variation, precision, analysis, cost and availability of investigations. The data collected during investigation from samples is recorded on pre-designed schedule or on questionnaire. The design of questionnaires depends on the facilities and objectives for analysis. Sample size purposing is a technique of electing the number of observations to include in a sample (Singh and Masuku, 2014).

Sample sizes become an important feature of any study or investigation in which the aim is to make inferences about the population from a sample. Therefore a sample size used in a study is determined based on the sufficiency of the statistical power and on cost of data collection. In advanced studies there may be several different sample sizes involved in the study: for example, in a survey sampling if population is heterogeneous involving stratified sampling there would be different sample sizes for each population. For example in a census,

information is collected through complete enumeration, where the sample size is equal to the population size. However in an experimental study, a study may be divided into different experimental groups, there may be different sample sizes for each experimental group (Singh and Masuku, 2014).

According to Dobson et al. (2017), sample sizes generally lead to increased accuracy when estimating unknown parameters. Sample sizes may be chosen in different considerations; Cost base, this includes those items readily available or convenient to collect. It is important to note that the choice of small sample sizes, although sometimes may be necessary, can result in wider confidence intervals or risks of errors in statistical hypothesis testing. Also the consideration of the variance base, through using a target variance for an estimate to be derived from the sample eventually obtained Statistical power base. Sample sizes are predetermined by the quality of the resulting estimates, sample size may be assessed based on the power of a hypothesis test (Creswell and Creswell, 2017).

Considering that this study used both the qualitative and quantitative research methodologies, the qualitative data sample consisted of 4 medical practitioners, 3 healthcare managers and 3 I.T healthcare professionals. These health practitioners were chosen purposively based on their involvement and experience in health operations and projects currently in Zimbabwe. More specifically, the sample consisted of healthcare professionals who have had at least 3 years of experience of working with RFID technology.

The quantitative (validation) phase of the study consisted of a purposively selected sample of 50 healthcare practitioners. Included in the sample were the respondents from the 1<sup>st</sup> (qualitative) phase of the study as well as a further 40 respondents who were identified on the basis of their knowledge, expertise and experience of working as professionals in the Zimbabwean public healthcare sector. The objective was *not* to ensure generalisation or external validity of the results, but to ensure that there is a broad level of acceptance of the proposed framework from the cohort of experts. A high level of priority is attached to the

requirement that all members of the sample must have expert knowledge of the medical healthcare system in Zimbabwe. The expertise may be in the areas of medical practice, medical administration or IT support for medical healthcare systems. This level of specialisation necessitates data collection from specifically targeted individuals who were identified during the 1<sup>st</sup> phase of the study. For the purpose of ensuring that the results of the survey may be accepted at the 95% confidence level, a sample size of 50 was been selected. The choice of sample size has been made based on the researcher's ability to access the targeted set of respondents. Also, a sample size of 50 enhanced the prospect of obtaining a normal distribution of the sample means thereby enabling the use of parametric statistical tests for correlation and regression. A normal sampling distribution also enabled the invocation of correlation tests such as the Pearson Correlation and multiple regression analysis. However, if the sampling means do not pass the test of normality, then non parametric route consisting of measures such as the median will be used to obtain an aggregated representation of the sample data. In this case, correlation analysis were performed by resorting to the Spearman's Correlation Co-efficient

### **3.5.3 Data Collection**

Data collection is a technique for gathering and evaluating data on variables of interest, through using a recognized methodical procedure that enables the researcher to formulate responses of the research questions to test hypotheses, and evaluating results. Saunders (2011), emphasises the importance of data collection to be a vital element of research design, that if a wrong approach is used the results of the study will be totally distorted. There are numerous methods to collecting data and each one consists of its own advantages and disadvantages. The most commonly used data collection methods are questionnaires, interviews, unobtrusive methods, and observations.

In the current study, in-depth semi-structured interviews were used for collecting the study's qualitative information from 10 professionals of the study's interest. The 3<sup>rd</sup> phase of data collection were commenced after the synthesis phase of the study was been finalised. The data collection plan for the study consisted of 2 phases, thereby necessitated a 2 phase ethical clearance application from UKZN. The 1<sup>st</sup> phase of the study required to acquire the respondents' personal perspective on the implementation of an IoT strategy to enhance

medical healthcare service delivery. This perspective was based on practitioners' experiential knowledge of the healthcare system in Zimbabwe. The validation (3<sup>rd</sup> phase) phase of the study required to acquire data from healthcare professionals who currently work in the public healthcare system in Zimbabwe. A Gatekeeper's clearance certification was obtained from the Medical Research Council of Zimbabwe.

#### **3.5.4 Interviews**

Interviews are conducted by means of human interaction aimed at probing verbal information that is required by the researcher. They can be structured, semi structured or unstructured. The main ways to conduct interviews are telephonically or face-to-face. Interviews are a more flexible method of data collection since the interviewer is able to probe deeper into insights of the questions as the interview progresses. Interviews are very useful for gaining an understanding into a subject matter and at giving respondents the freedom to be descriptive in their responses (Saunders, 2011). The main disadvantage with interviews is that due to its dynamic state it requires large amounts of resources that is, time and money to conduct them which is straining especially when there is a large sample size.

#### **3.5.5 Face-to-face semi structured interview**

The study's qualitative data was obtained through in-depth understanding of the complexities and intricacies associated with healthcare service delivery and the impact that an IoT approach will have on the service delivery imperative. The researcher made use of face-to-face semi structured interviewing strategy to enhance the prospect of gathering comprehensive data that can be used to enable meaningful qualitative data analysis.

#### **3.5.6 Questionnaires**

A complementary quantitative process included the distribution of questionnaires to 50 general healthcare practitioners. The plan was to ensure that all members of the 1<sup>st</sup> empirical phase of the study were included in the validation phase. A further 40 healthcare professionals were surveyed. The cohort of 50 included representatives from the medical, management and IT support domains of the public healthcare system in Zimbabwe.

### **3.6 Validity and Reliability of the Data**

Data quality Control, Validity and Reliability are the main subjects to be evaluated and monitored. According to Saunders (2011), validity is the degree to which a research study evaluates what it was intended to and the alignment of the data analysis to ensuring that the objectives of the study are fulfilled. In order to uphold the principles of validity, it should be ensured that the chosen design was able to provide responses to the research questions and therefore fulfil the purpose of the research. For the specific purpose of the study, the plan for the validity of the qualitative data was to conduct interviews with experienced practitioners. Also, the interviewees were to be re-engaged in order to verify the accuracy of data provided. From an analysis perspective, validity of the qualitative data analysis was upheld by making use of recognised methods of qualitative data analysis such as content and thematic analysis. According to Saunders (2011), reliability is the credibility of the results from the study. It is the extent to which the results of the research can be generalised to various measuring intervals, the person administering the test and the methods that are used for the test. The Cronbach Alpha test will be used to ensure reliability of the data collected during the quantitative phase of the study.

### **3.7 Data Analysis**

According to Sekaran and Bougie (2016), qualitative data analysis is done to enable the researcher to derive valuable insights and conclusions from the vast amount of data that has been collected. The analysis of qualitative data is done in three steps which are data reduction, data display, and the drawing of conclusions. In analysing qualitative data, techniques such as conceptual analysis, narrative analysis, relational analysis and content analysis can be used. This study made use of content analysis, which according to Sekaran and Bougie (2016) as “an observational research method that is employed in the methodical evaluation of representational content of every form of recorded communications”. Content analysis is performed by coding text into groups and then analysing it by means of conceptual analysis which identifies the frequency of occurrence of concepts such as themes, words, characters or the analysis can be performed through relational analysis. Relational analysis was derived from conceptual analysis through observing relationships between concepts in text. According

to Sekaran and Bougie (2016) content analysis is appropriate for analysing of data collected from interviews, document analysis, observation, and focus groups.

Considering that this study mainly used data reduction, the display of data and the drawing of conclusions was done during data analysis. Three main stages were executed on the data that will be collected during the first interview through content analysis.

*Steps that were taken to address the research's thematic analysis*

- The first step, the researcher read out the transcripts and preliminary explanations to the interviewees
- Secondly step, the researcher then analysed the data in more detail to find themes, then grouped all the themes and created codes that were used for the data. These codes were now applied to the whole set of data.
- After the coding data process was completed, the codes were ordered structurally based on their categories. Data was organised in context and arranged with similar data on the same subject to facilitate identification of patterns and relationships.
- The analysis was based on the patterns or relationships that were discovered under identified themes.
- Nvivo software package was used to facilitate this analysis.

For quantitative data analysis, by default the correlation analysis was conducted using Spearman's Correlation, unless the Shapiro Wilk test for normality reveals that the data is normally distributed, in which case parametric statistical analysis will be invoked. The Cronbach's alpha was used to measure the inter-item reliability of the survey data. The SPSS software package was be used to expedite this analysis.

### **3.8 Ethical Considerations**

To ensure that the study conforms to the University's ethical standards certain criteria need to be addressed and achieved before and during the research study. Two ethical clearances for both the 1<sup>st</sup> phase and 2<sup>nd</sup> phase of the study were applied and attained from the UKZN's ethical committee to allow the researcher to conduct the study. The researcher had to get consent to conduct the study from the respective of health management authorities in the public healthcare sector in Zimbabwe. In this regard a gate keeper's permission was

obtained from the offices of the Medical Research Council of Zimbabwe. A consent form was also be distributed out to the respondents to sign that they agree voluntarily participate in the study. An explanation of the information contained on the consent letter was issued to support that the data collected will be reported with honesty.

## CHAPTER FOUR: QUALITATIVE DATA ANALYSIS AND PRESENTATION

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### 4.1 Introduction

According to Miles et al. (2014) qualitative data analysis is the preparing and organising the data to then reduce the data into themes through a process of coding and code condensation. Dey (2003), further distinguishes qualitative data analysis as a pragmatic rather than prescriptive methodology that introduces different possibilities without promoting one particular approach. Qualitative data analysis is used to stimulate the emergence of patterns of data formation that has a wide range of applicability. According to Miles et al. (2014) qualitative data is best analysed by implementing methods that can interrogate rich textual descriptions of the phenomenon by subjects who can relate and explain their experience of the phenomenon. Data analysis involves an inductive and iterative engagement with the 'raw data' in order to abstract themes from the textual content. These themes are classified and coded so that prominent categories can be identified to enable conceptualisation of the research problem.

According to Romano et al. (2003) , if qualitative researchers do not engage in proper qualitative analysis techniques then they run the risk of compromising the richness inherent in their data sources for the purpose of presenting a routine research report. The most effective strategy to elicit the richness embedded in qualitative data is to resort to coding, although this technique has been widely acknowledged as time-consuming, laborious, and error prone, especially when there are many cases. These problems are compounded when one has to iterate through data to do a thorough multiple perspective analysis. Four major perceived constraints that have traditionally limited the use of qualitative approaches include complexity of record analysis, volume of data, flexibility and momentum of analysis and detail of classification. In order to minimise the prospect of these coding limitations from compromising the quality of the data analysis conducted in the current study, a phased approach has been adopted as explained in the subsequent section.



## 4.2 Steps approached for Qualitative data analysis

A typical sequence of activities that underpin qualitative data analysis is provided by Romano et al. (2003). This sequence is illustrated in Figure 7.

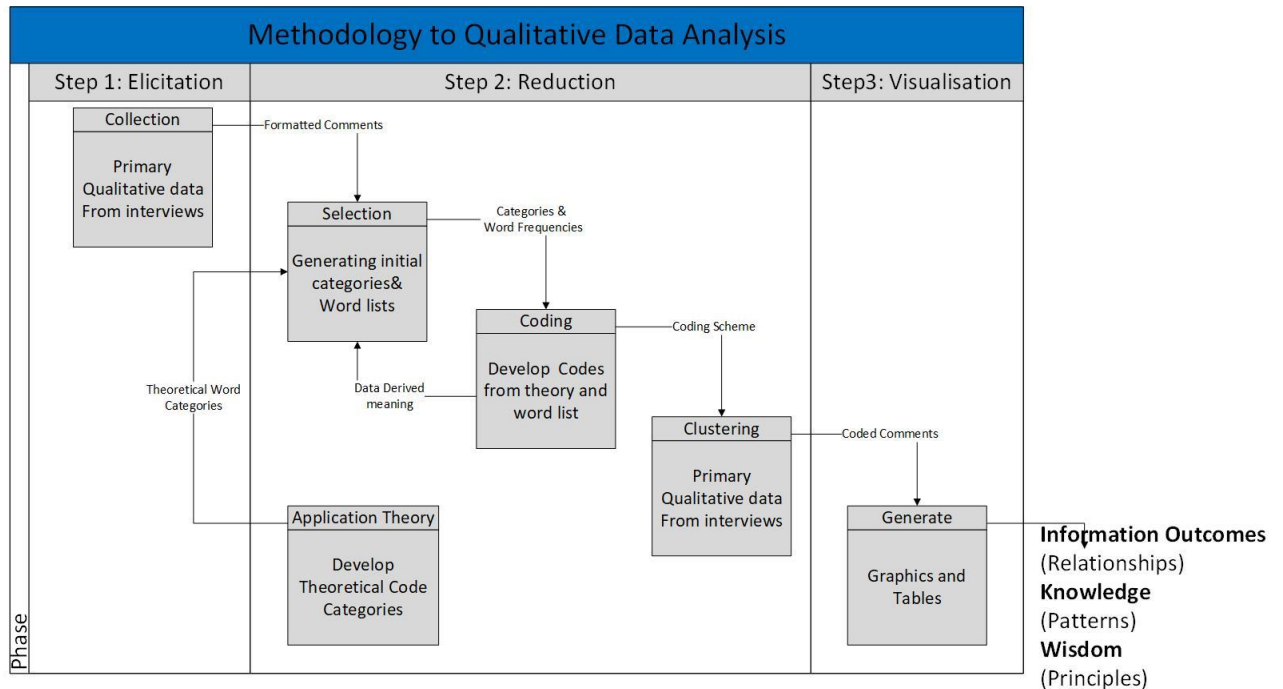


Figure 7 - Methodology for Qualitative data analysis in Romano et al. (2003)

### 4.2.1 Elicitation

According to Vatavu and Wobbrock (2015), elicitation is the collecting or recording of what is seen, spoken, heard, or written in words. Commonly used methods of elicitation are interviews, focus groups, field notes, and ethnographic observations. Vatavu and Wobbrock (2015) opine that elicitation is considered to be an important component of qualitative research. Qualitative data input can also be obtained as primary data through direct gathering via online or e-mail open-ended surveys, online group support systems, or any other means. Qualitative data input can also be gathered as secondary data from indirect sources, such as the Internet.

For the purpose of the current study, qualitative data was collected in the form of face to face interviews. A total of 10 interviews were conducted. The cohort of 10 interviewees comprised of 3 information technology specialists from the medical field and 7 medical practitioners. The dual objectives underpinning this data elicitation strategy was to obtain an understanding of the technical and medically oriented viability of implementing an IoT intervention in the medical healthcare sector in Zimbabwe.

#### **4.2.2. Data Reduction**

The reduction phase focused on abstracting, simplifying, and transforming the raw interview data so that it becomes meaningful information. During this stage, categories and codes are derived from general theory, the researcher's hypotheses, key relevant concepts, or from the data itself.

#### **4.2.3 Selection**

Selection in qualitative data analysis is all about determining categories and developing category schemes and unique word lists. Initial categories are shaped by pre-determined research questions and derived from application theory, yet researchers and practitioners should remain open to adding new meanings from the data (Vatavu and Wobbrock, 2015).

#### **4.2.4 Coding**

According to Romano et al. (2003), coding is a process of combining clusters of the research observations into the classes defined in selection to establish specific sets of codes for the categories developed in selection, derived from application theory, or based upon word frequencies. From this explanation, it becomes apparent that coding is part of the data condensation or data reduction process to enable to capture the essence of the volumes of data

that is typically gathered in a qualitative study. According to Miles et al. (2014) codes are themes that are used to categorise information as well as to convey the essence of the data by making use of expressive, descriptive themes. Coding is also a convenient method to enable reference 'chunks of textual transcripts' and quick retrieve to set the stage for further analysis and the development of a construct or a theory.

The next phase is to review the word frequency individually and adjust code classifications so that the elements of a coded list are closely aligned to each other. Finally, the lists are combined to form a single final coding that have a closer alignment with the theoretical constructs of the study.

#### **4.2.5 Clustering**

Clustering helps in deciding which information to code and how to code the information. Cluster analysis can be applied to coded qualitative data to illuminate the findings of prevention studies by aiding efforts to reveal such things as the motives of participants for their actions and the reasons behind counterintuitive findings. By clustering groups of participants with similar profiles of codes in a quantitative analysis, cluster analysis can serve as a key component in mixed-methods research (Romano et al., 2003).

### **4.3 Framework for Phenomenological Qualitative Data Analysis**

The qualitative data collection phase consisted of an interviewing strategy where the researcher leveraged knowledge from the literature review to enhance the richness of the dialog with the interviewees. There were two sets of interviews that were conducted with the 7 medical practitioners and the 3 IT specialists working in the medical field. The interviews with the medical health practitioners were focused on enabling an understanding of the medical ramifications of implementing an IoT strategy to enhance healthcare in Zimbabwe.

The interviews with the technical specialists were focused on understanding the viability of implementing IoT technology so that it is minimally disruptive to the current technical infrastructure that supports healthcare in Zimbabwe.

The hermeneutic phase of the interviews with the medical specialists consisted of opening questions where they were asked about their experience(s) in the use of technology in the healthcare system in general and a further probing question that made a specific reference to the current experience of using the primitive IoT infrastructure that exists in the healthcare system in Zimbabwe. The next section of questions in the interview had a strong phenomenological basis that aimed to discuss medical practitioners' knowledge and experience of using both general technology and IoTs for healthcare in Zimbabwe. Practitioners were asked to relate "stories" of success and failure of technology with a specific reference to the success levels and level of trust that has been bestowed upon the technological infrastructure to upkeep quality healthcare standards. This strategy of "story telling" is aligned to the guidance on phenomenological interviews advocated by Groenewald (2004). The responses to the first two questions in an interview are crucial in guiding the analysis phase that aims to establish an understanding of the common experiences by the interviewees of the study. For quality data analysis the researcher is expected to group the data and identify information and extracts of subjective evidence that are used to create 'clusters of meaning' from the observations of the information so that themes can be identified to provide an understanding of how the interviewees experienced the phenomenon.

The second set of interviews with the IT professionals who are practicing in the healthcare industry was designed to understand their experience with technology and IoT in healthcare. Additionally the interview also probed the IT specialists to interpret the viability and current challenges from the identified 5 layers from the theoretical framework namely the

Perception layer, Network layer / Communication Layer, Middleware layer, Application layer and the Business layer.

#### **4.3.1 The Use of Qualitative Data Analysis Software**

According to Bringer et al. (2006), it is vital to use Qualitative data analysis software programs like NVIVO (used in the current study) because it provides the researcher with the ability to transform the way information is viewed from static to dynamic forms such that it makes relationships between categories more visible by using text formatting and hyperlinks to other documents and categories. However it is not meant to replace the traditional manual way of examining data to establish relationships and patterns.

The current study used the Nvivo 12 Professional Version for the qualitative data analysis in order to enable the researcher to realise enhanced capacity for recording, matching, sorting and linking of qualitative data while also maintaining access to the source data or contexts from which the data have come.

#### **4.3.2 Initial Coding**

According to Bringer et al. (2006), initial coding is referred to as the process of conceptualising the raw data into a higher level of abstraction which represents a meaningful form of data reduction. However Creswell and Creswell (2017) warns that methodologies associated with qualitative data analysis have to be robust so that it can handle voluminous data during the analysis phase.

Based on this spiral approach, by Creswell and Creswell (2017), the data analysis for the current study is done through a strategy where the 10 interview transcripts were analysed as an initial incursion into the data analysis. The objective of this exercise was to obtain a sense of the main concepts that emerge from the initial set of interviews

The transcripts from each interview were entered into the Nvivo qualitative data software tool in sequential order. Each transcript was linked to a memo that incorporated field notes made by the researcher during the course of each interview to make reference to the interviewee's context in terms of the domain of the work environment as well as the capacity that the interviewee served in the healthcare sector.

In order to identify a viable set of nodes for this study, a word frequency count was computed from the analysis of the 10 interview transcriptions. These word frequency counts were analysed separately for the technical and healthcare professionals.

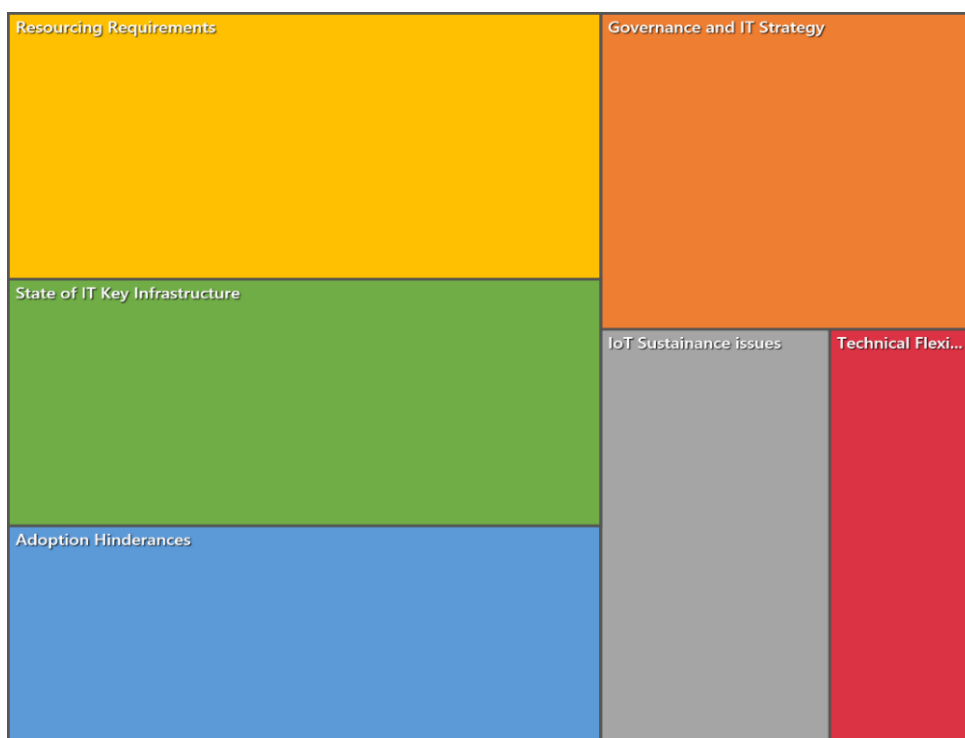
#### **4.4 Preliminary Data Analysis and Presentation**

According to Romano et al. (2003), a preliminary analysis is crucial for subsequent analysis of raw data together with the researcher's observations and recognition of patterns or trends in the data. It is a useful strategy to enable convergence of understanding of the main issues relating to the phenomenon of the study.

The data analysis for the current chapter consists of two sections that analysed two sets of interviews using different theoretical constructs. The medical practitioners set of the interviews was analysed in reference to a theoretical framework that consisted of a combination of the Technology Acceptance Model (TAM) theory and the Diffusion on Innovation (DOI) theory. The second set of the interviews was analysed in reference to the Technology Infrastructure Theory introduced as part of the overall conceptual framework used to guide the study (found in Chapter 3).

#### 4.4.1 Technical specialist interviews

Based on the analysis of the 3 interview transcripts from the IT practitioners, a total of 6 main 1<sup>st</sup> cycle nodes and 19 sub / 2<sup>nd</sup> cycle nodes were identified. For the purpose of the current study, a hierarchical chart in Figure 8 was used to obtain a broader perspective of the most influential categories based on the number of references that were attached to these categories.



**Figure 8 -IT Specialist Interviews Hierarchical Chart**

Figure 8 illustrates rectangles that represent proportional volumes of references attached to that category derived from the first set of interviews conducted with the *IT professionals* practicing in the medical sector. The objective of the interviews was to obtain an opinion of the *technical viability* of the implementation of IoT in the medical sector. From the first set of interviews conducted with the 3 IT practitioners, there was a substantial number

of references to the categories of the *State of IT Infrastructure* and *Resourcing* requirements being the most referenced nodes.

The most referenced portion on the hierarchical chart were the factors that affect Resourcing. In this node factors such as Capital Resources and Complementary IoT cost to acquire the required infrastructure were raised, that may affect adoption of IoT in the healthcare sector in Zimbabwe.

To have a better understanding of the interviews' key themes, an analysis of the key words that were used most frequently were identified through the use of a word cloud in Figure 9 for further examination of the context in which these words were used. These words were augmented with an additional words so that it would make an accurate representation of the context in which these words appeared in the transcripts.

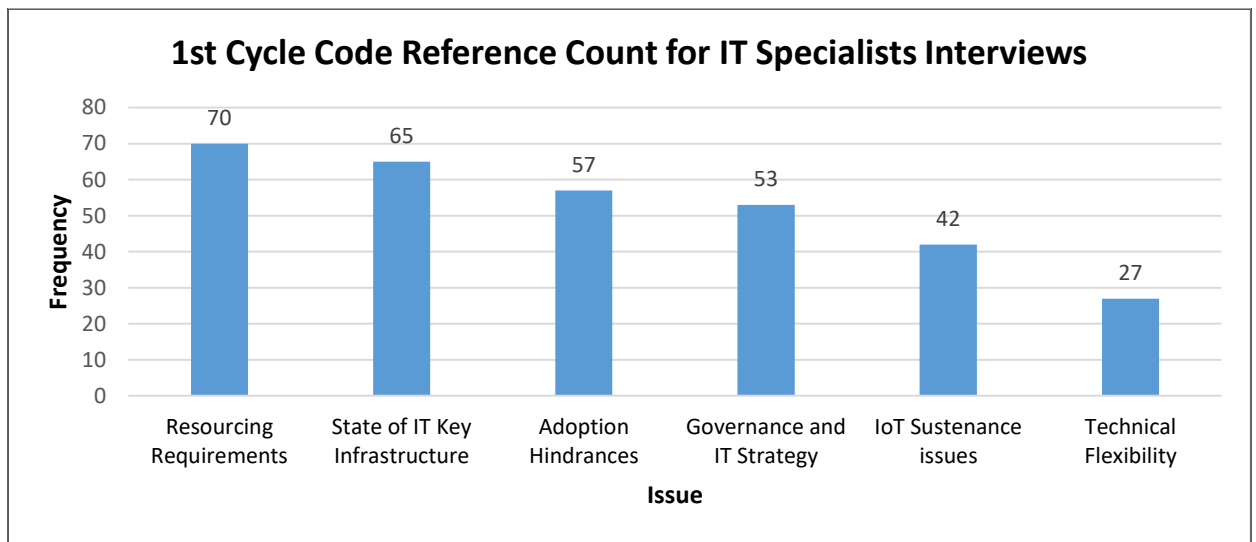


Figure 9 – IT Specialist Interviews –Word Cloud

The process of word augmentation was conducted by running a text search query and establishing the most common words that were found near a specific word. As an example, a text query of the words that were in proximity of the word “Technology” and “Data” yielded the word cloud illustrated in Figure 9.



After the word argumentation process was done, key themes were identified through a process of data condensation of 1<sup>st</sup> cycle codes. This process enabled the researcher to regroup the key topics into clusters and enable deeper analysis of the data. The identified codes were grouped and quantified as 1<sup>st</sup> cycle nodes as illustrated in the bar chart as Figure 10..



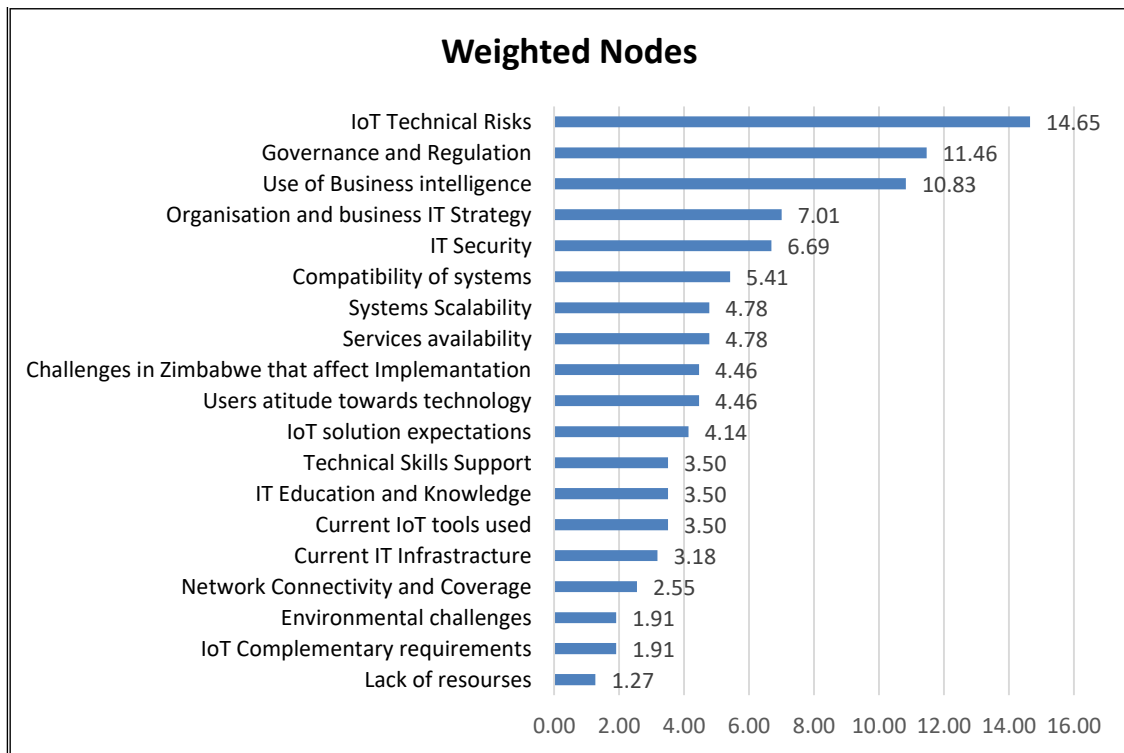
**Figure 10-1st Cycle Code Reference Count for IT Specialists Interviews**

The 1<sup>st</sup> cycle code references is illustrated in Figure 10. It can be seen that the most referenced node/category was resourcing requirements and the state of key IT infrastructure followed by references to the Adoption Hindrances, Governance and IT strategy, IoT sustenance and Technical flexibility issues respectively. This was done through the condensation of the main themes that emerged from the interviews. After the 1<sup>st</sup> cycle codes were identified, each code was broken down into 2<sup>nd</sup> cycle codes/themes shown in Table 1, in order to identify and discuss the collective elements that support the 1<sup>st</sup> cycle themes shown in Figure 10.

**Table 2-2nd Cycle Code Reference Count for IT Specialists Interviews**

Reference No.	Issue	Reference count	Weight
1	IoT Technical Risks	46	14.65
2	Governance and Regulation	36	11.46
3	Use of Artificial intelligence	34	10.83
4	Organisation and business IT Strategy	22	7.01
5	IT Security	21	6.69
6	Compatibility of systems	17	5.41
7	Systems Scalability	15	4.78
8	Services availability	15	4.78
9	Challenges in Zimbabwe that affect Implementation	14	4.46
10	Users attitude towards technology	14	4.46
11	IoT solution expectations	13	4.14
12	Technical Skills Support	11	3.50
13	IT Education and Knowledge	11	3.50
14	Current IoT tools used	11	3.50
15	Current IT Infrastructure	10	3.18
16	Network Connectivity and Coverage	8	2.55
17	Environmental challenges	6	1.91
18	IoT Complementary requirements	6	1.91
19	Lack of resources	4	1.27

The second phase of the analysis was followed by identification and analysis of the 2<sup>nd</sup> cycle codes illustrated in Table 2 and presented diagrammatically in Figure 11 in descending order, shown as weighted nodes. As indicated the most referenced codes were IoT Technical risks, governance and regulation issues and the use of artificial intelligence among other referenced themes.



**Figure 11- Weighted 2<sup>nd</sup> cycle nodes for IT Specialists Interviews**

Interviews were structured to investigate the technical feasibility based on IT specialist experience that addressed issues such as the requirements that affect IoT functions and challenges that affect every layer described in the research framework. The layers investigated being the Sensor layer, Network layer, Business layer middleware layer and the Application layer.

To investigate the technologies used by the various IT interviewees 1<sup>st</sup> cycle and 2<sup>nd</sup> cycle code analysis were used to enable clustering of the information. The Resourcing requirements node was the most referenced 1<sup>st</sup> cycle node. The 2<sup>nd</sup> cycle node were derived from the 1<sup>st</sup> cycle nodes. The greatest issue that was discussed was the lack of resources to fund the purchasing of systems, maintenance or support the existence of IoT products for the patients, IT specialists and the medical practitioners. The main hindrance of the adaptability of IoTs that has been noted are the costs of the medical monitoring devices, the availability of local suppliers of the accessories/ parts and very limited companies that offer technical support or policies or regulations that govern the administration, subsidiaries of health innovations in Zimbabwe. The other challenges faced particularly in Zimbabwe is that due to diminishing economic conditions, there is a lack of appreciation of such innovations as they are perceived as *luxurious*. In addition to the country's' economic state, the local foreign currency market is rather unstable and expensive to offer consistent IoT supplies. The verbatim extract below has been taken from one of the interviewees emphasising how the current economic environment Zimbabwe impacts their ability to adopt IoT.

*The environment where disposable income is very little for both individuals and businesses, and furthermore technology has been given very little preference such as having no equipment having no research centres where innovation hubs and they end up going for off the shelf solutions.*

**(Interview 2, IT Specialist)**

In addition, IT professionals in Zimbabwe say that there is high usage of cloud services such as Microsoft Azure and Amazon Web services. However the main drawback that is faced in Zimbabwe is the depreciating economic conditions that affect business. Most cloud services require to be paid in foreign currency. However the depreciation of the Zimbabwean currency makes it expensive to continuously pay for services. In addition, the failing economy has a 'ripple effects' on the spending behaviours of the potential IoT users, therefore the market for

the purchasing and implementing IoT technology is diminishing. The second issue noted was the gap between what is available and what is required to support the technologies. The middleware layer requires skills to integrate the technologies to provide seamless solutions. However, only a few IT professionals have the relevant skills to support the services.

A “troubling” outcome of the interviews analysis is that only a few patients in Zimbabwe can afford the use of advanced technology for their healthcare especially when the economy is not performing well. The other key issue associated with lack of resources was that of the poor network infrastructure backbone at a national level which is not adequate for IoT systems to operate on. The best network quality available in Zimbabwe is 3g and 4g; however it only covers 60% of urban networks. Meaning that this could affect the attractiveness of investment in the IoT fraternity. Due to the poor network quality and spread coverage there would be a lack of smooth transmission of data packets between network nodes.

The **second key issue that came out of the resources requirements** was that technically, IoT will likely suffer because of **lack complimentary resources** to support its systems. The first resource being the technical support; only a few technical personnel have the skills to repair, install or maintain IoT medical monitoring devices. It has been noted that a few private institutions have now resorted to introduce the use of IoTs to analyse their patients. However, this excludes almost 80% of Zimbabweans who can only afford public hospitals, and the government cannot afford to upgrade primarily due to the financial challenges as well as a lack of urgency for the introduction of technical innovations to enable better healthcare.

Other issues such as **high costs of data, lack of local storage infrastructure** and as well very **expensive high performance computers** are beyond the capital investment that the Zimbabwean Health ministry is able to provide.

The **second 1<sup>st</sup> cycle node** that was identified in the interviews were the state of **IT infrastructure in Zimbabwe** that may support the transmission of data between IoT medical monitoring devices to the doctors.

The **key infrastructure in Zimbabwe** that affect the IoT operations that were identified as 2<sup>nd</sup> cycle codes include the IT backbone infrastructure, environmental challenges and network connectivity complexities. Specifically at the client/patient interface, medical monitoring devices such as electronic thermometers, blood sugar strips, stethoscopes, probes, tongue depressors, cameras, blood pressure and heart rate monitors are used as a point of data entry into the medical network infrastructure. A significant problem that was identified was that many of these data collection medical monitoring devices are not main stream IT products / tools which IT specialists may be able to program or support. This created a lack of compatibility between the points of data entry and the data processing network that currently existed resulting in only a primitive form healthcare monitoring. The below extract from an IT expert supports the compatibility challenge that there is need to develop compatible and programmable Medical devices.

*...although we use blood pressure, temperature thermometers and sugar level readers, we don't have IT actuators that we can be able to program or maintain, so that it can be linked to the technologies that are already there. Therefore all we have done is that we have bundled all the healthcare into one device from which readings are taken manually and then entered into the system. This should happen automatically.*

### **(Interview 3. IT Professional)**

In terms of applications usage, most Zimbabwean specialists are able to mainly utilise SMSs and USSD communication rather than using mobile applications to either gather, or disseminate data from or to patients because of a lack of affordance.

The second main topic in infrastructure issues was to do with bandwidth, power and network connectivity/ quality issues. In Zimbabwe the best network offered is either 3g or 4g

networks or power supply, however it covers only 60% of the urban areas and a few rural regions. This would directly impact the overall coverage of data transmitted by IoT medical monitoring devices especially from the remote regions. Due to this drawback medical monitoring devices currently being used in Zimbabwe are not yet intelligent to auto switch between base stations to assure asynchronous data communication thereby compromising the overall affect the quality of data. In Zimbabwe as noted before only at most about 60% of the regions have electricity, of which, these are the main towns and cities, leaving rural areas underdeveloped and making it virtually impossible to implement IoT technologies. This point was derived from a comment made by one of the IT experts, shown in the below extract below.

*In Zimbabwe the only areas that cover 3g / 4g sites are approx. 60%. Due to inconsistencies some important data may be lost as the patients are in usually being transported to various medical facilities. There is no assurance that that there will be a smooth handover from one base station to the next and also between network nodes to the next and this is still one of our main concern.*

**(Interview 1. IT Professional)**

The **third key 2<sup>nd</sup> cycle code** that affects **infrastructure** was the **environmental issues**. One of the well-known characteristics of the African continent is its unique and unpredictable rough geographical terrains and climate. Attributes such as extreme temperature, pressure and humidity are a few of the many environmental factors that may distort the readings or data collection accuracy of the sensor layer of the network. Therefore it would be a requirement that when the medical sensor medical monitoring devices are developed they need to be resilient to the harsh environmental conditions that are normally associated with countries in Africa. This can be supported from a comment below from one of the IT experts who has experience in installing IoT medical systems around Africa.

*You would see that the geographically diverse climates that we experience, where it is sometimes very hot and humid in one city and quite cold in another. The actual medical monitoring devices are directly affected by the varying climatic conditions. Therefore the medical monitoring devices have to be configured in such a way that it can handle the varying environment challenges. Moisture and temperature are the biggest issues. Also various pressure factors e.g. for BP atmospheric pressure*

**(Interview 1. IT Professional)**

The **third 1<sup>st</sup> cycle code** that was condensed was the **IoT sustenance** theme. These are issues that cover sufficiency in support to sustain the operations of IoT products, education and IoT solutions expectations.

Technical personnel suggest that there are a **few skilled personnel** that can support high technical skills in Zimbabwe and more has to be done in terms of developing skills for disciplines such as data science and software development so that quality systems and information can be generated. The services that require support mainly are the installation of accessories / spares, configuration of software services and programming the equipment. There is also a need for medical students to have technology modules in schools curriculums that cover IT skills so that adoption and usage can be promoted. The extract below made by one of the IT experts supporting the need and requirement of local technical skills upbringing to support the proposed technology solution in Zimbabwe.

*Because around the world technology is emerging and requires special skills such as people that program, install or support new technologies. Therefore it is vital that our local educational institutions start upskilling technical students to be able to support IoT and other emerging technologies.*

**(Interview 3. IT Professional)**

To sustain IoT the model, technical experts highly recommend that there has to be extensive efforts prior to the project rollout to ensure at least 80% network coverage and the use of affordable and compatible medical monitoring devices across the country, even in remote regions. The network quality has to be improved to ensure seamless data transmission. It is



also suggested that IoT products are developed by local companies so that these products are economically feasible and aligned to local environmental conditions.

The **fourth 1<sup>st</sup> cycle code** that was condensed was **technical flexibility** issues; this theme refers to solutions that are scalable, interoperable, robust, secure and convenient to use.

The first 2<sup>nd</sup> cycle node that was identified was emphasising of systems to be **compatible** to different systems and environments. Considering that there are no set standards in Zimbabwe that regulate the use of IoT and other technologies in Zimbabwe. IT professionals suggest that it is vital to assure that protocols are seamlessly aligned, secure and understand each other in such a way that make it easy to configure and integrate medical sensor medical monitoring devices into the network infrastructure. At the same time it is encouraged that medical monitoring devices should be intelligent to switch from one network to the next. The extract below made by an IT experts explains his views towards the need of aligning technical standards and protocols and additionally commenting on the need to assure network quality to ensure service integrity and availability.

*Inconsistences in standards, some service providers use backward principles/ protocols. The main drawback is Network coverage. In Zimbabwe the only areas that cover 3g / 4g sites are approximately 60%. Due to these inconsistencies some important data may be lost as the patients are in motion. Therefore there has to be an assurance that there is a smooth handover from one base station / network node to the next is still one of our main challenges. We also do not have fail over networks / backups that may assist. Most of the medical monitoring devices are not yet intelligent to switch from one network to the next.*

**(Interview 1. IT Professional)**

The **second point in the Technical Flexibility** code was the assurance of **system availability**. Technical experts suggest that it is key to ensure that there is a smooth handover from one base station / network nodes to the next. In this theme the issue of network availability and robustness has been highlighted. The main concern is that the network needs to provide guarantees of quality and the capacity to ensure that information transmission is

reliable and quick. In Zimbabwe currently the network infrastructure does not guarantee reliability and speed of processing thereby compromising the prospect of using the network infrastructure to deliver quality healthcare. Much of the problems are rooted in the financial domain and the lack of value of the Zimbabwean currency makes it virtually impossible to leverage global technology services such as cloud computing to ensure seamless **data availability**

The **third issue under Technical Flexibility** was about the **scalability** of the services. This is to ensure that all systems implement the same standards and protocols so that new nodes may be added to the network in a seamless manner that does not require much configuration overhead. There is also the problem that the available network bandwidth and speed is poor and this will in all probability affect projects that depend on optimum services that an IoT intervention may provide. This point was mainly supported by a comment by one of the interviewees in the below extract, indicating concerns over the quality, affordability and scalability of internet in Zimbabwe.

*....my reservations would be to assure that the same quality is scalable across the country, the same sentiments would also be that how many people can afford to acquire medical monitoring devices that allow use of 4g.*

**(Interview 1. IT Professional)**

The **fourth 1<sup>st</sup> cycle** theme that was identified was **Governance and IT Strategy** issues. This theme covers key issues such as IoT technical risks, governance and regulation and Organisational IT strategy and IT alignment.

The main key **2<sup>nd</sup> cycle issue in this theme is IT Technical risk**. IT specialist suggest that it is key to always ensure service availability in order to support the implementation of IoT in Zimbabwe. Then other geographic variables such as topology, natural disasters and culture are also potential risks that may negatively affect IoT implementation

in African countries. Additionally as indicated in earlier, Zimbabwe is immensely affected by a lack of adequate IT infrastructure, a poor economic state, incapacitation and lack of IT service companies that offer support of IoT products may add as potential risks for the success of implementing the product. The last major key risk identified was IT Security. IT professionals fear that with the rate technology is advancing, and so are the growing vulnerabilities that systems are exposed to. Particularly exposure to security issues such as hacking and ransomware attacks are among other security threats have increased in 2018. This would be a huge setback for institutions particularly affecting privacy and confidentiality of patient information. The below extract made from one of the interviews indicating concerns over data security readiness in Zimbabwe.

*.....we are in an IT era where almost every information and systems are hosted in the cloud. Therefore data security measures need to be put in place in order to avoid repercussions of the negative effects of security breaches*

**(Interview 2. IT Professional)**

The **second issue from the Governance and IT strategy** 1<sup>st</sup> cycle was the **governing or regulation of IT standards** and policies. IT professionals in Zimbabwe think that the health sector is a heavily governed sector probably based on the sensitivity of its cause. Therefore that is why it becomes a rigorous process for an innovation to be accepted, certified, made acceptable and adopted in Zimbabwe. It was also reported that it is important that standards need to be regulated in terms of assuring that protocols are seamlessly aligned and understand each other considering that each organisation has different manufacturers that have products that use different set of rules or standards.

This also extends to the issue of **IT strategy and governance**. IT specialists suggest that there is need to set business and IT governance intertwined within health institutions in order to focus on holistic value creation efforts to better manage the performance of those responsible for its operations and its stakeholders. This point was derived from the below

interview extract, were the IT specialist outlined the current challenge misalignment of objectives between the business and the IT department.

*Our biggest challenge is communication from the business side, interpretation of an anomaly or requirement or business case might not be the same interpretation from the developers / to configure. Therefore the proper business problems must be understood and governed according to consistent standards to enable appropriate middleware technologies to be configured to give the desired outcomes.*

**(Interview 2. IT Professional)**

The **last 1<sup>st</sup> cycle node** that came out of the IT professionals interviews was the **Technology Adoption Hindrances**. This code discusses the perceived general holistic challenges that could affect the IoT projects. The key issues that emerged from the Technology adoption hindrances in summary were that Zimbabwe being in an economic depression: foreign currency shortages, inflexible legal environment and lack of investment are some of the key macro-economic variables that stall investment towards IoT.

Additionally other issues noted were that; the IT sector in Zimbabwe is not as innovative to embrace the technology, it also lacks appropriate and adequate IT skills to support its users. Additionally there is generally poor network infrastructure cover in Zimbabwe and most of the population cannot afford purchasing IoT products.

In addition to this node IT specialist suggest that another key factor to consider is **user attitude** and understanding the **culture** of people in order to influence its adoptability. In Zimbabwe culturally there is a deep belief especially in the elderly that the doctor's touch is irreplaceable with technology, therefore understanding such basis factors should enable strategic positioning of technology that may not violate the culture. IT specialists suggest that there is a need to place a good change management structure in order to curb for issues such as resistance. This was supported by an extract from one of the interview extracts below,

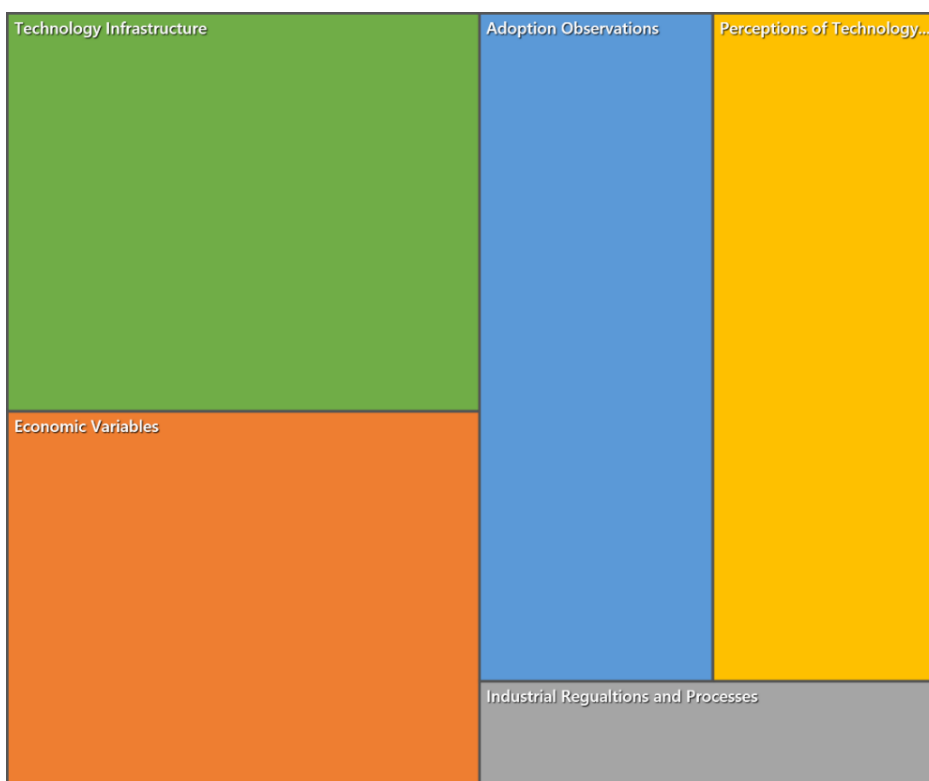
indicating some of the key challenges to do with worker resistance to change and other people related factors that may be as a result of technology disruption.

*Most health institutions have very rigid processes and manual operations that may be difficult to replace easily mainly due to the “People component”. We will need to implement change management structures where institutions start to understand the capabilities of such technologies and how it can improve their efficiencies.*

**(Interview 2. IT Professional)**

#### 4.4.2 Analysis of the Medical Doctors’ interviews

Based on the analysis of the 7 interview transcripts from the Medical Practitioners, a total of 6 main 1<sup>st</sup> cycle nodes and 23 sub / 2<sup>nd</sup> cycle nodes were identified. For the purpose of the current study, Figure 12 is a hierarchical chart that was developed in order to obtain a broader perspective of the most influential categories based on the number of references that were attached to these categories.



**Figure 12 – Medical Practitioners Hierarchical Chart**

Figure 12 illustrates rectangles that represent proportional volumes of references attached to that category. From the first set of interviews conducted with the 7 Medical practitioners there was a substantial number of references attached to the *Technology Infrastructure*. In this node factors such as Compatibility of systems and processes, Technical readiness, Technical Risks, Patient Tracking, Currently utilized IT resources, IoT medical monitoring devices used, Network quality and coverage issues were raised that may affect adoption of IoT in the healthcare sector in Zimbabwe.

In order to establish the validity of the core concepts that have been identified thus far, a further set of 6 interview transcripts were added to the data corpus for analysis. The process of 1st Cycle coding was conducted on the latest data set described above. At this stage there were a total of 7 interview transcripts that were subjected to 1st Cycle coding for the Medical professionals. The coding process was becoming a routine exercise because the list of 1st Cycle codes was extensive and ensured that much of the text from the newly added sources was easily accommodated in the existing set of 1st Cycle codes. In addition to the 1<sup>st</sup> cycle codes, the conflation of 1<sup>st</sup> cycle codes into 2<sup>nd</sup> cycle codes was easily achieved.

The extract below is a comment regarding relevance of identifying key factors that affect the adoption of IoT technology in order to determine its success in an environment. This comment was made by an experienced medical practitioner who also has extensive knowledge of the use of IT in the medical field. This comment was made in response to an open ended question where the interviewee was asked to offer an opinion on the adoption of IoT in healthcare in Zimbabwe.

*It's about understanding this a business, there are various key factors you need to delve into, healthcare is not a voluntary organization, and we need profit and we have costs and limitations. However to implement this model if you concentrate in making profit in the early stages you will fail, therefore you really need to include proper strategies, set up sustainable infrastructure to support the system and get the numbers and then eventually start gaining*

*momentum over time. I'm sure what puts people away are the costs or the pricing. Cost of infrastructure and substitutions among other key factors.*

**(Interview 4, Medical Practitioner)**

This comment became a catalyst for the researcher to explore issues related to the adoption of IoT methodology, not just from a Technical perspective but also from a practical, economic and health organisational perspective.

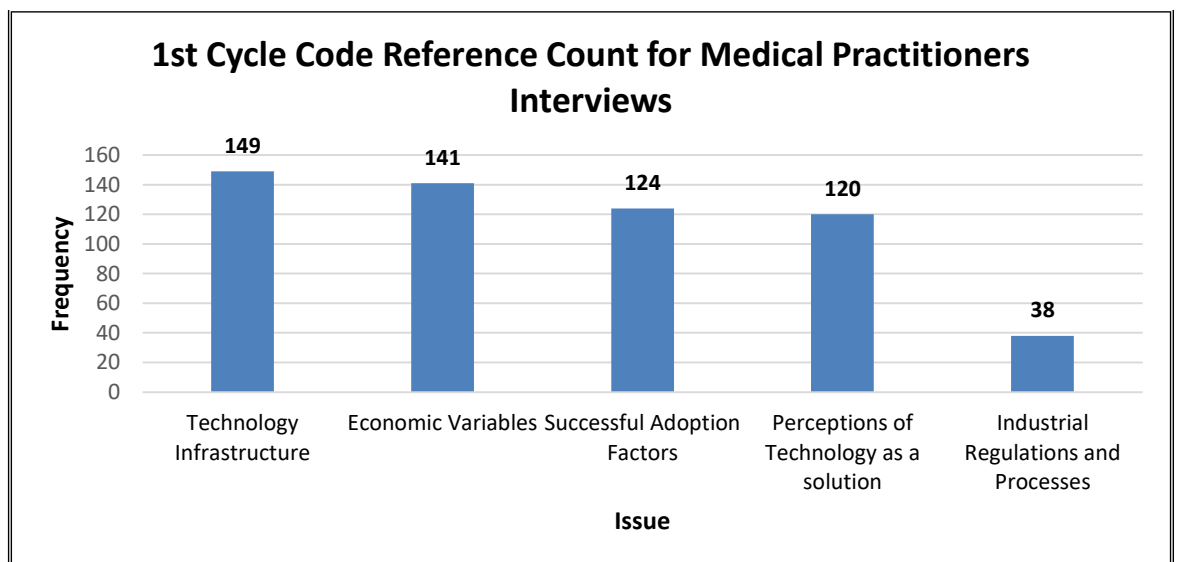
The researcher then resorted to the constructs that underpinned the conceptual framework that was identified for the study. Although this framework was identified with the quantitative phase in mind, the data from the interview transcripts seem to align itself quite conveniently into categories that were named in accordance with the constructs from the study's conceptual model. As a recap, the conceptual model identified consists of constructs taken from TAM and DOI. These constructs were : Perceived Usefulness of IoT, Perceived Ease of Use of IoT, Behavioural Intention to use IoT, Attitude towards using IoT, Relative Advantage of using IoT, the Observability of using IoT medical monitoring devices, and the Complexity of engaging in an IoT intervention. The Figure 13 presents a word cloud indicating key phases that were augmented in the interviews so that the researcher used to outline key themes of the context in which these words appeared in the transcripts.



Figure 13- Medical Practitioners –Word Cloud

As indicated, Figure 13 the most used words were “Work”, “changing”, “patients” “Technology” and “Use”. These word cloud mainly indicate intrinsic factors around their professional environment that direct towards a need for innovative interventions to enable better efficiencies.

After the word argumentation process was done, key themes were identified through a process of data condensation of 1st cycle codes. This process enabled the researcher to regroup the key topics into clusters and enable deeper analysis of the data. The identified codes were grouped and quantified as 1st cycle nodes as illustrated in the bar chart Figure 14.



**Figure 14– 1st Cycle Code Reference Count for Medical Practitioners Interviews**

**1<sup>st</sup> Cycle codes** that were interrogated for the medical practitioners were Technology infrastructure, Economic Variables, Successful Adoption factors, Perceptions of technology as a solution and Health industry regulations and processes.



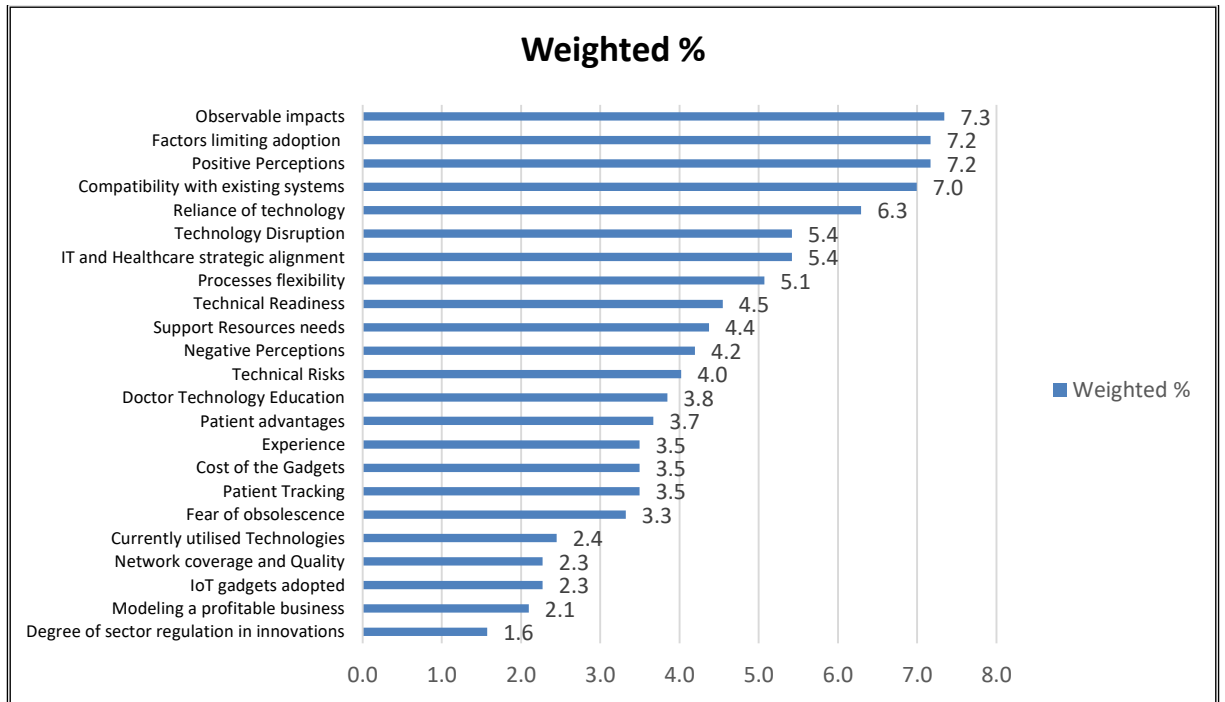
Following the identification of the 2<sup>nd</sup> nodes the 2<sup>st</sup> cycle themes were condensed. Table 3 illustrates all 2<sup>nd</sup> cycle nodes that came out of the Medical practitioners interviews.

**Table 3-2nd Cycle Code Reference Count for Medical Practitioners Interviews**

No	Issues	References
1	Observable impacts	42
2	Positive Perceptions	41
	Factors limiting adoption	41
3	Compatibility with existing systems	40
4	Reliance of technology	36
5	IT and Healthcare strategic alignment	31
6	Technology Disruption	31
7	Processes flexibility	29
8	Technical Readiness	26
9	Support Resources needs	25
10	Negative Perceptions	24
11	Technical Risks	23
12	Doctor Technology Education	22
13	Patient advantages	21
14	Patient Tracking	20
15	Cost of the Medical monitoring devices	20

16	Experience	20
17	Fear of obsolescence	19
18	Currently utilised Technologies	14
19	IoT medical monitoring devices adopted	13
20	Network coverage and Quality	13
21	Modelling a profitable business	12
22	Degree of sector regulation in innovations	9

Interviews were structured to investigate from Medical practitioners through their experience and perceptions, key issues that may affect IoT implementation in the health care fraternity. To investigate the technologies used by the various IT interviewees 1st cycle and 2nd cycle code analysis was used to enable clustering of the information. The Technology Infrastructure node was the most referenced 1<sup>st</sup> cycle node. The 2nd cycle node that were derived from the 1st cycle nodes.



**Figure 15 -Weighted 2<sup>nd</sup> cycle nodes for Medical Specialist Interviews**

Figure 15 illustrate key issues that were discussed by the medical practitioners also identified as the 2<sup>nd</sup> cycle codes. The mainly referenced 2<sup>nd</sup> cycle codes were; observable impacts of IoT implementation, factors limiting adoption, Positive Perceptions and Compatibility of IoT with currently existing healthcare systems.

In the **Technology Infrastructure node**, the 2<sup>nd</sup> nodes consists of: Compatibility with existing systems, Technical readiness, Technical risks, Patient Tracking, Currently utilised Technologies, IoT medical monitoring devices adopted and Network coverage and quality issues.

The **compatibility theme** mainly comprised of issues that enhance a flawless implementation of the proposed IoT solution in healthcare in Zimbabwe with minimal disruption to the existing systems and processes.

The first requirement was that IoT should do is closely analyse the **current workflows** and systems in Zimbabwe. Most hospitals use computers mainly for **administrative and accounting** purposes therefore ensuring that IoT is designed to complement the existing systems to enhance efficiency is recommended. Furthermore IoT systems should be designed with attributes such as ease of use and avoiding too much of cognitive stress to the users. It is encouraged that if the hospital systems may be integrated to have a synchronised seamless systems talking to each other such as from theatre, pharmacy and laboratory to enhance real timeliness of the entire system. Medical practitioners are positive that an IoT solution can work in Zimbabwe if it has been proven to work elsewhere. It is encouraged however that guidelines of the effective use cases be shared as a standard to all to ensure interoperability between hospitals and other stakeholders. It is also important to highlight that Medical practitioners mention that they are not intimidated by technology that they may be made replaced in the future, but perceive technology to be a complementary tool. However it is advised that to avoid potential disaster and ease of shift with lesser risk, that there traditional manual methods should maintained parallel to the new system to avoid negative disruption. The extract below from the interviews, emphasises the need to use IoT medical systems as a complementary tool that does not completely eliminate the traditional methods.

*In Healthcare due to the potential impact of losing information, there should be manual backup systems to complement the systems to avoid disaster if technology fails*

**(Interview 6, Medical Practitioner)**

The next 2<sup>nd</sup> phase cycle in the IT infrastructure was IT Risk and Readiness. In the risk theme, the mainly mentioned risk was the level of information security that practitioners fear of the risk of exposure or breach of patient's information through attacks such as hacking. However it was advised that to mitigate potential risks it is highly recommended that users

become educated of the risks and implement best practices to protect their systems and patients information. The second main risk that was mentioned was fear that the systems may fail to be available when needed or exposure to complete blackouts, this could impact total catastrophes in continuity of the service in the case of retrieving valuable information. In this case it was suggested that new technologies such as IoT should run parallel to traditional manual systems to avoid total loss of control in managing processes and patient information. Network coverage and availability in Zimbabwe also has been mentioned to threaten as a security risk that may limit the effectiveness of the implementation of IoT in Zimbabwe as most parts of the country particularly rural areas are technologically under developed. Other suggestions were towards setting good practices standards that are to be used by health practitioners so as to ensure uniform approaches towards the uses and protection of systems. Other risks that were outlined were basically about the affordability or costs to run and or purchase total equipment that enables the desired system to be successfully be effective. The extracts below indicate information security and data cost related concerns that may affect the use of IoT in the healthcare systems.

*I think technology is an aid/ support tool there even in the absence of technology we can revert back to the old traditional methods to acquire and process information, therefore technology just makes work easier but does not replace the skills but can just administer us*

**(Interview 7, Medical Practitioner)**

*Technology infrastructure, access of internet is still hard for most people in Zimbabwe some cannot afford. And as well many areas in the rural areas do not have access to a mobile network*

**(Interview 5, Medical Practitioner)**

The third 2<sup>nd</sup> cycle code in **Technical readiness** consists of the combined utilised systems and IoT technologies currently utilised in Zimbabwe themes. Most doctors have indicated that they have **limited exposure to the use of technology** within their practice,

the use of technology in most hospitals has been mainly **restricted to the use of electronic record keeping, billing and accounting**, although a few other practitioners have more advanced systems, the rest of public the systems are manually managed. However practitioners perceive that technology can positively leverage their operational efficiency capacity in **tracking** patients' by eliminating process routines such as use **paper and pen** in manually collecting data. This can be achieved through methods such as the proposed IoT intervention were through the use of **intelligent medical monitoring devices** IoT may assist in making more accurate decisions and thereby **lowering the costs** of healthcare access for all. Based on the fact that the patient to doctor ratio in Zimbabwe stands at 1:12 000, doctors suggest IoT **technology shall immensely impact** the gap as it will **leverage efficiencies** of tracking patient's conditions. It is also suggested that **trust** has to be built for practitioner on technologies through **continuous education**. The below extract indicate that medical practitioners perceive technology as an essential tool that may enable leapfrogging the current healthcare challenges faced in African nations.

*.....technology is an indispensable tool that allows low income / developing countries such as Zimbabwe to leapfrog and catch up with the rest of the other advance countries.*

#### **Interview 7: Medical Practitioner**

The quote above from the medical practitioner indicates the better expression of how doctors regard the proposed solution, although they have limited technology in Zimbabwe due to low investment, however they perceive that it will leverage their capabilities.

In terms of IoT technologies currently adopted in Zimbabwe, only a few healthcare centres are offering the technology as a service. Most institutions at their best are using technology systems as administrative services. The few who have adopted IoT are using it to remotely monitor mainly blood pressure and glucose patients using 3g and Wi-fi technologies to transmit the data, and the data is mainly decoded into SMS format which is then sent to the doctors. There is no evidence of intelligent systems being used to enable decision support

or predictive analysis that may be made available to the doctors. The main hindrance that is suggested is that of the cost, knowledge and backwardness of the supporting IT national infrastructure in Zimbabwe.

Within the Technical readiness node the other main issue was the ability to remotely monitor patients. Through the second node: perceived advantages of IoT and technology; practitioners perceive that IoT shall reduce inefficiencies especially in consultations, also that IoT remote monitoring enables doctors to be able to be more precise in terms of which patient needs attention and also identify their location. Practitioners also praise the use of IoTs because it enables them to receive early warning mechanisms that can be linked to technologies such as artificial intelligence that may assist doctors to be more precise in their diagnosis. It is believed that IoTs will reduce the hospital visitations pressure on doctors in consultations and additionally IoTs are said to benefit patients who may be in remote and rugged areas whose access to medical centres may be limited. However there is fear that IoT technology may expose the health sector to the risk of cyber security and that may breach of privacy of hospital confidential information. The other potential disadvantage is that patients may misinterpret the results of the readings that may cause unnecessary panic and doctors may be affected. The below extract is one of the views from a medical practitioners regarding IoT perceptions to improve the quality of healthcare in Zimbabwe especially to track chronic patients.

*IoT has the potential to improve the quality of healthcare, it can enable better treatment outcomes for example in monitoring chronic illnesses such as HIV and BP. IoT allows the practitioner to the monitor his patients remotely*

**(Interview 7: Medical Practitioner)**

The second 1<sup>st</sup> cycle node themed **Perceptions of Technology as a solution and Practitioners Adoption Observations**. In this theme, topics that were identified consisted of; Fear of obsolescence, negative IoT perceptions, positive IoT perceptions, patients' advantages, and doctor's experience with technology and reliance of technology

The key topic that came out from this theme was the fear of obsolescence from the doctors because of the introduction of technology. The key fear of the practitioners is that with the disruption of technology in other industries through artificial intelligence and robotics

which will become pervasive in the medical field as well will result in a reduction for the need to have human expertise. However health practitioners in Zimbabwe are more positive than being intimidated by technologies such as IoT, and view them as a complimentary tool that may enhance efficiencies in their practices. They believe culturally there is already a human relationship that may not be easily replaced with technology between them and their patients especially the elderly. Also considering the fact that there is already a catastrophe that the doctor to patient ratio in Zimbabwe is estimated to be 1:12 000. If there is a lack of technological intervention, any medical disaster situation would be catastrophic for the country. The below extract from a medical practitioner, dismisses the potential resistance from other practitioners in Zimbabwe especially if the model is developed to benefit them financial and as well if Medical practitioners are educated properly of the implications of IoT systems.

*I think there won't be any resistance from doctors if the practitioners are educated to see how they will benefit financially; one possibility is that patients can subscribe for the service so that the doctors can earn some kind of income for their efforts at monitoring and reporting on a patient's well-being*

#### **Interview 8: Medical Practitioner**

The second issue in the user perceptions were to evaluate the positive perceptions of technology. Health practitioners were highly complementary of the benefits of IoT implementation. The key benefits that practitioners view are, improvement in efficiency to identify, consult and manage patients through IoT especially with the dilemma in Zimbabwe of the lack of doctors. Other tasks that will be also made more efficient include communication, process automation improvement, a reduction in cognitive strain to manage patients and medical resolution time.

Under practitioner's adoption two key topics came out, Medical practitioners experience and patients advantages of IoT implementation. Most practitioners in Zimbabwe have not received any IT related training within their career path making IoT a further challenge that needs to be handled. The only exposure that many doctors have had, is attendance at seminars where the value of technologies in the medical sector have been discussed from a theoretical perspective. At most cases the best use of technology is used for searching information online and hospital administration systems. The below extract from a



medical practitioner supporting the idea that medical practitioners positively observe the benefits of IoT technology, but however require training and education of how to use the systems.

*I think looking at my colleagues they are willing to learn better ways to enhance efficiencies in their working processes and anything that will go paperless, we are likely to be willing to adopt particularly in the public healthcare system where there is a lot of manual processes*

**(Interview 4 .Medical Practitioner)**

It has been suggested that IoT technology should be modelled in such a way that enables doctors to generate additional revenue for their efforts in participating in technology driven initiatives. Medical practitioners strongly suggest that the desired model should be backed by a strong business model that also offers a lucrative offer to the doctors were they can earn more. In addition to the point that medical practitioners perceive IoT useful, the below extract is a suggestion made inline to the observed importance of IoT. It is suggested that, IoT systems should be structured in a financial model such as monthly subscriptions that creates a sustainable revenue generator for them.

*...If it would make me gain more money. It can open up other avenues such as subscriptions payments. Revenue collection.*

**(Interview 6 .Medical Practitioner)**

The current challenge in most African countries is there is still a huge proportion of its residents staying in remote rural areas, and these populations lack access to proper medical attention. Medical practitioners suggest that IoT shall enable these populations to access equal attention through the use of IoT Technology. Furthermore, technologies such as artificial intelligence can enhance predictability of some patients' conditions which could resultantly save a lot of lives. The below extract from the one of the Medical practitioners interviews supports the idea that medical practitioners view IoT as a potential tool that my bridge the gap for patients to get enough attention as the urban patients counterparts.

*You get an early alert of the patient's conditions meaning you can intervene early hence you don't have to wait for the patient to reach complication stages. Because currently patients come to the hospital when they have pain or their medical condition has worsened to a point where recovery is compromised*

**(Interview 8: Medical Practitioner)**

The third 1<sup>st</sup> cycle node was the “**Perceptions of Technology as a solution**”, Medical practitioners have indicated **reservations** with regard of the implementation of IoT with the key concern of the **vulnerability of patient information on the internet**. That if security is violated patients' information is prone to breach the **privacy** through malicious software or hacking may ruin lives or the institutions name. The other related threat of IoT is in the case that if the **system collapses** or becomes **unavailable**. This may threaten the operations of the healthcare system in particular cognisance of the poor technology infrastructure that support internet service in Zimbabwe. The other drawback is that 80% of patients in Zimbabwe can only afford public hospitals which are unfortunately heavily regulated and under resourced. Therefore the impact of observing the ultimate effectiveness of the IoT solution may be limited. Also as mentioned earlier some practitioners are resistant to change, therefore educational programs for change management may be needed. The below extract illustrates an idea that medical practitioners view IoT intervention as an innovation that it may positively impact their work efficiency but may be susceptible to resistance from other practitioners.

*...resistance from some practitioners and patients who believe in physical examinations. However the challenges we are facing of not having enough human resources technology needs to be installed so that it is viewed as a support tool*

**(Interview 9: Medical Practitioner)**

The last key factor derived from the Medical Practitioners was The **Reliance on Technology**. Through this theme practitioners discuss key perceptions that evolve around dependence of the proposed IoT System. The key problem area that affects reliance are concerns of the **current state of infrastructure in Zimbabwe** that is perceived not yet **ready to support** such a sophisticated technology. Key issues here are the slow, low quality, less coverage and inconvenient internet connectivity and as well electricity power shortages

in Zimbabwe, which may negatively may affect the reliability of service to the health institutions. However the point of confidence is that if the same implementations have been done elsewhere around the world and the results have been proven, so can the same be replicated in Zimbabwe. As a process medical practitioners suggest that they can rely on technology because it can make them remotely monitor and reach patients in real time that can be proven more effective to save time, life and resources. The below extract suggestions were suggested measures by one of the medical practitioners that need to be put in place that assure service reliability and in the interim traditional methods be maintained to ensure continuity.

*...understand IT may sometime fail, for instance ensuring an uptime of 100% is barely guarantee therefore let there be parallel traditional channels be in place so as to mitigate the risk and as well communication channels can be backed up as well.*

**(Interview 10: Medical Practitioner)**

The fourth 1<sup>st</sup> cycle node that was identified was the **Economic variables** theme. In this node key main issues that came out were; the Cost of the medical monitoring devices, medical practitioners IT education, IT and Healthcare strategic alignment, modelling a profitable IoT model, support resources required and technology disruption.

In the Economic variables theme the main 2<sup>nd</sup> cycle theme that was coded was the **cost of the IoT medical monitoring devices** as commented by the practitioners. The main key hindrance for adoption for the hospitals and the patients is the **extremely priced medical monitoring devices** that are sold and supplied currently by the local retailers. The second challenge is the inconsistent supply of complimentary equipment, for instance in diabetes patients need non reusable strips to test their conditions. The problem is in Zimbabwe there is no stable supplier for these strips and so the regulation of the pricing the medical monitoring devices. The second type of costing refers to the healthcare institutions to have the capable computing resources that may support the use of IoT technologies. Then the other cost is that associated with the use of the medical monitoring devices is the cost of data in Zimbabwe which is very expensive currently, this also limits the appetite for users to acquire the medical monitoring devices. As mentioned in earlier discussions, most patients in Zimbabwe can only

afford to get public healthcare assistance, yet public healthcare practitioners suggest that the governing body does not have capital and an intention to invest in technology, this would mean that most patients may not experience the technology in a long time. The below extract made by a medical practitioner advising the potential risk of failure if the cost of the medical devices and systems are high.

*We would really support and like the idea of having IoT products to our patients. However the key drawback is the cost of the medical monitoring devices and the cost to maintain the medical monitoring devices, there are no local vendors that are ready to service the medical monitoring devices and supply complimentary products at a globally competitive pricing.*

#### **(Interview 10: Medical Practitioner)**

The second issue under the Economic issues is the **Technical education** or skills of the medical practitioners and as well the literacy levels of the patients. Most medical practitioners have indicated to have minimal and most no education skills on technical tools that may assist them in their practice. It is feared that most of the resistance that is anticipated shall mainly be as a result of fear of obsolescence due to the lack of technical skills or IT education. Then the last type of education is for IT professionals to be educated to create, install and support the technologies. Doctors suggest that the educational curriculum should gradually be made to introduce doctors and IT professions into these new cutting edge technologies. However doctors suggest that in the medicine curriculum, institutions should start to put related **technical courses** and ongoing **workshops** that equip current and future doctors with relevant **technical skills**. The same applies to the patients particularly the elderly, who are accustomed to culturally believe in the direct face to face doctor consultation, these patients need to be educated to start understanding that technology can be equally trusted. The below extract made by one of the medical practitioners supports the idea that doctors need to receive education and training of the use of IoT to enable a smooth change management process.

*I don't think it will be easy but it's possible, because there is already negative perceptions by patients and doctors. Therefore enough efforts have to be made to convince people who*

*have a resistance towards technological interventions that the doctor patient relationship will still be maintained but in a more sophisticated manner.*

**(Interview 10: Medical Practitioner)**

The third issue under economic issues are the **IT and Healthcare strategic alignment** and the **Modelling of the business**. Medical practitioners highly recommend that in Zimbabwe, for **the** ideal of implementation of IoT to be successful, IT should be well intertwined with the current business model and processes and have a clear value chain. Organisations should also be in a position to supply **adequate resources** to support the acquiring, maintenance and disposal of the required equipment. The key concern particularly in Zimbabwe for the doctors is the spending power of their patients or potential users, Zimbabwe has one of the **lowest GDP per capita** in the world and so most of the population can barely afford basic goods and services. The second related issue is the modelling of the IoT financial structure that it should be designed that in such a way that it empowers the medical practitioners. The below extracts indicates what some practitioners suggest, that if possible users should pay monthly subscriptions and if implemented in such a way there will be minimal resistance from the practitioners.

*... it will depend on how you will model the pricing or charging the services. There has to be proper analysis so that both the doctor and the patient have a win- win situation so that the doctors also get their share of money for the technology to be adopted without any resistance.*

**(Interview 6: Medical Practitioner)**

*.. , we are not a voluntary organisation, and we need profit. If you concentrate in making profit in the early stages you will fail, therefore you really need to have proper pricing strategies to get the numbers and then eventually start gain over time.*

**(Interview 7: Medical Practitioner)**

The last key factors that came up under the economic variables was the impact of **Technological disruption**. There is a neutral acceptance of IoT by Medical practitioners with the reservations of the impacts of the **level of disruption** it may cause to the industry.

As mentioned earlier, patients in Zimbabwe have a cultural belief that doctors are the best medical specialists who can only assist them. However at the other hand doctors are also excited that with technologies like IoT that they will become **more efficient** and may be able to assist patients even those **geographically apart** from them which could have more **positive impact**. The below extract indicates how medical practitioners strongly observe the possibility of the IoT solution may work in Zimbabwe.

*...you are not inventing this, already in Europe the IoT systems are already there and it is benefiting both the doctors and the patients and they have seen a great reduction in the costs. So here in Zimbabwe we may do the same and reap the same benefits*

#### **(Interview 7: Medical Practitioner)**

The last 1<sup>st</sup> cycle node was identified was the **Industrial Regulations and Processes**. In this code the factors that affect adoption are policies, regulations and trade factors bulked in one. One of the primary hindrances doctors fear is the access to the imports in terms of the **conditions to import, charges of importing and ease of the transactions**. The other concerns that mainly affect the IT side is that the **parliament** has to create favourable **standards / laws** regarding how IoT technology shall be acquired, processed, preserved, transmitted and disposed. The fear that the doctors have regarding regulations and governance of IoT is that the government in Zimbabwe is not a modern government that believes in change. Therefore that may affect restrictions in terms of the bill that allows IoT to be used being passed by parliamentarians' to appreciate IoT use in the healthcare system. The other related internal process factor are the management commitment and resistance to change. Some doctors fear that technology will soon eliminate their relevance and therefore they end up resisting technology introduction. Therefore management commitment to support and promote technology is also suggested to influence the adoption of IoT technology in healthcare. The below two extracts both suggest the importance of installing policies and regulations to guideline the implementation and usage of IoT in Zimbabwe.

*I think it's about policy, we need to upgrade in terms of regulation and policy, there are various systems coming, things are changing we do not want to be left behind as a discipline in medicine.*

**(Interview 5: Medical Practitioner)**

*So it's mainly about regulation and policy, you need to speak to parliamentarians so that these changes can be challenged and they need be able to see the advantages versus the little disadvantages of implementing such a system.*

**(Interview 8: Medical Practitioner)**

**4.5 Proposed Model for the IoT Framework for the Implementation for Healthcare in Zimbabwe**

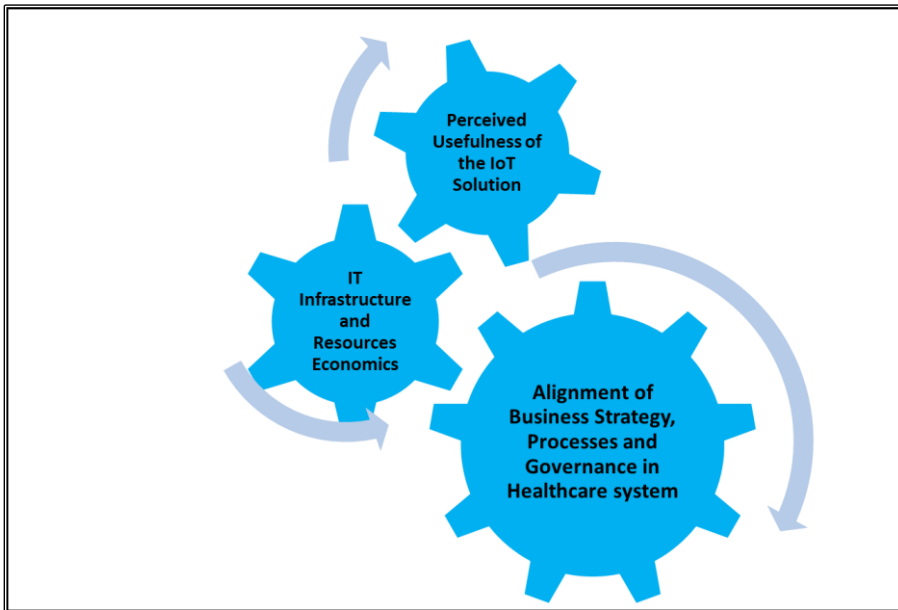
The synthesis stage is the 2<sup>nd</sup> phase from the proposed research methodology. The analysis of the narratives which was based on the experience of practitioners has an influential role proposing a best practices guide/framework to arguably ensure future success in implementation of an IoT ecosystem for Healthcare in Zimbabwe. This affirmation is made on the basis of the researcher's engagement with the IT specialists and the health practitioners who were driven to describe their experience in the use of IoT but to also make suggestions that will contribute to an improvement of the software development process.

The three main ideas/themes that binds the data corpus is listed below:

1. ***Perceived Usefulness of an IoT solution effects the overall acceptance for users to adopt IoT in Zimbabwe. Health practitioners, patients and IT specialists in Zimbabwe indicate to value a solution that would bring them utmost efficiency and effectiveness in their operations.***
2. ***The state of IT infrastructure in Zimbabwe and Resources Economics affect the perceived usefulness of the IoT solutions. As well IT Infrastructure and Resources Economics has to be integrated or bundled to Align with the Healthcare Business Strategy, Processes and Sector Governance/ Regulations. For IoT products to be usable in the local environment, the supporting IT infrastructure such as network has to be able to fully support its functionalities. As well Resources Economics such as product cost, data costs and IT Infrastructure has to be strategically aligned to the business strategy, industry processes and sector governance.***
3. ***Healthcare Business strategic alignment, Processes and Governance influences the perceived usefulness of IoT solutions. Alignment the business model strategy,***

*processes and standards with a technological solution enhances its perceived value for its potential users because of its notable relevance and clear positioning within the Healthcare value chain.*

The illustration in Figure 16 indicate the core ideas that emanated from the empirical evidence gathered this far. The diagram below demonstrates the need for alignment of the proposed framework constructs.



**Figure 16- Mechanisation of Technical and Business Alignment**

The relational format adopted in Figure 16 is used to display the researcher's interpretive effort to map relationships and present a cogent overview of the main constructs that have emerged from the empirical evidence presented thus far. The influence of IT Infrastructure and Resources Economics being integrated / bundled to strategically align with the business model, processes and industry governance has been accorded the highest priority because it has a cascading influence on perceived usefulness that effects IoT adoption and acceptance in the healthcare sector in Zimbabwe.

To influence the adoption of IoT in Zimbabwe key important factors emerged from the Medical practitioners and IT specialists that were packed into 3 main facets in the Mechanisation of Technical and Business Alignment. The primary key factor that was

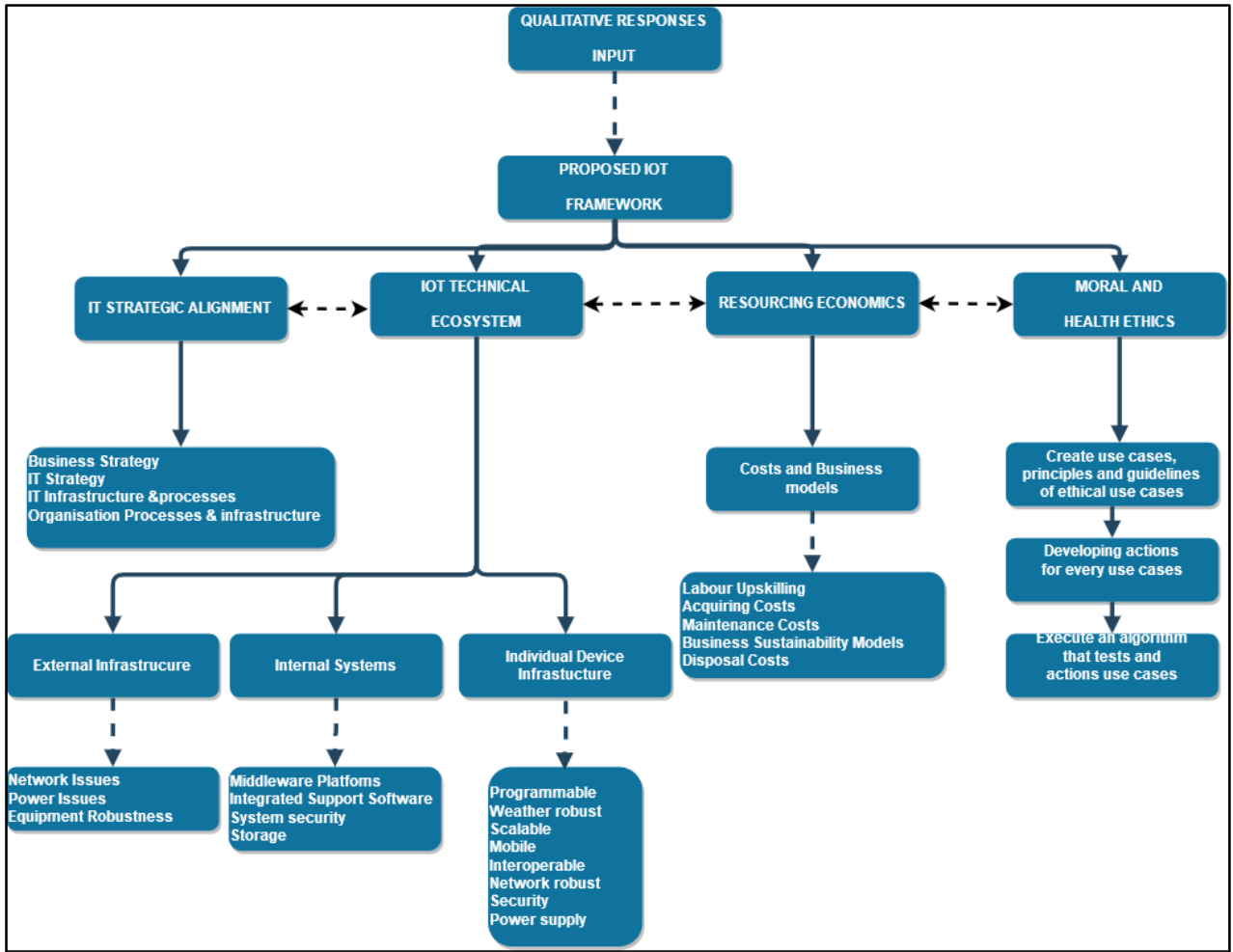


identified was the IT Infrastructure and Resources Economics. IT Infrastructure term is unpacked to define both the IoT medical monitoring devices technicalities and as well its technical environment that supports the IoT medical monitoring devices such as network and power attributes. The Resources Economics are factors that influence mainly the Affordability and serviceability of IoT medical monitoring devices and data costs as well.

The IT Infrastructure and Resources Economics factor should be integrated or bundled in such a way that it aligns to the healthcare business strategy, processes and industry governance factor. This relationship is important were the IT infrastructure is positioned to optimally align with the business needs in a manner that complements the organisational processes and adheres to meet the sectorial regulation and governance issues. The overall effect of the synergy of IT Infrastructure and Resources Economics and the healthcare business strategy, processes and industry governance influences the perceived usefulness of IoT to be adopted in Zimbabwe. Illustrating a clear value chain that is built to effect to improve the potential stakeholders of the healthcare ecosystem.

#### **4.5.1 Introduction of the proposed framework**

Based on the findings from the questionnaire, part of the study's objective was to develop a framework that may mitigate challenges that could hinder the success of the implementation of an IoT solution in the healthcare system in Zimbabwe. Therefore, the current section uses various knowledge sources to advocate the solutions to the challenges that were identified. The solutions proposed in the current chapter may be used to guide future research or practice on the topic of IoT intervention in the medical health sector.



**Figure 17. IoT Technology Transformation Alignment (IITTA) model**

The framework solution has been broken down into four key themes. These are IT Strategic Alignment, IoT Technical system design, Resourcing Economics and Moral and Health Ethics. Each theme has granular subtopics that explore the different factors that solve specific functions of that subtopic or theme. Therefore Figure 17 demonstrates the hierarchical architecture of the proposed framework for IoT implementation in the public healthcare system in Zimbabwe.

### The IoT Technical Ecosystem

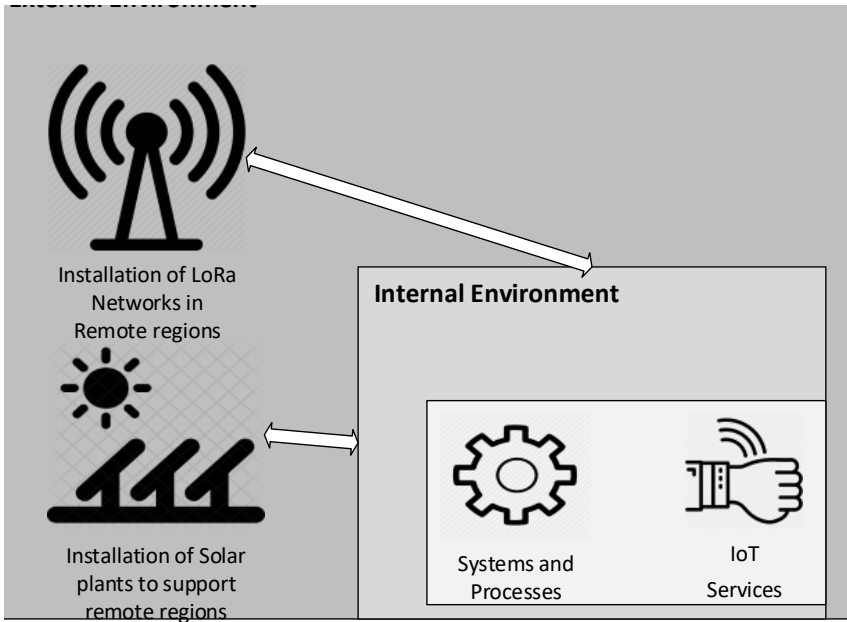
The technical environment consists of 3 main levels, the External, the Internal and the individual device level.

#### External Technical Infrastructure

The External Technical level are mainly the factors that construct the national backbone infrastructure that support organisational and individual technical needs. Key External Technical components comprise of Network and Power infrastructure. The network component main variables that affect the Zimbabwean environment are; network coverage, network type and network bandwidth.

Based on the empirical evidence provided in the interviews, there were key external technical areas that were identified in the study were the poor network coverage in Zimbabwe. Only key cities and towns experience better connectivity of network. The same applies with network type and bandwidth, the best network that is present in Zimbabwe is the 4g network. Besides being present only in key towns, its coverage remains poor in some areas. The importance of evaluating this factor is that IoT technology is highly dependent on network connectivity, therefore considering the underdeveloped state of such infrastructure especially in the rural regions it becomes a key hindrance to implement IoT to impact the population.

The same applies to power supply connectivity and availability. Generally the supply of electricity even in cities is not consistent were blackouts are random and frequent. Most rural regions do not have electricity connections at all. Therefore an external technical solution that can be proposed to enable a sustainable and reliable solution is indicated in Figure 18.



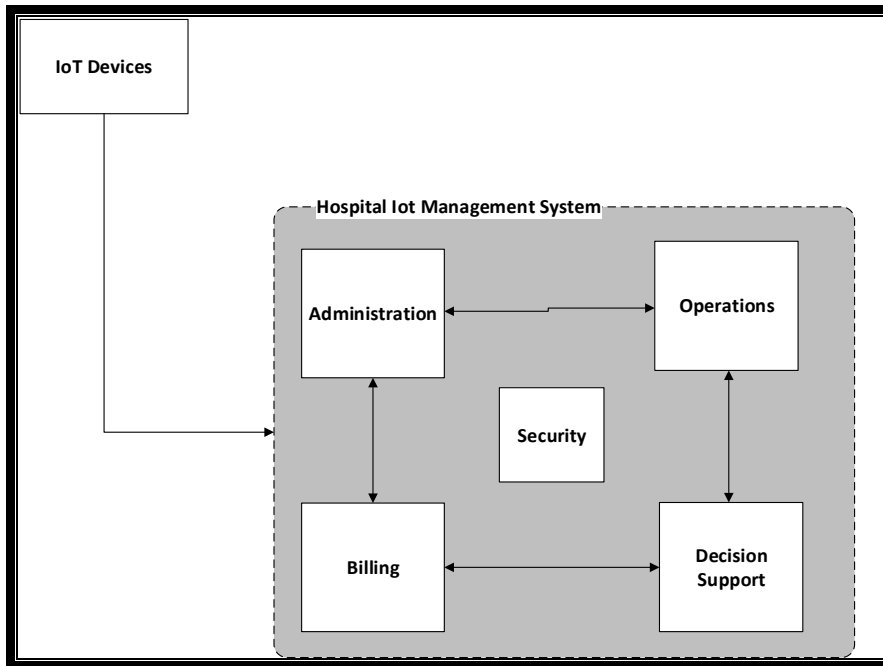
**Figure 18 – Proposed External Technical Solution.**

The solution as indicated in figure 18, applies to the Technical challenges, should be designed to be compatible to support renewable and rechargeable power source. Strategically setting up network solution should have a smart network switch that can automatically change to the available networks and as well to be compatible to Low frequency Radio transmission. The LoRa and LoRaWAN permit inexpensive, long-range connectivity for Internet of Things (IoT) medical monitoring devices in rural, remote and offshore industries. These can be set up strategically in remote regions and installations be prioritised based on the density of potential patients population it shall support.

**The Internal / Institutional Technical infrastructure**

The Internal Technical level are the main technologies that are utilised by health care systems. These systems can be categorised into administration, operational, security systems, decision support and billing. In Zimbabwe public healthcare systems barely have any IT systems in place, basically they mainly have operational technologies which are rather not IT

main stream systems. However some private institutions have managed to adopt administration and billing systems for their daily operations. The main challenge for public institution is capitalise resourcing to implement a scalable technology that is synchronised to one database. Figure 19 indicates the proposed internal solution, showing how the hospital subsystems shall be related to each other and the IoT medical devices.



**Figure 19 – Proposed Hospital Management System**

As indicated in Figure 19, the ideal solution is to create a scalable, serviceable, robust and easy to integrate system such as an IoT, Enterprise Resources Planning system that has specialised sub systems that are synchronised to support the functions of hospital IoT related operations. This system should support related hospital IoT administration, operational, decision support, billing and security solution, synchronised in such a manner that is easily installable and manageable. The main key issues that may need to be emphasised is to put strong mechanisms on Identity, Mobility and Access control management.

### Individual Device Technical Infrastructure

This level explains the current architecture of IoT medical monitoring devices, and evaluating their utility and challenges in adjustment to a Zimbabwean perspective. The key layers that construct an IoT medical monitoring devices are; the Perception layer, Network Layer, Middleware layer, Application layer and the Business Layer. The key IoT medical monitoring devices that are used in Zimbabwe are electronic thermometers, blood sugar strips, statoscopes, probes, tongue depressors, cameras and mobile medical monitoring devices to collect data. The main IoT medical monitoring devices currently used in Zimbabwe consist of the perception layer, network layer and at times the Application layer. The Middleware layer is hosted and stored in the Cloud. The Business layer is the one that normally resides at the internal systems as the Decision support systems were doctors can be able to analyse information.

The issues that emanated for the Perception layer is that IT specialists have limited control on customising and programming the actuators considering they are not IT components they have access to customise their functionality. The second issue that came out was that most actuators considering IT specialists cannot adjust their settings, they cannot influence adjusting environmental climatic variables that may affect the accuracy of the readings such as heat, humidity or pressure.

The Network layer is responsible for providing data routing paths for network communication. Data is transferred in the form of packets via logical network paths in an ordered format controlled by the network layer. The challenges that may affect the Network layer is that due to poor network connectivity and quality in Zimbabwe, the medical monitoring devices are failing or very slow to transmit data especially in remote regions. Also

most medical monitoring devices are not smart enough to be able to switch networks or base stations to ensure continuous availability.

The Application layer is the next layer that may reside within the actual IoT device. The Application layer consists of protocols that focus on process-to-process communication across an IP network and provides a firm communication interface and end-user services. Based on the feedback, challenges that affect the Application layer were that medical monitoring devices use different protocols IoT medical monitoring devices in the field often communicate using a new generation of protocols. This data is often aggregated by gateways, presented to cloud data stores, and then connected to enterprise or mobile applications which can be a challenge to deal with the need of implementing multiple protocol device compatibility. So far most of the data presentation of IoT medical monitoring devices in Zimbabwe is channelled via sms and that may not be as interactive and personalised as the potential mobile applications that may manipulate analytics from the Business layer.

The ideal solution for the Individual Device Technical Infrastructure is to ensure that all layers should be programmable, serviceable, secure, robust and scalable, integrate compatible, interoperable and mobile to be flexible to accommodate different technologies and conditions the medical monitoring devices may experience. Particular emphasis was to enable actuators to be serviceable that IT specialists to be able to adjust or program the actuators in the perception layer to curb for settings such as integrations and climate (Temperature, humidity and pressure). The Network layer should be designed to handle Smart Network switching that enables the medical monitoring devices to switch from an unstable networks to stronger ones, intention to be backward compatible to low radio frequency networks in instances that have no access.

As of the Application layer, given the challenge that medical monitoring devices may receive different types of protocols, the device should be designed to consider a multi-protocol strategy for different parts of the architecture in order to curb for the device compatibility. Ideally smart mobile applications can be built to enable users to interface the information and access more intelligent functionalities.

### *Ethics in the Use of Internet of Things (IoT) in Healthcare*

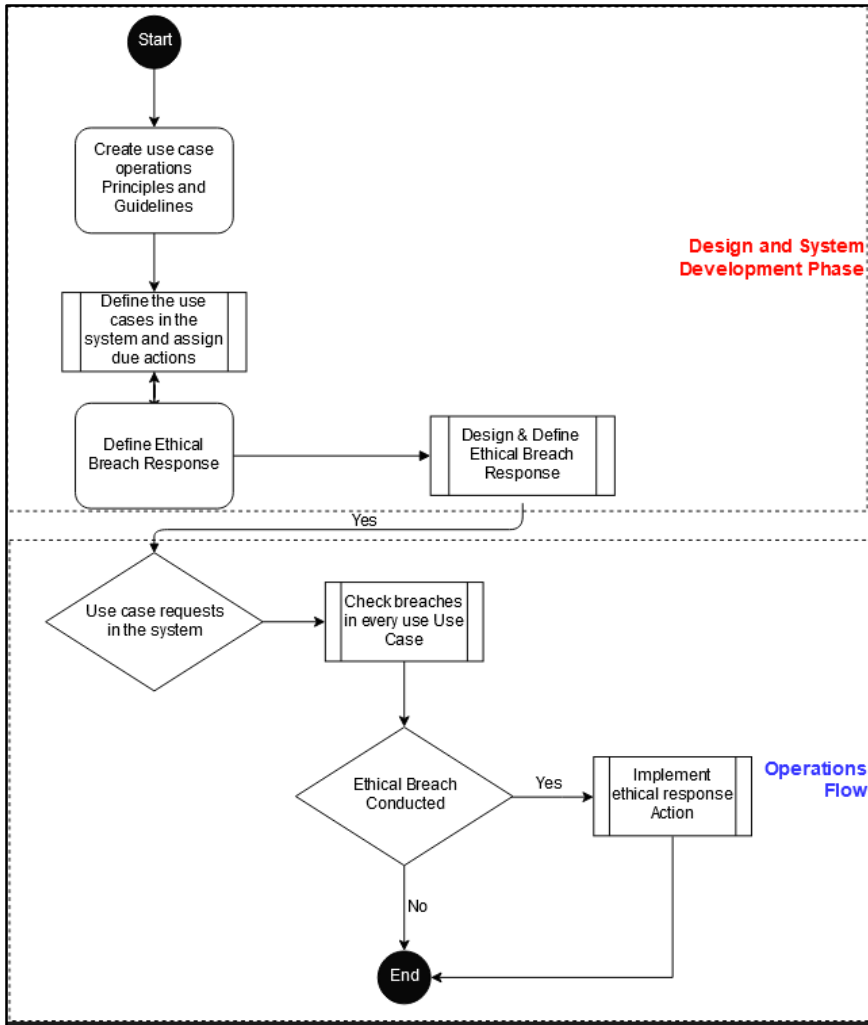
With the various healthcare benefits that IoT offers, the increased ubiquity of smart healthcare systems does create an ethical dilemma. The obtrusive nature of IoT devices certainly create an entire area of discourse around privacy of personal healthcare information and the concern regarding accessibility of this information to healthcare workers. Currently, the lack of legislation regarding access to private health information is an area that warrants serious attention from healthcare authorities. The reason for the preceding claim is based on the knowledge that most healthcare providers are driven by the desire of maximising profit, thereby compromising patient confidentiality. In the current study, the researcher does concede that medical ethics has not been the focus of the study. However, the proposed system is designed by implementing layers of security whereby confidential data is accessible only to the medical professionals who are part of the healthcare system. As such the researcher trusts that the ethical considerations will be upheld by the professionalism of the medical practitioners who form part of the system. The system does however incorporate a facility whereby an audit trail can be maintained indicating the personnel who have access to confidential patient information. Table 4 provides an indication of how the researcher has integrated controls into the system thereby implicitly coercing users of the system to be aware of the sensitive nature of the data that is being handled.



**Table 4 Guidelines and principles of Ethics check**

Principles \ Guidelines	1. User control	2. Confidentiality standards	3. Privacy by default	4. Alternative consent	5. Duties of care and inclusion	6. Transparency and oversight	7. Uncertain utility of data	8. Data access rights	9. Unobtrusive devices
1. Engagement with public health and research			⊙	⊙		⊙			
2. Non-maleficence and beneficence				⊙	⊙		⊙		
3. Autonomy and nudging		⊙		⊙			⊙		⊙
4. Individual privacy	⊙	⊙	⊙	⊙		⊙			
5. Group privacy	⊙	⊙	⊙			⊙			
6. Inclusiveness and diversity					⊙	⊙			⊙
7. Data minimisation			⊙				⊙		
8. Trust and confidentiality					⊙	⊙	⊙	⊙	
9. Transparency and accountability	⊙					⊙	⊙		

As seen in Table 4, the system is programmed to identify various scenarios or use cases of the devices operation that could lead to ethical breaches to enable the design of appropriate ethical system response. The system design algorithm (illustrated in Figure 20) also provides an ethical response algorithm that consistently checks all operations that occurs in the system and if a breach is predicted it also should be able to react accordingly.



**Figure 20 The Implementation of Ethical Controls in the IoT Healthcare Algorithm**

Resourcing Economics

This theme mainly describes the economics that may govern IT infrastructure packaging in order to enable users to manage them. Resourcing Economics consist of issues like the initial IoT acquiring cost, maintenance costs and Disposal cost life cycle. In addition these other costs also impact the economics of the resources such as support and up skilling labour.

Also external factors affect the economics of IoT resources, for instance in Zimbabwe, such as general spending power of the majority of Zimbabwe, ease of doing business, regulation of data costs, ease to get foreign currency to pay for services, taxes and ease to import spares. The other key external economic issue is government expenditure budget and support on health innovations such as IoT projects.

As highlighted in the interviews, one of the major concerns both IT specialists and Medical specialists highlighted was the capital cost of acquiring the IoT equipment both from the hospital support systems end and the patients' medical monitoring devices. It is anticipated that if the technology can be made affordable to all, it would have more impact. The same applies to the other associated type of costs of having cheap locally available repairs or servicers of the equipment would make it easier to be adoptable locally. Currently there are no specialist IT companies who offer support in Zimbabwe. The other currently availing difficulties in terms of economics are high costs of data from services providers, high taxes on IT products and companies, very strenuous import clearance processes and expensive importing costs. The other issue that may affect the resourcing economics of IoT projects in Zimbabwe is that the government has allocated a very low budget to the Ministry of health which could impact streaming the funding of the project.

The Ideal solution to enable resourcing easier would be to firstly making the whole capital cost of the composite system affordable for all health institutions. The Government or Private investors may assist by subsidising / loaning the resourcing to the hospitals in a plan that can repay the debt over time. To make it also affordable for the patients to acquire the IoT resourcing required, the IoT model can be designed in such a way that the purchase price be heavily subsidised and be paid off overtime through monthly subscriptions. If bundled, that would also ensure a sustainable revenue source overtime for both the manufacture and the

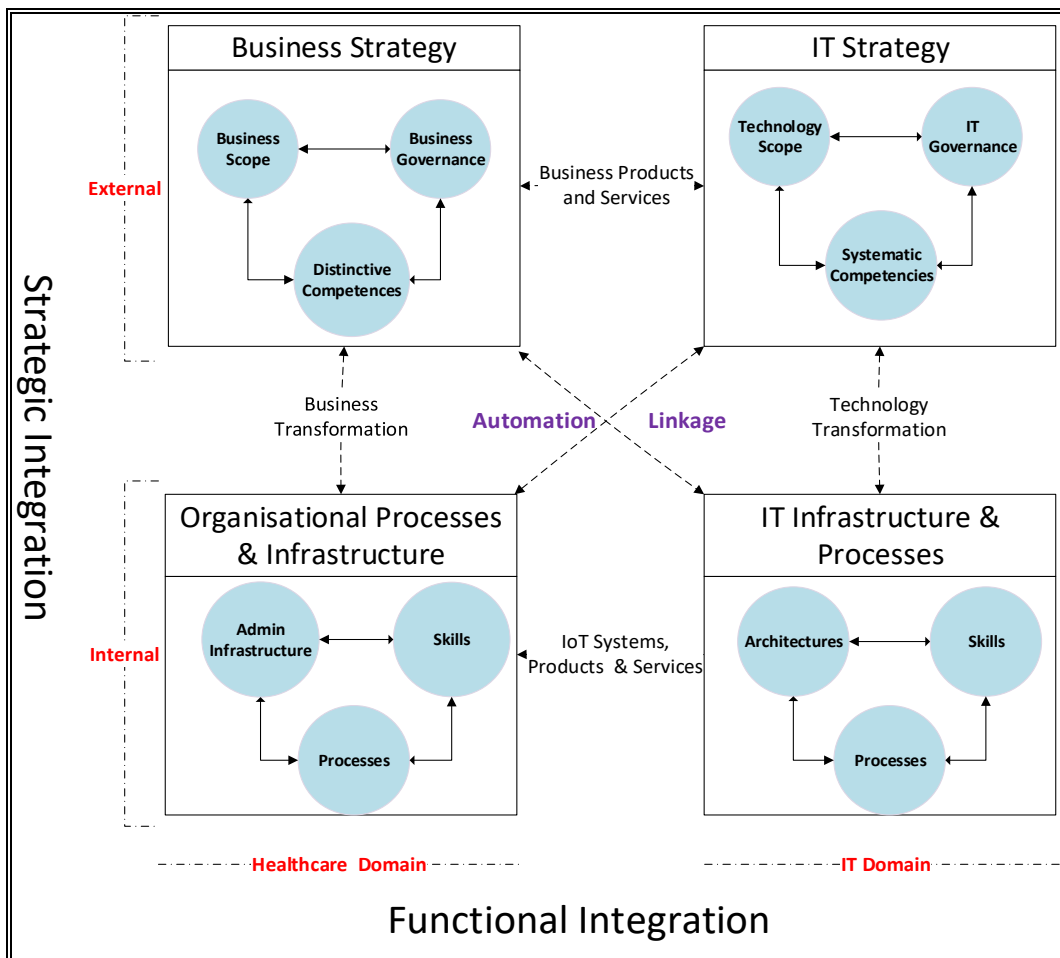
health institutions. The second solution is for the government to regulate zero costing the costs of data associated with the use of Health technology, the monthly subscription should be bundled to pay for all the costs associated and data as well. Lastly necessary policies need to be put in place that protect health technological products to receive less straining processes to import, lesser import taxes, and access to foreign currency to pay for services that require such e.g cloud hosting services. There is also a need for the government to increase budget on Medical Technology innovations especially when there is a crisis of a shortage of practitioners in Zimbabwe.

#### *The impact of a Healthcare Operational and Governance Strategic Alignment with Technology*

One key pillar that has been noted to lack in Zimbabwean healthcare system is the lack of appreciation of the potential IT systems to improve the operational services in the healthcare systems. There are also concerns that doctors fear that introduction of such technology may reduce their relevance in the industry and reduce sources of money channels as it may eliminate consultation fees. The same applies to lack of regulations that are set to govern the standards of the usages or rules for potential implementers to comply with. One of the main key references by the interviewees was that the current regulators in Zimbabwe that are responsible to set up the cyber laws are not as innovative minded to appreciate and drive such an initiatives . Furthermore it is also said the Health industry is heavily regulated that it would take so much convincing that the technology can safely be used in the healthcare system in Zimbabwe.

This section attempts to solve how healthcare should plan their strategic alignment of healthcare processes to business objective/ goals through the optimisation of IoT. Ideally a solution that may solve business challenges by optimising the implementation of IoT solutions should be designed as illustrated in the proposed model in Figure 21.

The figure 21 illustrates organisational IT strategic alignment by Henderson and Venkatraman (1999), which the current study intends to framework the alignment of the implementation of IoT in the Medical healthcare system. IT emerges as a critical enabler of the Healthcare transformation with capabilities to deliver the organisation absolute advantages.



**Figure 21- IT Strategic alignment by Henderson and Venkatraman (1999)**

According to figure 21 there are four main pillars in the strategic alignment that construct the Business strategy, IT Strategy, IT Processes and Infrastructure and the

Organisational Processes & Infrastructure. There are also flows and relationships that are used to gear the alignment between the different functions. The model also is structured in two functions Healthcare function and IT Function which consist of Internal and External strategic integrations. There are four types of alignment perspectives which may be used in strategic alignment the Strategy execution, Technology Transformation, Competitive potential and the Service Level. They differ based per business nature, type of solution the organisation and the project development lifecycle

The strategic Integration is the link that is made between the Business strategy and the IT Strategy as the external component that deals with the capabilities of IT functionalities to shape and support the business strategy. Whereas the Functional integration deals with corresponding internal domains (links between the organisational infrastructure and processes) ensuring internal coherence between the organisational requirements and expectations and deliver capabilities within each function.

The business strategy are the overall go to market objectives, scope of business goals, business governance and distinctive competence value proposition of the business. In this case based on the healthcare case, their current business case is to be able to track all the hospitals' patients with chronic and other diseases of interest. On the other hand the IT Strategy are the available IT solutions plan matrix and IT governance, technology scope and systematic competences issues that are used to formulate to meet either a competitive or absolute advantage product offering. These could be synergies, outsourcing or a hybrid plan of how to meet the business objective. In the instance of the healthcare industry, the IT strategy would be to identify a combination of IoT medical monitoring devices, networks and backend systems that fully solve the desired business problem.

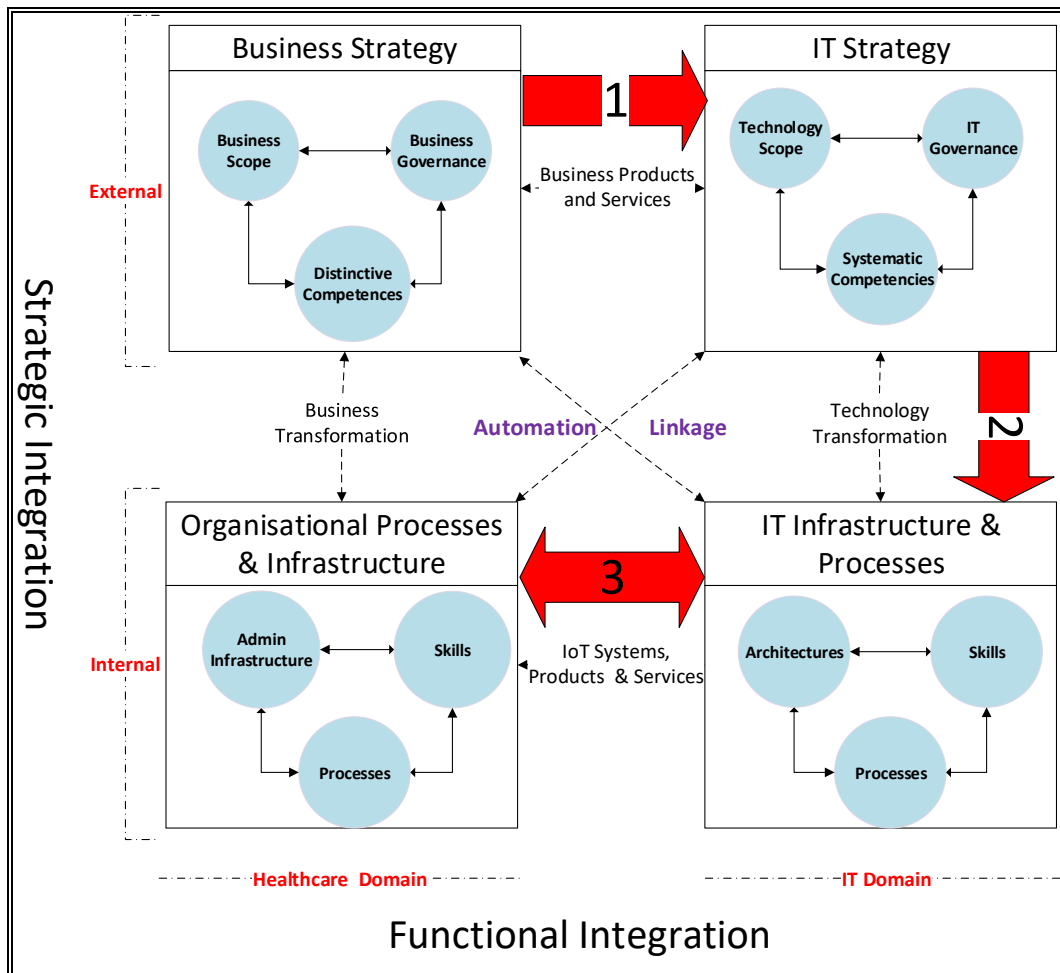
The Organisations System processes and infrastructures are Administration Infrastructures, processes and skills that support the core operations functions of a business. In this case, the core main operations of a hospital are catered for, from processes such as record keeping, scheduling of doctors consultations, operational health services and tracking patients. It also consists of Administration infrastructure for handling day to day hospital operations and key skills that support the healthcare system such as doctors, nurses and administrators.

Lastly the IT infrastructure and processes are technological architecture solutions, processes and skills that are created from the IT strategy to support the organisational processes and infrastructure. In this case the proposed IoT systems and supporting operational administrative and decision making solutions are developed, maintained and supported by the IT infrastructure, skills and processes.

Within both the Business and IT Domains there are inner bundles of attributes that support each functions and integrations. **IT architectures**, are choices that define portfolio applications, configurations of IoT hardware, software, data and communications that collectively define technical infrastructure. This is analogous to the choices within internal **business strategy** arena, to articulate the administrative structure of the healthcare roles, responsibilities and authority structures.

The second inner pillar are the **IT and Operational processes**, which are choices that define work processes central to the processes of IT infrastructure such as system development, maintenance and controlling the IoT systems. This is analogous to the need for designing business processes that support and shape the ability of the healthcare systems to execute business strategy.

Lastly the **IS and Operational skills** pillar pertaining to acquire, training and development of knowledge and capabilities of individuals to effectively manage and operate the Organisational and IS infrastructure within the healthcare system. Logically the ideal solution should be a model as indicated in Figure 22, which is an objective oriented approach that focuses and implements technology solutions based on the business needs



**Figure 22 -The Proposed IoT Technology Transformation Alignment model**

This study shall mainly focus on the Technology Transformation Alignment (ITTA) illustrated in Figure 22. Considering that IoT is an entirely new system that may disrupt both the market and the internal operations. For the model to be successful, the logic and alignment



of the business strategy has to begin with understanding the business strategy, the overall objectives the organisation needs to achieve. In this case the healthcare need a solution to effectively, accurately and scalable track its patients. The solution has to be able to also generate revenue and manage the massive number of patients suffering from chronic illnesses.

From identifying the Business strategy an IT Strategy is built to be able to effectively meet the organisational needs. In this case IoT solutions are the major identified solution. However, abstractly the solution should be able to fit the market technical variables identified such issues as poor network and power coverage in Zimbabwe. Creating equipment resourcing IoT vendors partnerships for the device and systems. Crafting the entire requirements of the entire solution and ensuring proper IT governance issues are in place in alignment to the operational environment.

Once the IT Strategy has been defined and implemented, the appropriate solution is built, integrated and supported in the IT Infrastructure and processes function. In this domain, the end to end systems system architecture is developed in full alignment with the Organisational Infrastructure function to ensure that a seamless and optimum solution is made available. The IT Infrastructure will provide software, hardware and data solutions to support both the patients and the internal administrators and the doctors' work in sync with their work processes.

Lastly in the organisational processes, the end to end IoT solution is being used here to support the core operations which fulfils the objective of effectively, accurately and scalable tracking patients suffering from chronic illnesses in a manner that generates revenue and manage the massive number of patients.

## CHAPTER FIVE: QUANTITATIVE DATA ANALYSIS AND PRESENTATION

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### 5.1 Introduction

According to Sukamolson (2007), quantitative research is the numerical manipulation and representation of observations for the purpose of describing and explaining the phenomena that the observations reflect. Creswell and Creswell (2017) define quantitative research as a type of research that explains phenomena by collecting numerical data that is analysed using mathematically based methods.

According to the study's research methodology plan, the second phase of data collection is the validation phase of the proposed IoT framework for the public healthcare sector in Zimbabwe. The quantitative (validation) phase of the study consisted of a purposively selected sample of 50 healthcare practitioners. Included in the sample were the respondents from the 1st (qualitative) phase of the study as well as a further 40 respondents who were identified on the basis of their knowledge, expertise and experience of working as professionals in the Zimbabwean public healthcare sector.

The objective of the current phase of data collection was to leverage quantitative research methodology to establish the level of acceptance of the proposed IoT Technology Transformation Alignment (IITTA) model that was developed as the main output from the synthesis phase of the current study. The technology acceptance exercise was conducted to enable validation and refinement of the proposed IITTA model. The quantitative approach for the validation phase was underpinned by technology acceptance theory that becomes the focus of the subsequent discussion.

## 5.2 The Quantitative Data Presentation

A total of 50 questionnaires were distributed and 46 of the questionnaires were completed and returned, thereby yielding a response rate of 92%. The justification of using 50 participants for the sample size was based on 2 main parameters. Firstly, the researcher was constrained by limited resources and secondly and more significantly, the sample was purposively selected so that the respondents all abided by the criteria that they needed to be medical professionals who were knowledgeable about the use of IoT technology. The demographics of the various participants is presented in Appendix F. The questionnaire consisted of a total of 31 questions (refer to Appendix C). The Likert Scale values were presented on a continuum from 'strongly agree' (coded as 5 for the purpose of analysis) to 'strongly disagree' (coded as 1). All the questions were positively worded. The quantitative data analysis was conducted through making use of the Statistical Package for the Social Sciences (SPSS) software.

### 5.2.1 Reliability Testing

According to Sekaran (1984), the reliability of data collection instrument is established by testing for both consistency and stability. Consistency indicates how well the objects measuring a concept align together as a set. Therefore accordingly, the Cronbach alpha test is a reliability coefficient that indicates how well the items in a set are positively correlated to one another. The closer Cronbach alpha is to 1, the higher the internal consistency reliability. However, if the Cronbach Alpha co-efficient value is less than 0.6, it is regarded as a weak coefficient and in contrast values that are in the range from 0.7 to 1 are reflective of a reliable measure of a specific construct. Table 5 shows the results of the Cronbach Alpha results.

**Table 5-** Cronbach Alpha Test

<b>Construct</b>	<b>Number of Likert Items</b>	<b>Cronbach Alpha</b>
Perceived usefulness	5 (abbreviated as PU1 to PU5)	0.729
Perceived Ease of Use	5 (abbreviated as PEO6 to PEO10)	0.765
Behavioural Intention	3 (abbreviated as BE11 to BE13)	0.802
Relative Advantage	3 (abbreviated as RA14 to RA16)	0.877
Compatibility	3 (abbreviated as C17 to C19)	0.945
Observability	3 (abbreviated as O20 to O22)	0.739
Trialability	3(abbreviated as TR23 to TR25)	0.852
Technical Infrastructure	6(abbreviated as TI26 to TI31)	0.783

Based on the results in Table 5, all the constructs used for the quantitative phase of the study have been found to be in an acceptance region of reliability.

### **5.3 Quantitative Data Analysis**

According to Razali and Wah (2011) parametric statistical analysis is one of the key techniques that leverage credibility from the assumption of normality. They also make the claim that parametric statistical analysis techniques are robust thereby enabling the delivery of accurate analyses that compare favourably to non-parametric methods. Based on this assertion the current study will uphold the credibility of underpinning the choice of parametric and non-parametric testing on the level of normality displayed by the study's data.

Royston (1982) suggest that the Shapiro-Wilk (SW) test is the most reliable test to test for the normality of data. This opinion has been accepted for the purpose of the current study where the SW test has been used to test for the normality of data. The fundamental idea behind the SW test is to evaluate the variance of the study sample in two ways; the regression line in the distribution plot enables estimation of the variance and the variance of the sample can also be regarded as an estimator of the population variance. The estimated values should be at least at 95% significance of confidence as a condition to accept the null hypothesis that the sample has a normal distribution. If the quotient is significantly lower than 0.05 then the null hypothesis should be rejected (Royston, 1982, Razali and Wah, 2011). Table 6 indicates the Shapiro Wilk test results of the study.

**Table 6** Shapiro –Wilk test

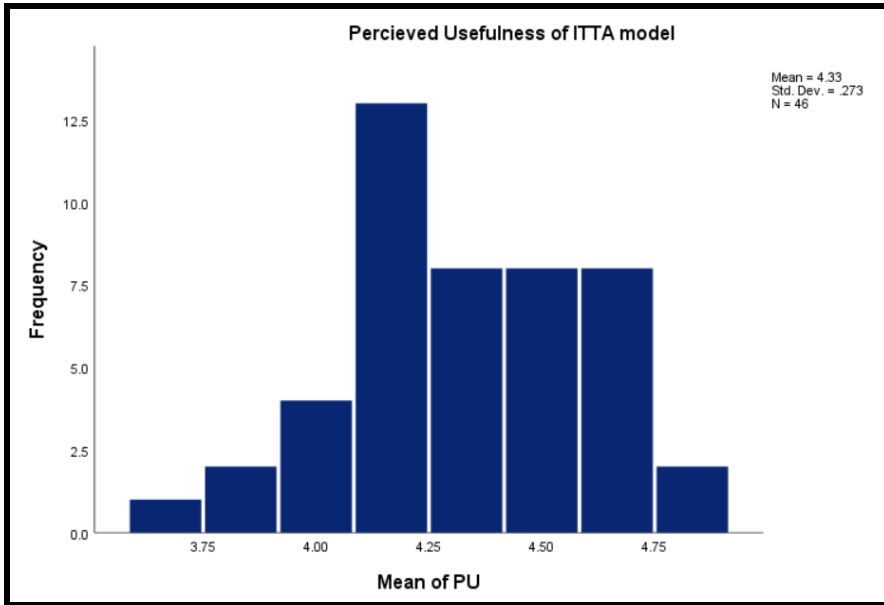
	Tests of Normality					
	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
PU	.159	46	.005	.952	46	.056
BI	.214	46	.000	.865	46	.000
PEOU	.185	46	.000	.914	46	.002
TI	.146	46	.015	.955	46	.075
O	.216	46	.000	.912	46	.002
RA	.208	46	.000	.848	46	.000
TR	.177	46	.001	.930	46	.009

According to the results in Table 6: PEOU, O, TR, RA and BI fail to meet the Shapiro-Wilk test for normality at 0.05 level of significance (Null hypothesis rejected,  $p < 0.05$ ). However the TI and PU scores at 0.075 and 0.056 significance respectively, pass the test of normality (Null hypothesis accepted,  $p > 0.05$ ). Both these constructs will now be subjected to parametric testing of the mean values by subjecting the reported means to the t-test of significance. The analyses will be presented via frequency charts and tables. The main design of the statistical testing phase is based on the testing of the validity of the sample's reported means. The tests

will determine if the values reported are by chance or a genuine representation of the sample mean. This will be achieved by using a strategy (as suggested in Boone and Boone (2012)) whereby an assumption is made that the sample mean has a neutral value of 3. In the case where the sample distribution is normal, a one sample t-test is used to test the significance of the difference between the mean value and the neutral value in the case where the sample distribution is not normal, the non-parametric Wilcoxon one-sample signed rank test will be used to determine if there is a significant difference between the sample median and a hypothesised median of 3. In order to elucidate the statistical analysis, a hypothesis testing is used where a null hypothesis ( $H_0$ ) will assume the neutral value of 3. In the case of the parametric approach, the test statistic that will be used is the mean ( $H_0: M=3$ ) and in the case of the non-parametric equivalent, the test statistic that will be used is the median ( $H_0: Mdn=3$ ).

### *Analysis of Perceived Usefulness of ITTA*

In order to highlight the main measures of central tendency for the ITTA model, user responses have illustrated by means of a histogram illustrated in Figure 23.



**Figure 23- Perceived Usefulness responses distribution**

As indicated in Figure 23, the report of the mean ( $M=4.33$  and  $SD = 0.273$ ) suggests that the mean is greater than the neutral/hypothesised value of 3 indicating an overall positive response from a PU perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant, from the hypothesised neutral value of 3 ( $H_0: M=3$ ), a one sample t-test was conducted. Table 7 provides an indication of the results of the t-test analysis for PU.

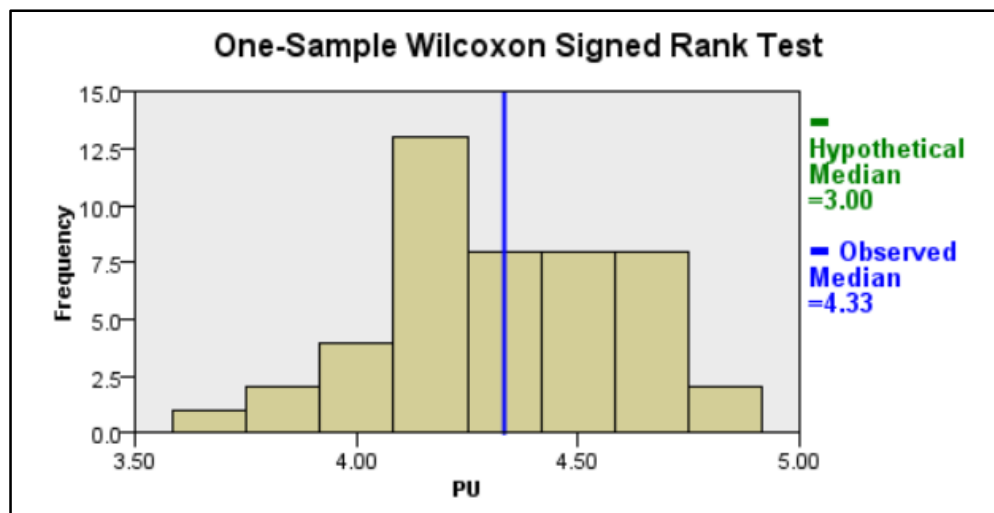
**Table 7.** Perceived Usefulness One sampled t-test

One-Sample Test						
Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
PU	33.002	45	0.000	1.32971	1.2486	1.4109

From Table 7, it can be concluded that the mean for PU is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting a rejection of the null hypothesis and an acceptance of the alternate hypothesis ( $H_a: M \neq 3$ ). In an attempt to

ascertain whether the observed mean is significantly *greater* than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 6 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 1.685$  which provides a boundary/critical value for the region of rejection of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 33.002$ ,  $p < 0.05$ ), which is greater than the critical value, thereby providing a basis for the rejection of the null hypothesis, suggesting that the sample mean is significantly greater than the hypothesised mean of 3.

The t-test results can also be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 4.33 .The results are illustrated in Figure 24.

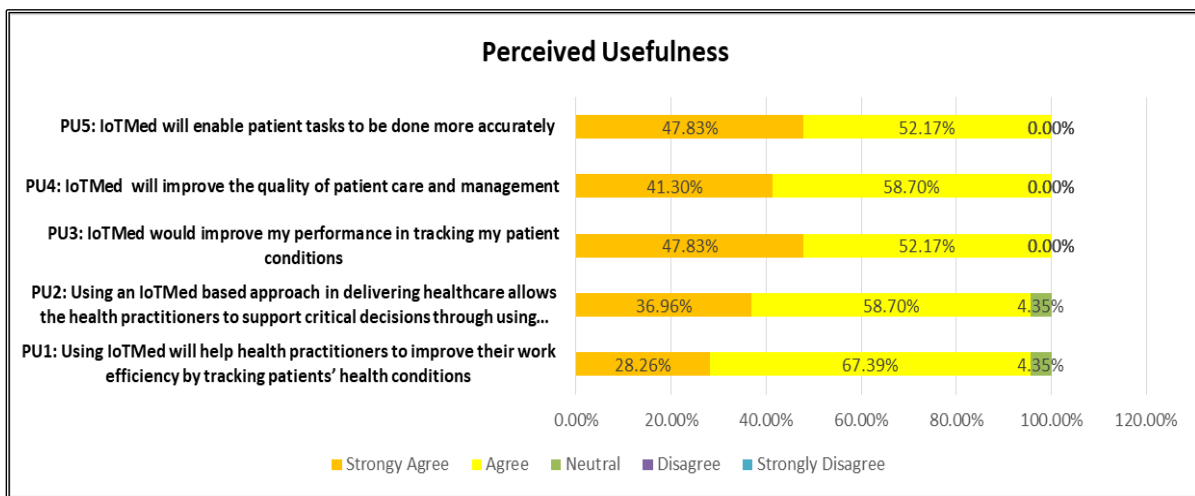


**Figure 24- Non Parametric test of the PU Median**

Based on Figure 24, it can be observed that the median is significantly ( $p < 0.05$ ) greater than the hypothesised median of 3.



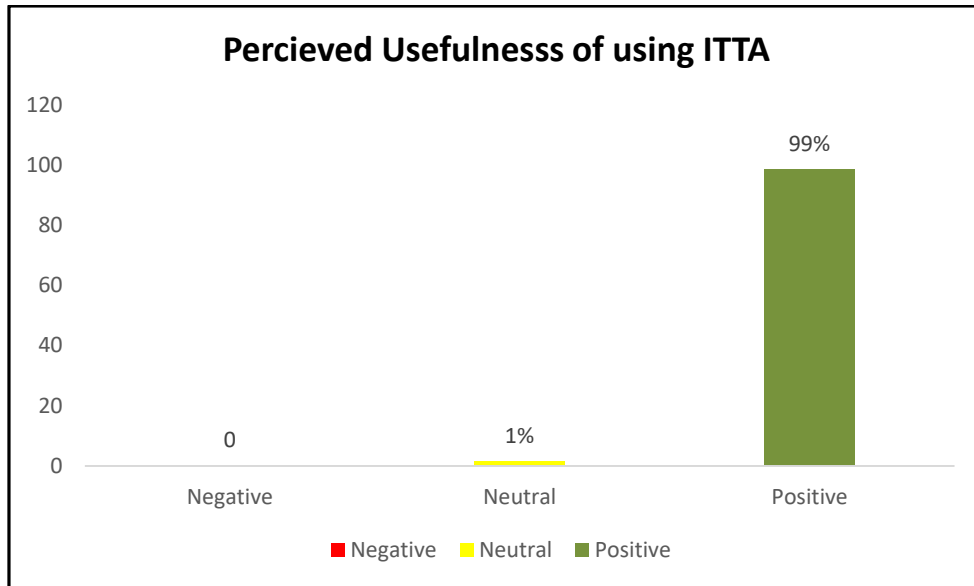
The overall positive perception of the PU of the proposed ITTA model is further with greater granularity by virtue of the actual questionnaire responses is presented in Figure 25.



**Figure 23 –Perceived usefulness Weighted responses**

Based on Figure 25 it is evident that most of the responses were strongly and positively rated, meaning that, it is perceived that the proposed ITTA model would be of great utility value that enables an enhancement of medical service delivery in the healthcare system in Zimbabwe.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 26.

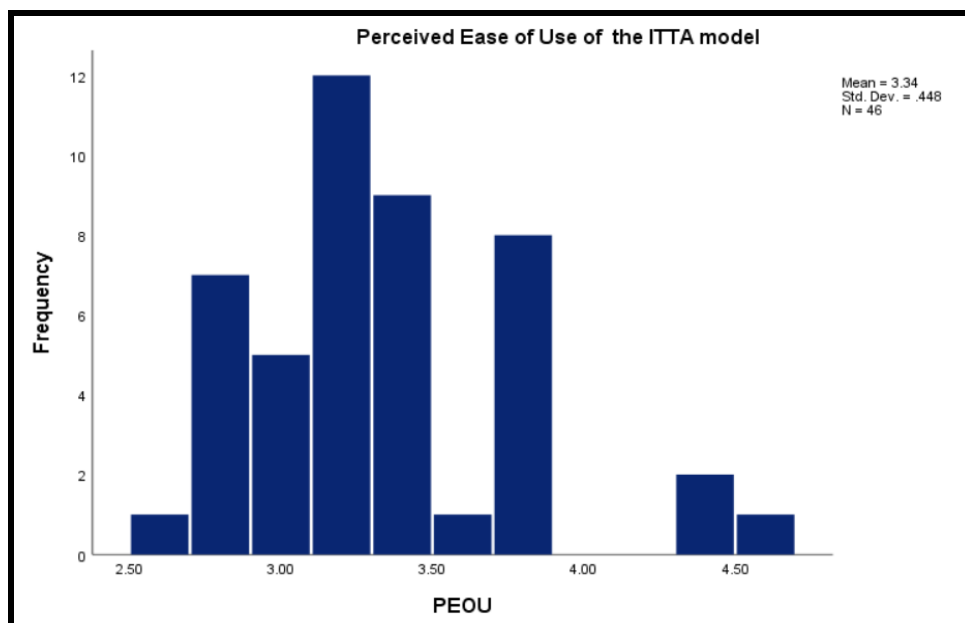


**Figure 26 -Aggregated Percentages for PU**

Through Figure 26, it can be observed that 99%, of the respondents have a positive perception towards the perceived usefulness of the ITTA model.

*Analysis of Perceived Ease of Use (PEOU) of the ITTA Model*

In order to highlight the main measures of central tendency for PEOU towards the ITTA model, user responses have been illustrated via a histogram illustrated in Figure 27.



**Figure 27- Perceived Ease of Use Responses Distribution**

As indicated in Figure 27, the report of the mean ( $M=3.334$  and  $SD = 0.448$ ) suggests that the mean is greater than the neutral/hypothesised value of 3 indicating an overall positive response from a PEOU perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant, from the hypothesised neutral value of 3 ( $H_0: M=3$ ), a one sample t-test was conducted. Table 7 provides an indication of the results of the t-test analysis for PEOU.

**Table 8- Perceived Ease of Use One sampled t test**

One-Sample Test						
Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
PEOU	5.135	45	0.000	0.33913	0.2061	0.4722

From the t-test in Table 8 , it can be concluded that the mean value for PEOU is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting an acceptance of the null hypothesis and a rejection of the alternate hypothesis ( $H_a: M \neq 3$ ). In an attempt to ascertain whether the observed mean is significantly greater than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 7 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 2.932$  which provides a boundary/critical value for the region of rejection of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 5.315, p < 0.05$ ), which is greater than the critical value, thereby providing a basis for the rejection of the null hypothesis, suggesting that the sample mean is significantly greater than the hypothesised mean of 3.

The t-test results can also be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 3.20 .The results are illustrated in Figure 28.

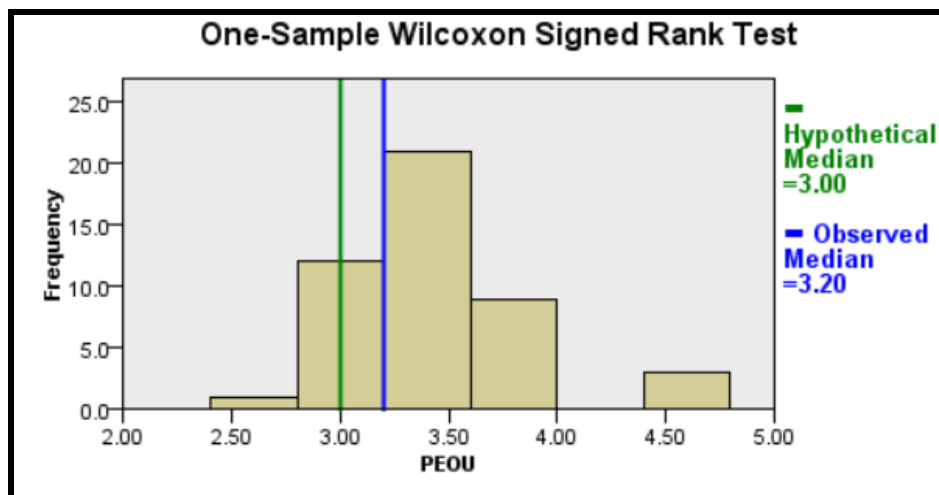
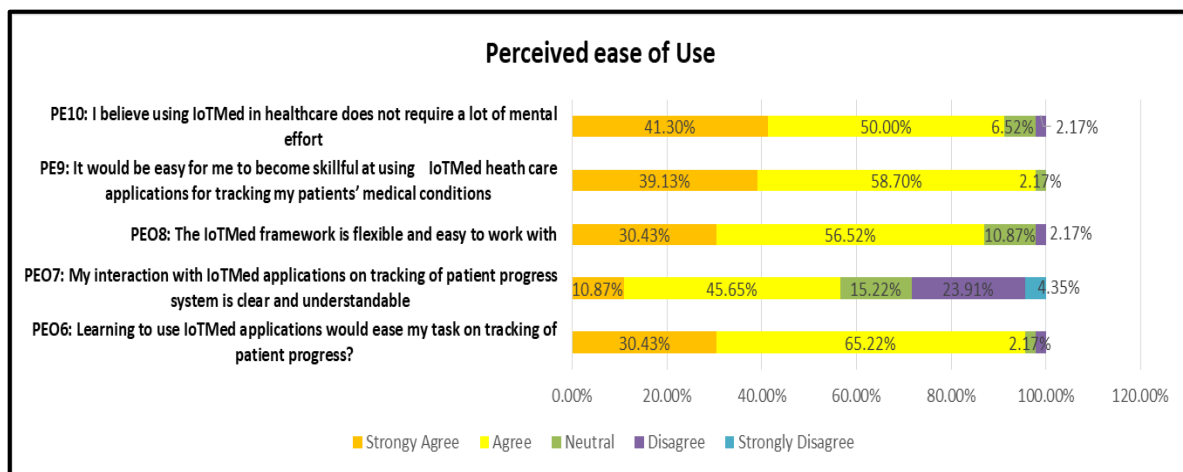


Figure 28- Non Parametric test of the PEOU Median

Based on Figure 28, it can be observed that the median is significantly ( $p < 0.05$ ) greater than the hypothesised median of 3.

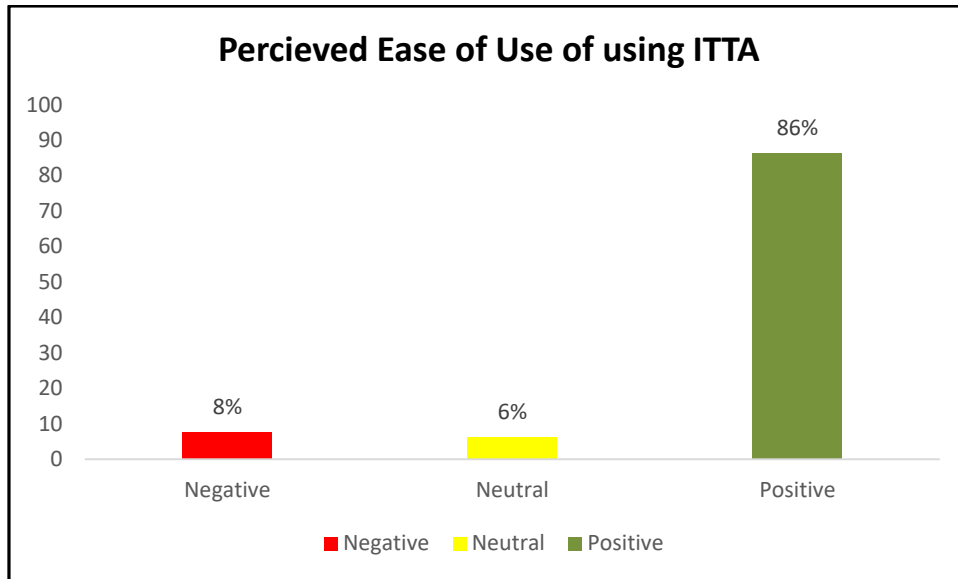
The overall positive perception of the PU of the proposed ITTA model is further with greater granularity by virtue of the actual questionnaire responses is presented in Figure 29.



**Figure 29 Perceived Ease of Use Weighted responses**

Based on Figure 29 it is evident that most of the responses were strongly and positively rated, suggesting that the level of effort required to implement the proposed ITTA would not be that great thereby making a unobtrusive contribution towards enhancing healthcare delivery in public sector in Zimbabwean.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 30.

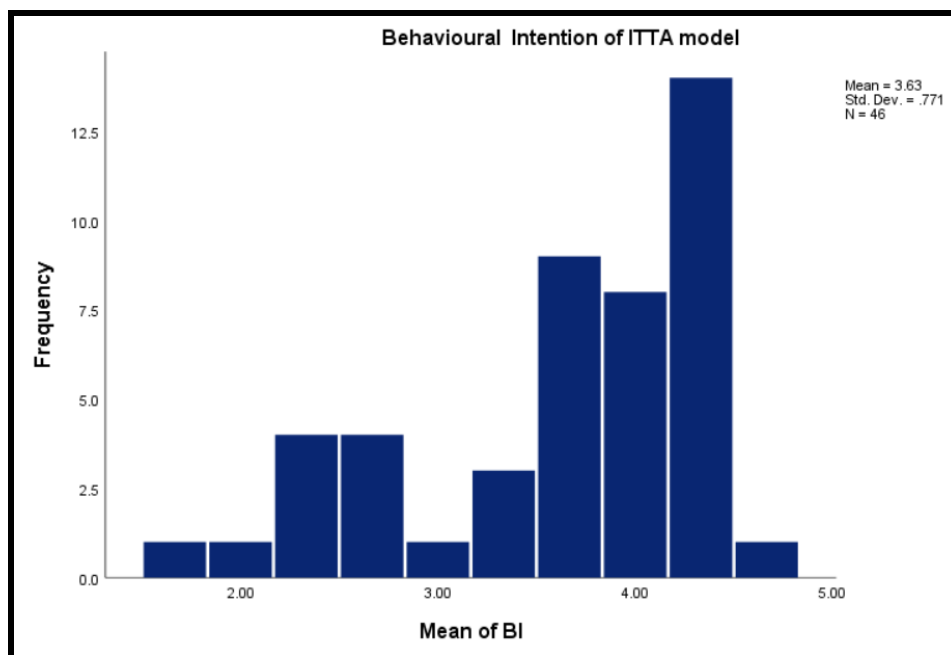


**Figure 30- Aggregated Percentages for PEOU**

Through Figure 30, it can be observed that 86%, of the respondents have indicated a positive perception towards perceived ease of use the proposed ITTA model for the Medical Healthcare process in Zimbabwe.

*Analysis of Behavioural Intention (BI) to Use ITTA*

In order to highlight the main measures of central tendency for the behavioural intention to use the ITTA model, user responses have been illustrated by means of a histogram illustrated in Figure 31.



**Figure 31- Behavioural Intention Responses Distribution**

As indicated in Figure 31, the report of the mean ( $M=3.63$  and  $SD = 0.771$ ) suggests that the mean is greater than the neutral/hypothesised value of 3 indicating an overall positive response from a BI perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant, from the hypothesised neutral value of 3 ( $H_0: M=3$ ), a one sample t-test was conducted. Table 9 provides an indication of the results of the t-test analysis for BI.

**Table 9 - Behavioural Intention One sampled t test**

One-Sample Test						
Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
BI	5.549	45	0.000	0.63043	0.4016	0.8593

From Table 9, it can be concluded that the mean for BI is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting a rejection of the

null hypothesis and an acceptance of the alternate hypothesis ( $H_a: M \neq 3$ ). In an attempt to ascertain whether the observed mean is significantly greater than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 8 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 7.2517$  which provides a boundary/critical value for the region of rejection of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 5.549$ ,  $p < 0.05$ ), which is greater than the critical value, thereby providing a basis for the rejection of the null hypothesis, suggesting that the sample mean is significantly greater than the hypothesised mean of 3.

The t-test results can also be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 3.83 .The results are illustrated in Figure 32.

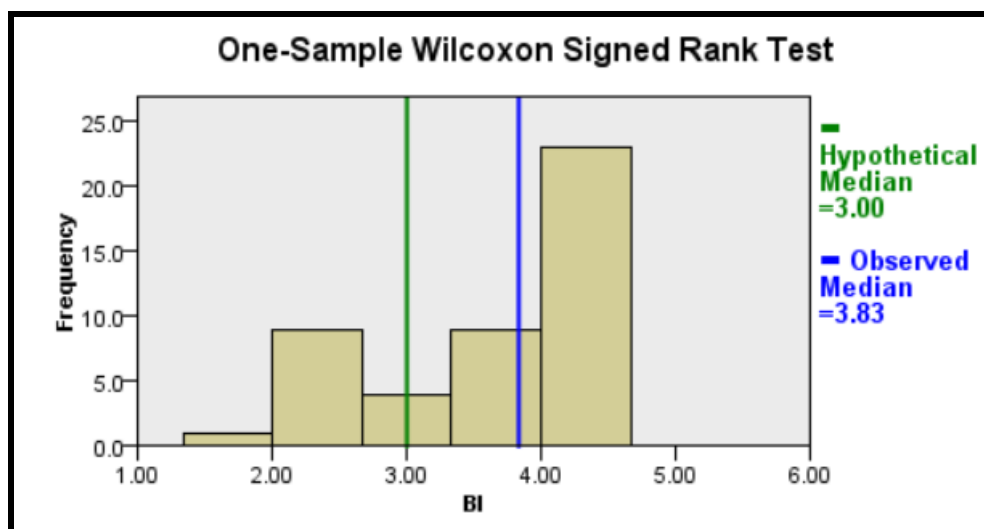
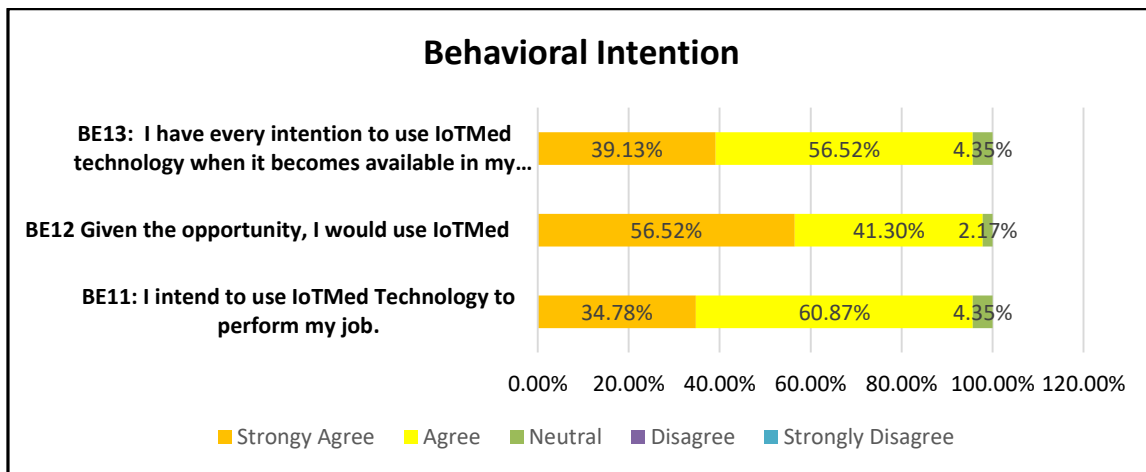


Figure 32- Non Parametric test of the BI Median



Based on Figure 32, it can be observed that the median is significantly ( $p < 0.05$ ) greater than the hypothesised median of 3.

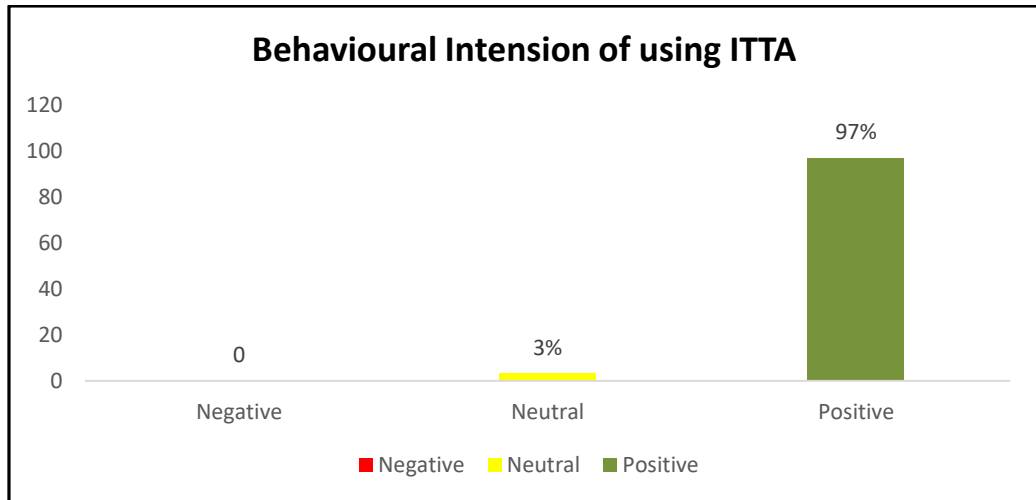
The overall positive behavioural intention to use the proposed ITTA model is further highlighted by providing a more granular illustration of the actual questionnaire responses that is presented in Figure 33.



**Figure 33- Behavioural Intention Weighted responses**

Based on Figure 33 it is evident that most of the responses were positively rated, meaning that there is a positive intention to use the proposed ITTA model to enhance medical service delivery in the healthcare system in Zimbabwe.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 34.

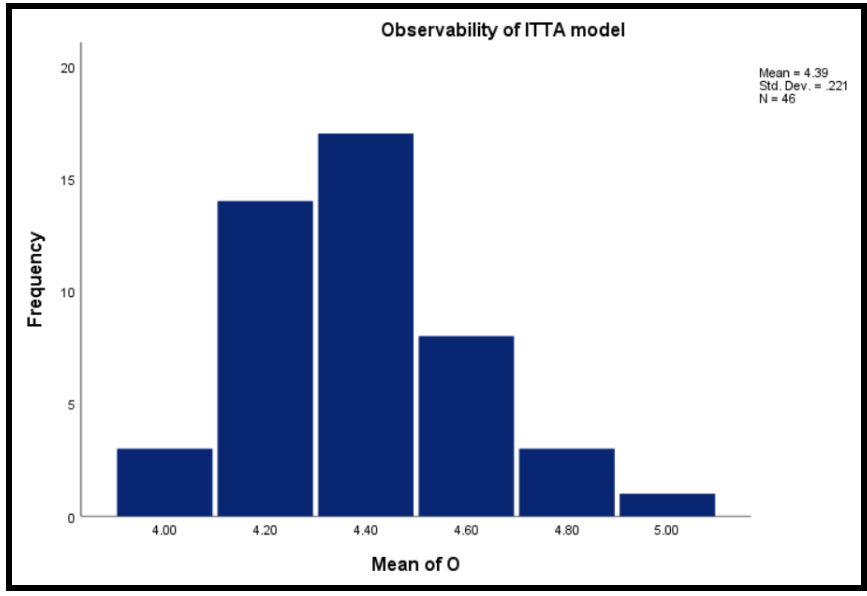


**Figure 34- Aggregated Percentages for PU**

Through Figure 34, it can be observed that 97%, of the respondents have a positive perception towards the utility value of the ITTA model.

#### *Analysis of Observability (Obs) of the ITTA*

In order to highlight the main measures of central tendency for the Obs of the ITTA model, user responses have been shown by means of a histogram illustrated in Figure 35.



**Figure 35- Observability responses distribution**

As indicated in Figure 33, the report of the mean ( $M=4.39$  and  $SD = 0.221$ ) suggests that the mean is greater than the neutral/hypothesised value of 3 indicating an overall positive response from an Obs perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant from the hypothesised neutral value of 3 ( $H_0: M=3$ ), a one sample t-test was conducted. Table 9 provides an indication of the results of the t-test analysis for Obs.

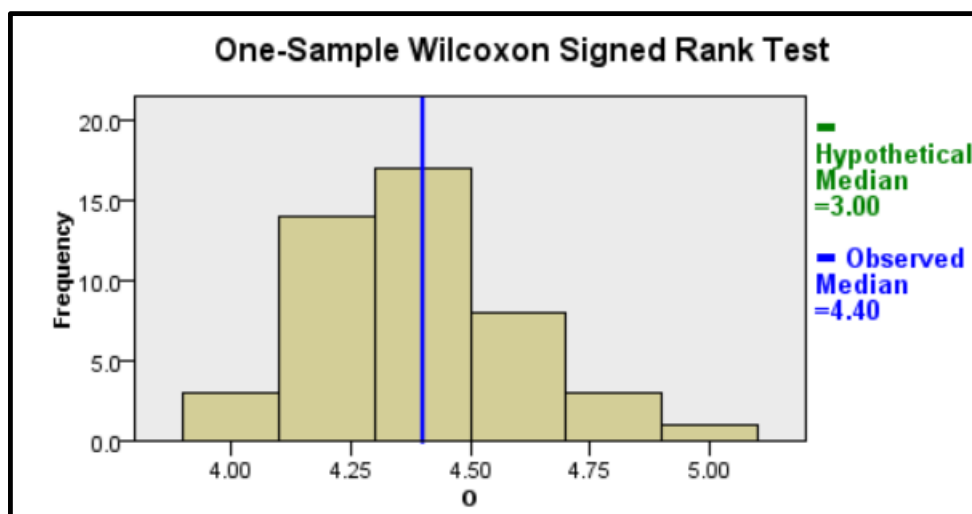
**Table 10– Observability One sampled t test**

One-Sample Test						
Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
O	42.620	45	0.000	1.38696	1.3214	1.4525

From Table 10, it can be concluded that the mean for Obs is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting a rejection of the

null hypothesis and an acceptance of the alternate hypothesis ( $H_a: M \neq 3$ ). In an attempt to ascertain whether the observed mean is significantly greater than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 9 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 2.527$  which provides a boundary/critical value for the region of rejection of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 42.620$ ,  $p < 0.05$ ), which is greater than the critical value, thereby providing a basis for the rejection of the null hypothesis, suggesting that the sample mean is significantly greater than the hypothesised mean of 3.

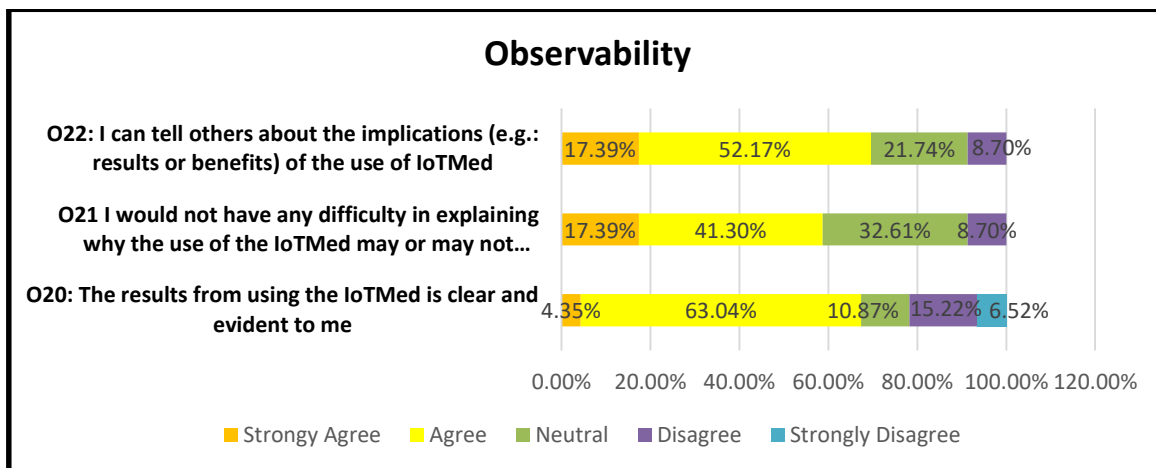
The t-test results can also be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 4.40 .The results are illustrated in Figure 36.



**Figure 36- Non Parametric test of the Observed Median**

Based on Figure 36, it can be observed that the median is significantly ( $p < 0.05$ ) greater than the hypothesised median of 3.

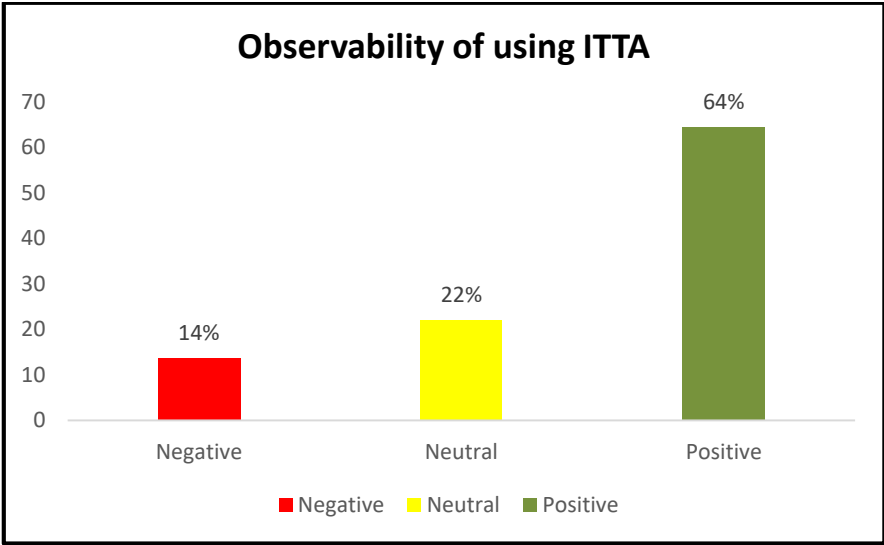
The overall positive perception of the Observability of the proposed ITTA model is highlighted by providing a more granular illustration of the actual questionnaire responses that is presented in Figure 37.



**Figure 37- Observability Weighted responses**

Based on Figure 37 it is evident that most of the responses were positively rated, implying that observable benefits of implementing the proposed ITTA model is something that the respondents attach great value to.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 38.

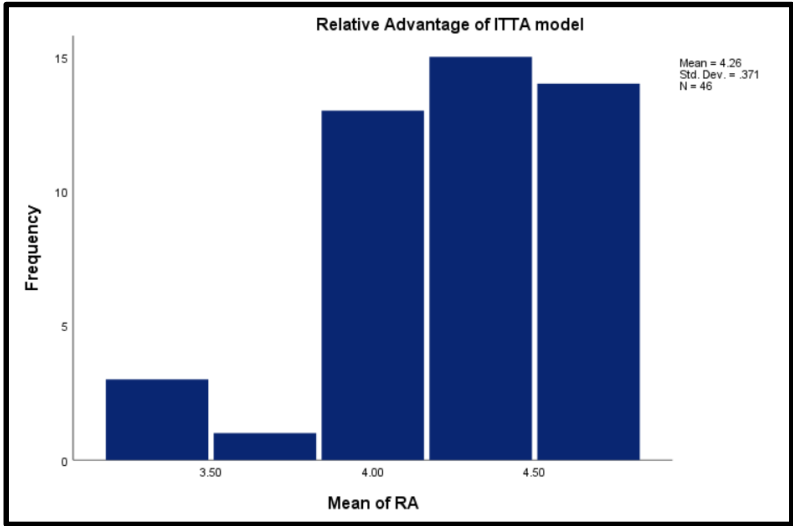


**Figure 38- Aggregated Percentages for O**

Through Figure 38, it can be observed that 64%, of the respondents feel that the Observability of the using the proposed ITTA model is a positive aspect of the model,

*Analysis of Relative Advantage (RA) of IoT use in Medicine*

In order to highlight the main measures of central tendency for the RA of using the ITTA model, user responses have been illustrated by means of a histogram shown in Figure 37.



**Figure 39- Relative Advantage responses Histogram**

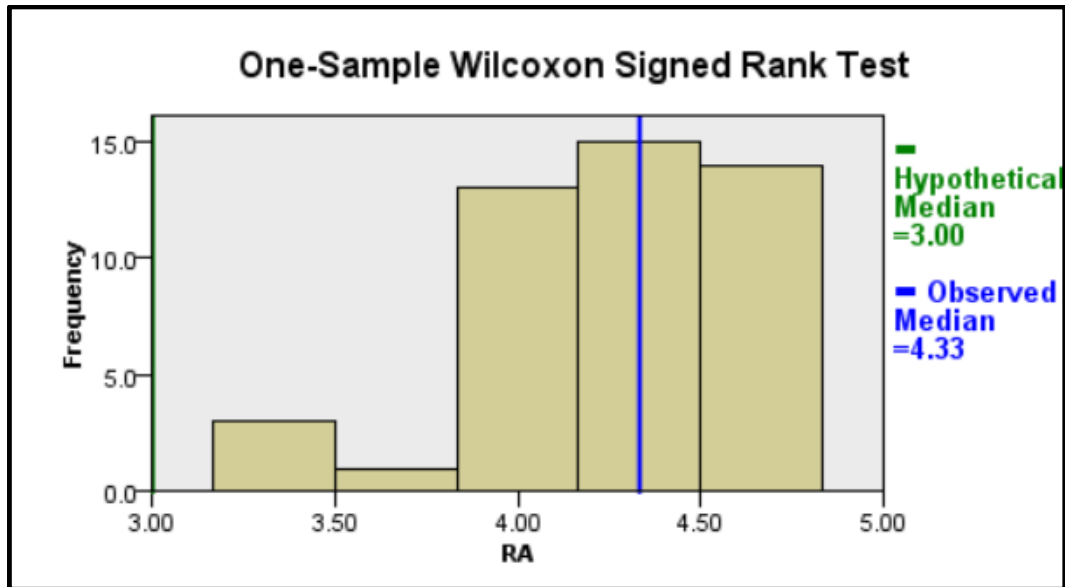
As indicated in Figure 39, the report of the mean ( $M=4.33$  and  $SD = 0.273$ ) suggests that the mean is greater than the neutral/hypothesised value of 3 indicating an overall positive response from a RA perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant, from the hypothesised neutral value of 3 ( $H_0: M=3$ ), a one sample t-test was conducted. Table 11 provides an indication of the results of the t-test analysis for RA.

**Table 11**– Relative Advantage One sampled t-test

One-Sample Test						
Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
RA	23.033	45	0.000	1.26087	1.1506	1.3711

From Table 11, it can be concluded that the mean for RA is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting a rejection of the null hypothesis and an acceptance of the alternate hypothesis ( $H_a: M \neq 3$ ). In an attempt to ascertain whether the observed mean is significantly greater than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 10 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 7.6633$  which provides a boundary/critical value for the region of rejection of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 23.033$ ,  $p < 0.05$ ), which is greater than the critical value, thereby providing a basis for the rejection of the null hypothesis, suggesting that the sample mean is significantly greater than the hypothesised mean of 3.

The t-test results can be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 4.33 .The results are illustrated in Figure 40.

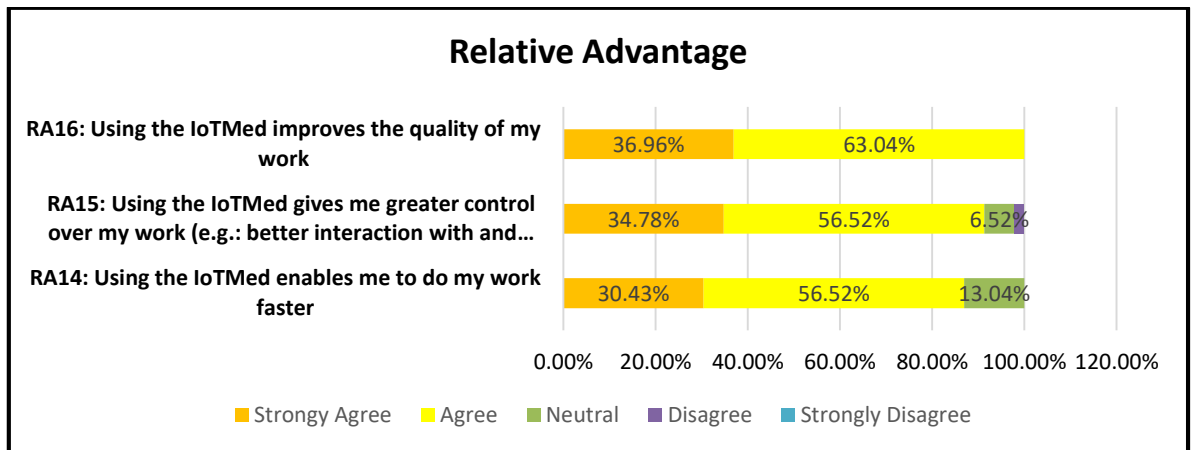


**Figure 40- Non Parametric test of the RA Median**

Based on Figure 40, it can be observed that the median is significantly ( $p < 0.05$ ) greater than the hypothesised median of 3.

The overall positive perception of the RA of the proposed ITTA model is highlighted by providing a more granular illustration of the actual questionnaire responses that is presented in Figure 41.

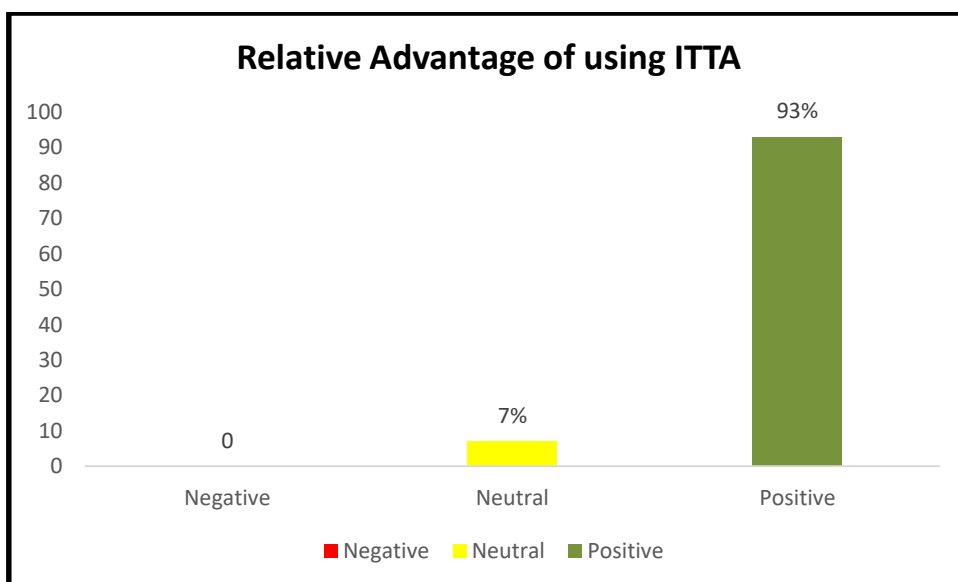




**Figure 41 –Relative Advantage Weighted responses**

Based on Figure 41 it is evident that most of the responses were positively rated, implying that the proposed ITTA model would ensure that the respondents would be able to gain significant advantage in the performance of work related activities.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 42.

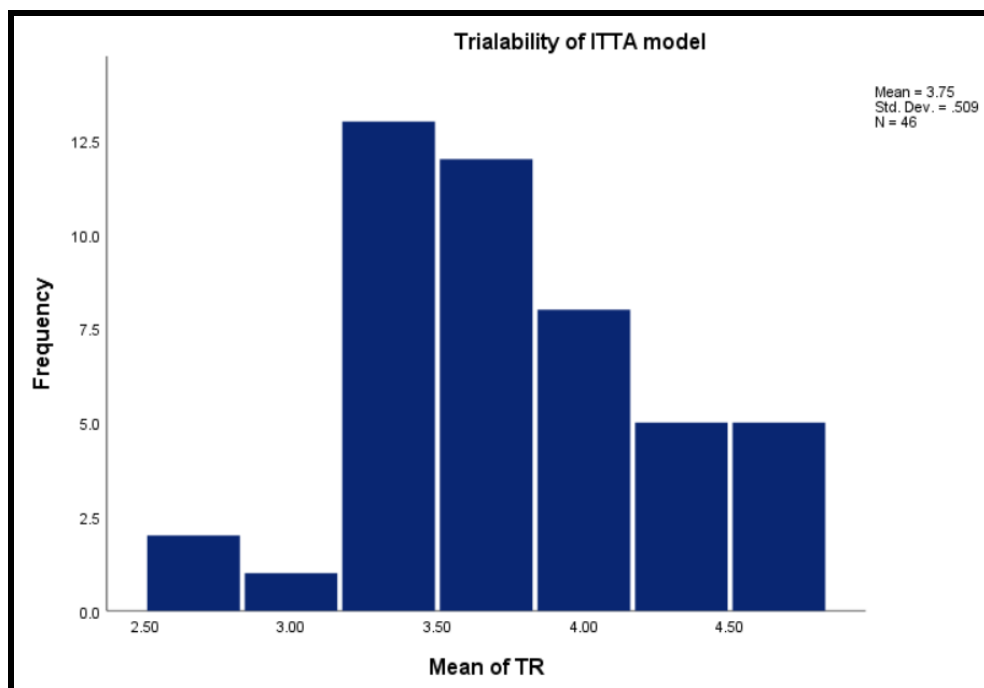


**Figure 42- Aggregated Percentages for RA**

As illustrated in Figure 40, it can be observed that 93%, of the respondents have a positive perception towards Relative advantage in ITTA model.

### Analysis of Trialability (Tr) of IoT use in Medicine

In order to highlight the main measures of central tendency for the Trialability of the proposed ITTA model, user responses have illustrated by means of a histogram illustrated in Figure 43.



**Figure 43- Trialability Responses Histogram**

As indicated in Figure 43, the report of the mean ( $M=3.75$  and  $SD = 0.509$ ) suggests that the mean is greater than the neutral/hypothesised value of 3 indicating an overall positive response from a Tr perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant, from the hypothesised neutral value of 3

( $H_0: M=3$ ), a one sample t-test was conducted. Table 12 provides an indication of the results of the t-test analysis for Tr.

**Table 12-** Trialability One sampled T test

One-Sample Test							
Test Value = 3							
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference		
					Lower	Upper	
TR	10.045	45	0.000	0.75362	0.6025	0.9047	

From Table 12, it can be concluded that the mean for Tr is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting a rejection of the null hypothesis and an acceptance of the alternate hypothesis ( $H_a: M \neq 3$ ).

In an attempt to ascertain whether the observed mean is significantly greater than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 11 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 2.260$  which provides a boundary/critical value for the region of rejection of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 10.045, p < 0.05$ ), which is greater than the critical value, thereby providing a basis for the rejection of the null hypothesis, suggesting that the sample mean is significantly greater than the hypothesised mean of 3.

The t-test results can also be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 3.67. The results are illustrated in Figure 44.

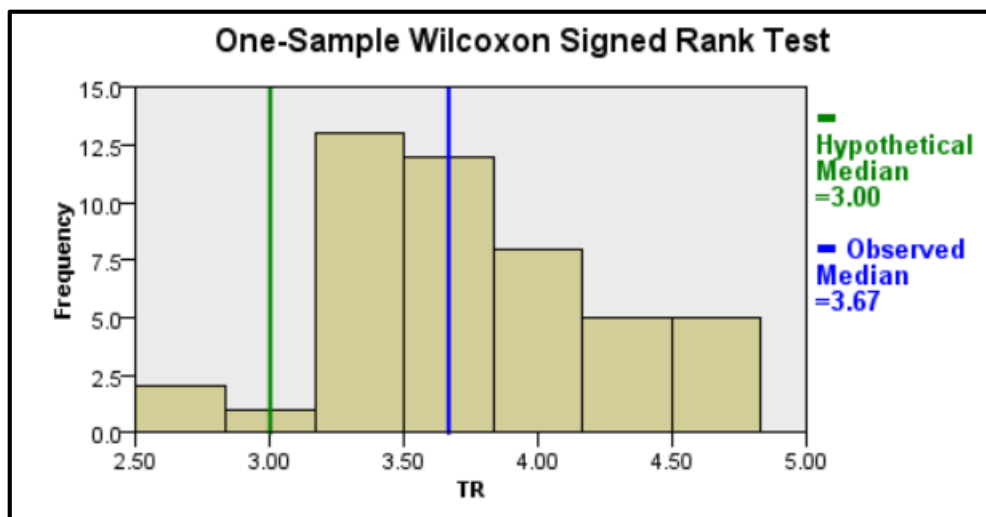


Figure 44- Non Parametric test of the Tr Median

Based on Figure 44, it can be observed that the median is significantly ( $p < 0.05$ ) greater than the hypothesised median of 3.

The overall positive perception of the Tr of the proposed ITTA model, a further granulated illustration of the actual questionnaire responses is presented in Figure 45.

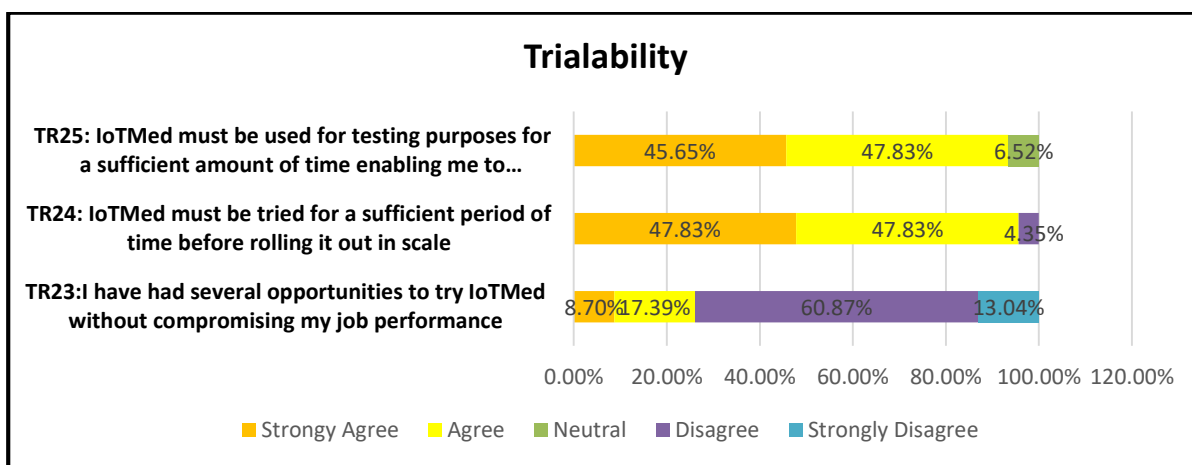
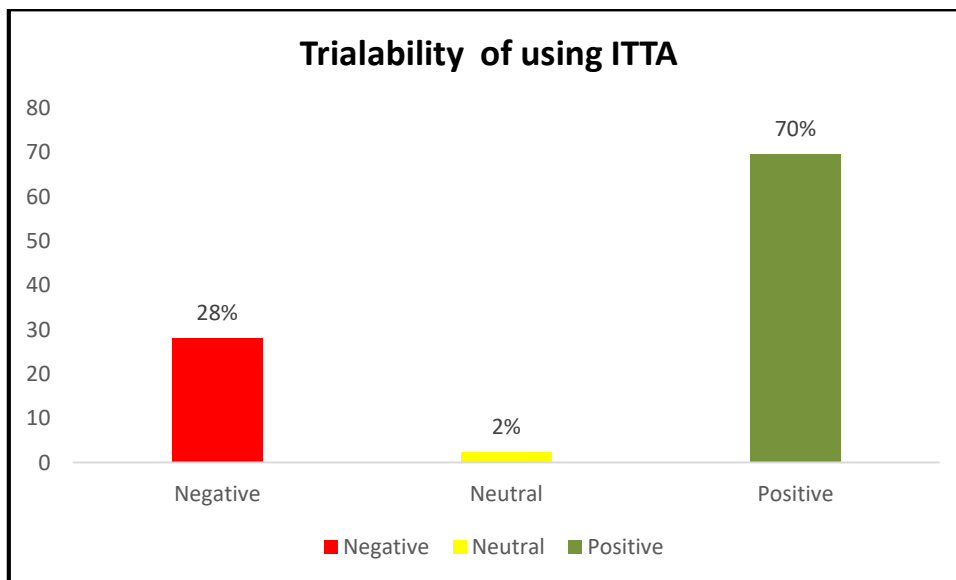


Figure 45- Trialability Weighted responses

Based on Figure 45 it is evident that most of the responses were strongly and positively rated, meaning that, it is perceived that the proposed ITTA model innovation may be subjected to experimentation in the Medical Healthcare system in Zimbabwe.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 46.

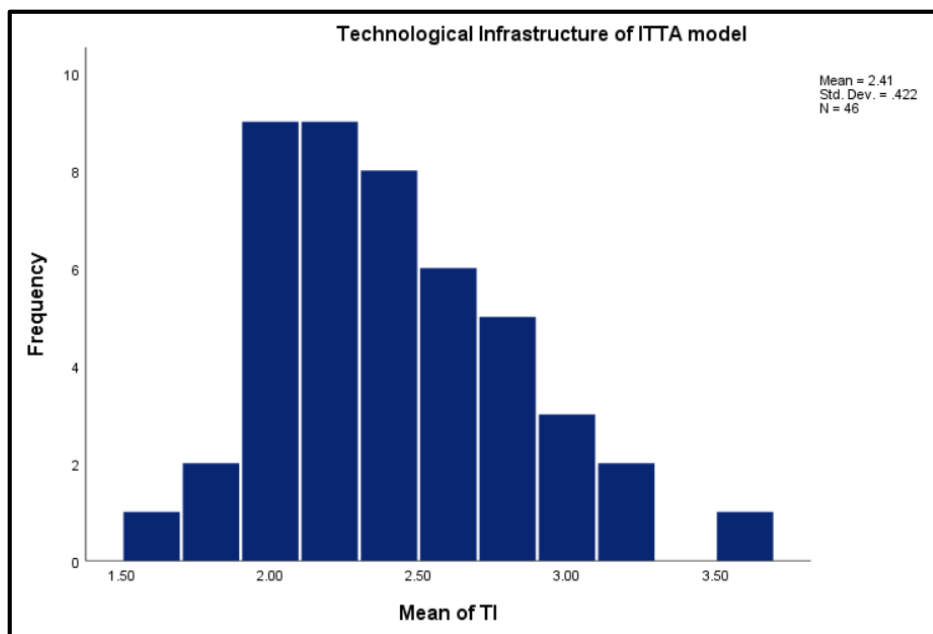


**Figure 46- Aggregated Percentages for TR**

Based on Figure 46, it can be observed that 70%, of the respondents have a positive perception towards the Triability of the ITTA model suggesting that the model may be subjected to experimentation in the Medical Healthcare process in Zimbabwe without there being any major drawbacks.

### *Analysis of Technical Infrastructure (TI) of IoT use in Medicine*

In order to highlight the main measures of central tendency for the TI ITTA model, user responses have been illustrated by means of a histogram shown in Figure 47.



**Figure 47- Technical Infrastructure responses distribution**

As indicated in Figure 47, the report of the mean ( $M=2.41$  and  $SD = 0.422$ ) suggests that the mean is lesser than the neutral/hypothesised value of 3 indicating an overall negative response from a TI perspective towards the proposed ITTA model. However, in order to determine whether this difference was significant, from the hypothesised neutral value of 3 ( $H_0: M=3$ ), a one sample t-test was conducted. Table 13 provides an indication of the results of the t-test analysis for TI.

**Table 13-** Technical infrastructure one sampled t test

One-Sample Test						
Test Value = 3						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
TI	19.164	45	0.000	1.08261	0.9688	1.1964

From Table 13, it can be concluded that the mean for TI is significantly different from the hypothesised mean at the 95% confidence interval thereby suggesting a rejection of the null hypothesis and an acceptance of the alternate hypothesis ( $H_a: M \neq 3$ ). In an attempt to ascertain whether the observed mean is significantly greater than the hypothesized mean, the null and alternate hypotheses are changed to read  $H_0: M \leq 3$  and  $H_a: M > 3$  respectively. The parameters of the t-test analysis shown in Table 12 needs to be adjusted to provide a t-value that may be compared with a critical value from the Student's t distribution table. From this table, it is reported that  $df(45) = 1.4186$  which provides a boundary/critical value for the region of acceptance of the null hypothesis. From the results of the One-sample t-test ( $t(46) = 19.164$ ,  $p < 0.05$ ), the null hypothesis is accepted suggesting that the sample mean is significantly lesser than the hypothesised mean of 3.

The t-test results can also be confirmed through non-parametric tests of significance. The Wilcoxon-one sample signed ranked test against the hypothesised median value 3 and illustrated a sample median of 2.40. The results are illustrated in Figure 48.

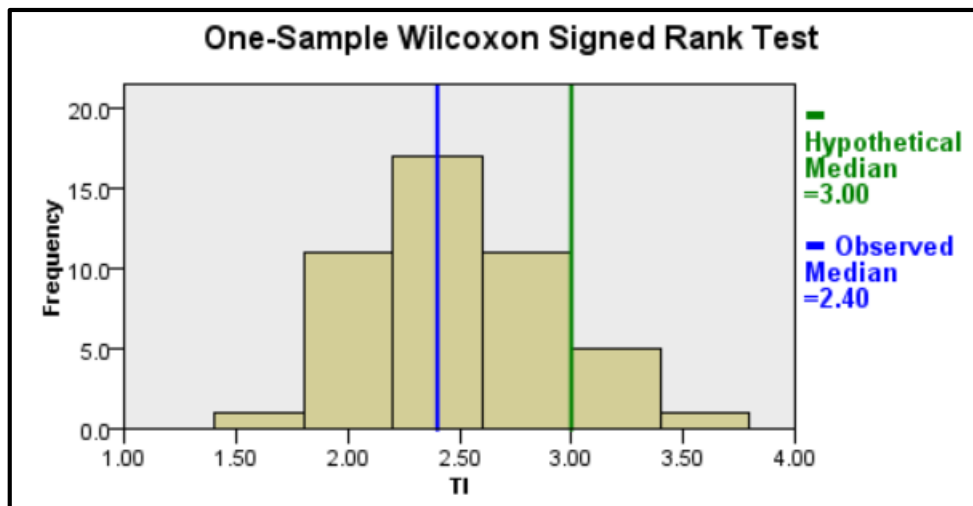
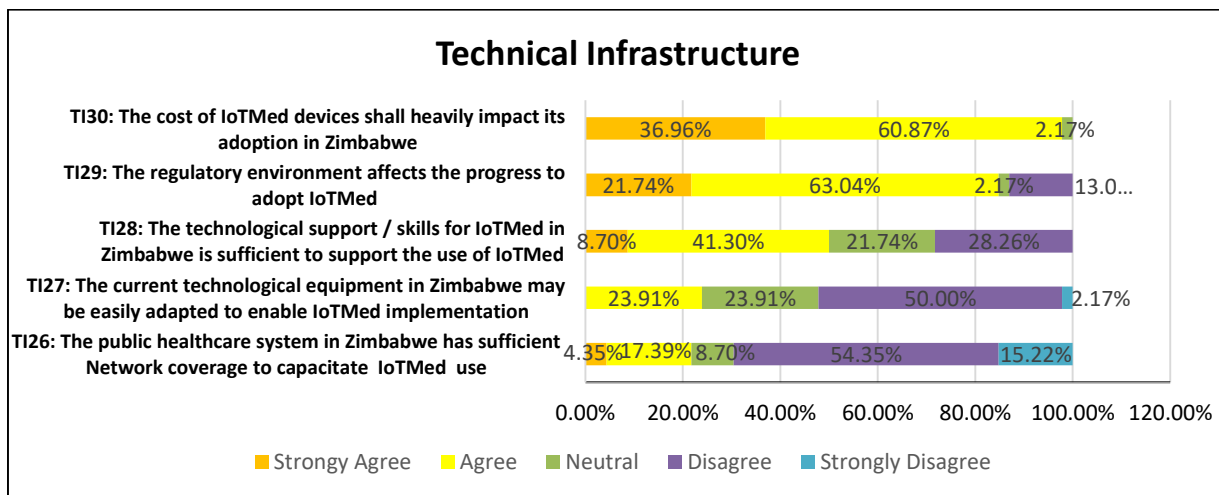


Figure 48- Non Parametric test of the TI Median

Based on Figure 48, it can be observed that the median is significantly ( $p < 0.05$ ) lesser than the hypothesised median of 3.

The overall negative perception towards the TI of the proposed ITTA model is further granulated by showing an illustration of the actual questionnaire responses in Figure 49.

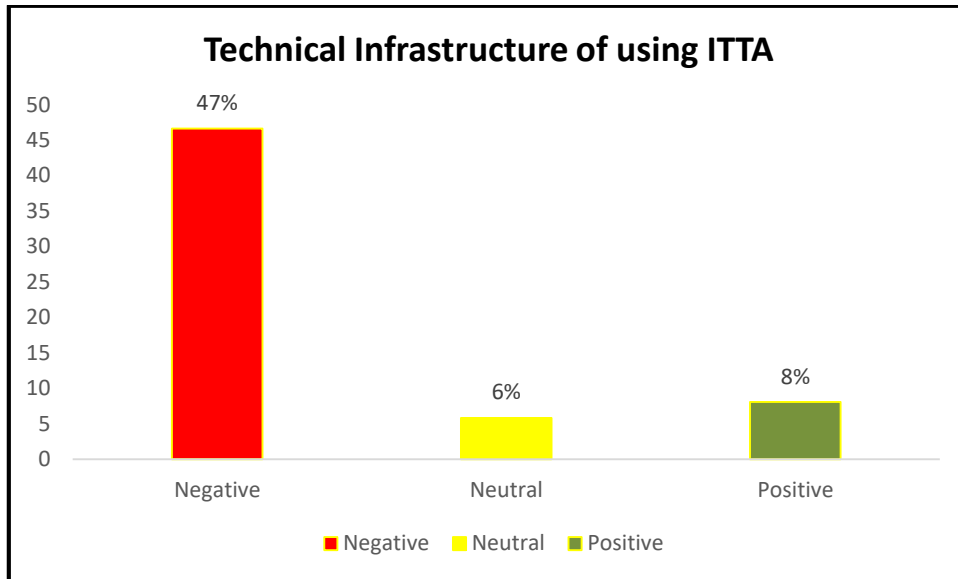


**Figure 49- Technical Infrastructure Weighted responses**

Based on Figure 49 it is evident that most of the responses were negative indicating that the overall perception is that that the TI requirements to implement the proposed model is not adequate.

A further useful analysis was undertaken by conflating the Likert Scale responses to 3 main classifications. These are Negative (1 and 2), Neutral (3) and Positive (4 and 5). The outcome of this exercise is illustrated graphically in Figure 50.





**Figure 50- Aggregated Percentages for TI**

Through Figure 50, it can be observed that 47% of the respondents have a negative towards the capacity of the Technical Infrastructure resources in Zimbabwe to be able to support the ITTA model.

#### **5.4 Bivariate Analysis of the Constructs from IoT in the Medical system**

According to Haining (1991), bivariate analysis is the concurrent analysis of two variables of interest. It is meant to explore relationships between two variables, to determine if there are existing associations and the power of the associations. The standard hypothesis testing procedures for parametric and nonparametric tests of relationships assume that the observations are independent. A parametric statistic that is commonly used is the Pearson product moment correlation coefficient that provides an indication of the strength of the relationship between variables in a study(Haining, 1991). From an analysis perspective, a multiple correlation exercise was conducted to illustrate the strength of the relationships between the main variables in the study is presented in Table 14. However, the main objective

of this analysis was to determine the strength of the relationship between the dependent variable, *behavioural intention* and the independent variables that constituted the main constructs from the conceptual framework used in the study. From a correlation analysis perspective, the main outcome of this exercise was to determine the main factors that contributed towards the behavioural intention to accept/reject of the proposed ITTA model.

A Pearson product-moment correlation analysis was conducted to examine the relationship between BI and PU, PEOU, Tr, Ra, Obs and TI. The outcome of this correlation analysis is illustrated in Table 14.

**Table 14-** ITTA Bivariate Correlation Analysis

		<b>Bivariate Correlations (N=46)</b>						
		<b>BI</b>	<b>PEOU</b>	<b>PU</b>	<b>Obs</b>	<b>TI</b>	<b>Ra</b>	<b>Tr</b>
<b>BI</b>	Pearson Correlation	<b>1</b>	.813**	.601**	0.128	0.115	0.051	.342*
	Sig. (2-tailed)		0.098	0.724	0.397	0.447	0.736	0.020
<b>PEOU</b>	Pearson Correlation		<b>1</b>	0.367*	-0.098	-0.053	0.213	0.173
	Sig. (2-tailed)			0.266	0.517	0.000	0.154	0.250
<b>PU</b>	Pearson Correlation			<b>1</b>	-0.173	0.148	0.247	-0.024
	Sig. (2-tailed)				0.251	0.326	0.000	0.873
<b>Obs</b>	Pearson Correlation				<b>1</b>	-0.066	-0.193	-0.201
	Sig. (2-tailed)					0.665	0.200	0.181
<b>TI</b>	Pearson Correlation					<b>1</b>	.307*	0.086
	Sig. (2-tailed)						0.038	0.569
<b>Ra</b>	Pearson Correlation						<b>1</b>	0.073
	Sig. (2-tailed)							0.628
<b>Tr</b>	Pearson Correlation							<b>1</b>
	Sig. (2-tailed)							
* . Correlation is significant at the 0.05 level (2-tailed).								
** . Correlation is significant at the 0.01 level (2-tailed).								

While Table 14 also shows the inter-relationships between the independent variables in the study, the main focus is on the relationship between the dependent variable, BI and the independent variables. An analysis of this result shows that there is a strong, significant positive relationship between BI and PU ( $r=.601$ ,  $p<0.01$ ) as well as a strong, significant positive relationship between BI and PEOU ( $r=.813$ ,  $p<0.01$ ) and a moderate, significant positive relationship between BI and Tr ( $r=.342$ ,  $p<0.05$ ). The relationships between BI and Obs, TI and Ra were not statistically significant at the 95% confidence level.

## **5.5 Discussion of the Quantitative Data Analysis**

The quantitative research phase was included in the study so that a validation of the proposed ITTA model could be conducted.

The objectives of the quantitative data analysis were to:

- Determine the acceptance and viability of technology infrastructure of ITTA model in Zimbabwe
- Determine the influence of the dependent variables in the conceptual framework on the behavioural intention to use the proposed ITTA model.

To achieve the above-mentioned objectives, it was crucial to develop an appropriate data collection instrument. This was achieved by using standard questions that were taken from data collections instruments that were developed by the original authors of each of the technology acceptance models that contributed towards the study's conceptual framework. The technology acceptance phase of the study was not designed with any intention of inferring the results to a general population. However, the main purpose was to obtain an intimate understanding of the main factors that influenced acceptance of the proposed ITTA model.

A sample size of 50 respondents was targeted and 46 responses were acquired. A combination of parametric and non-parametric statistical methods were used to analyse the responses from the study's sample with regards to the acceptance of ITTA. The relatively small sample size did however have a compromising influence on the statistical analysis. The sample was however highly representative of the actual intended users of the proposed ITTA and in this regard, the data collected provided a relatively accurate reflection of a typical user's perception of the proposed ITTA model with regards to each of the constructs from the study's conceptual framework. The outcome of this analysis is discussed in the subsequent sections.

### *Perceived Usefulness*

The response for PU reflected a normal distribution thereby enabling the conducting of parametric statistical tests. The main outcome from this analysis was that the overall positive mean response 4.33 (80<sup>th</sup> percentile) was indicative of a high level utilitarian value has been attached to the proposed ITTA model. This result is quite significant because in the annals of technology acceptance theory, PU is the most significant predictor of the behavioural intention to use a technology. These results are commensurate with the main corpus of empirical studies regarding technology acceptance behaviour. There was also a significant positive correlation between PU and BI to use ITTA.

### *Perceived Ease of Use*

Although the distribution of means for PEOU did not pass the test for normality, the non-parametric tests did confirm the reported mean of 3.34 (66<sup>th</sup> percentile) as being significantly greater than a hypothesised neutral value. Hence, there was a positive disposition towards the PEOU of the proposed ITTA model. The use of the model was thus

perceived to be free from effort on an average and although this was not at the same level as PU, it was aligned to the results of previous studies on technology acceptance behaviour. There was also a significant positive correlation between BI and PEOU.

### Observability

The observability construct was also viewed in a positive light with a median value of 4.4 (88<sup>th</sup> percentile) and a total of 64% of the responses were deemed to be positive. However, 14% of the respondents had a negative disposition with regards to the observability of the ITTA model. This could be attributed to a lack of understanding of the inner workings of the proposed ITTA model.

### Relative Advantage

The Relative Advantage responses were not normally distributed, responses were skewed to the right with a mean of 4.26 and a median of 4.33 (86<sup>th</sup> percentile). The mean and median were computed to be significantly greater than a hypothesised neutral value. Also, 93% of the respondents indicated a positive response to the Relative Advantage that the proposed model provided.

### Trialability

The results of the study indicate that medical practitioner's responses were slightly skewed to the right with a mean of 3.75 and a median of 3.67. About 70 % of the responses were positive, implying that most practitioners assume ease with which the ITTA innovation may be subjected to experimentation was deemed to be a positive influence towards the behavioural intention to use the model. There was however, 28% of the sample who provide a

negative response indicating a lack of confidence in the ability of the ITTA to be experimented with. This cautionary behaviour is expected because medical practitioners have a natural tendency to be extra vigilant when it comes to experimentation involving healthcare systems.

### *Technological Infrastructure*

The results of the study indicate that the responses were normally distributed with a mean of 2.41 and a median of 2.40, however slightly skewed to the left. Also, 47% of the respondents had a negative perception towards the ability of the infrastructure to provide adequate support for the proposed ITTA model. This outcome corroborates the qualitative phase of the study where many interviewees indicated their lack of faith in the Zimbabwean Government to provide adequate resources to enhance the medical healthcare system in Zimbabwe.

## CHAPTER SIX. SUMMARY AND CONCLUSION

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The conclusion chapter comprises of the study's summary, which is structured as follows

- An evaluation of the research objectives and questions underpinning the study;
- A discussion of the study's findings;
- Literature review contribution and the theoretical contributions of the study;
- The implications arising from the study and areas for future research;
- The study's conclusion.

### 6.1 Key Research Problem and study Objectives

This section reviews an argument for an IoT intervention that may contribute to the alleviation of the healthcare challenges in Zimbabwe. The strategy of resorting to IoT is supported by healthcare experts who concede that the IoT strategy may enable the circumvention of many 'bottleneck' situations in the healthcare system thereby enabling efficiency in the operational aspects of healthcare delivery.

The main research questions underpinning the study were framed according to constructs from the Davis (1985) Technology Acceptance theory and Roger's (2003) Diffusion of Innovation theory. The synthesis phase of the study entails the development of a "best practices" model referred to as the ITTA model that enables IoT implementation in the public healthcare system in Zimbabwe. The validation phase of the study entails an evaluation of the behavioural intention of healthcare professionals in Zimbabwe to adopt the proposed ITTA model.

### **6.1.1 Key Research Question:**

*How can experiential knowledge of Zimbabwean healthcare professionals be leveraged to develop a “best practices” framework for the implementation of IoT technology to enhance healthcare services in Zimbabwe and what is the intention to adopt such a proposed framework?*

The main research question was answered by decomposing the question into constituent parts that are contextualised in the subsequent discussion.

### **6.1.2 Main Research Objectives**

The study’s main objective was to propose a framework for the implementation of an IoT based framework to enhance medical healthcare in Zimbabwe. This objective was achieved by structuring the study according to the following sub objectives:

#### Research Sub Objectives

- Determining the perceptions of healthcare professionals towards the current implementation of IoT technology to enhance public healthcare service delivery in Zimbabwe.
- Developing a best “practices framework” based on IoT technology to enhance public healthcare service delivery in Zimbabwe.
- Determine the intention of medical healthcare professionals to adopt the proposed best practices IoT based framework to enhance public healthcare service delivery in Zimbabwe.



## **6.2 Study Findings**

### **6.2 .1 Synthesis of literature and study findings**

The study has presented a synopsis of various research articles that has enabled an understanding of the current state of the involvement of IoT in the healthcare system. The study's research design, theoretical model and methodologies were concordant with the approaches used in previous studies to ascertain the influence of an IoT based intervention in society in general and specifically in the medical sector. The various challenges and best practices that emerged both in the literature and the interviews enabled the researcher to define a recommended framework for the IoT implementation in the public healthcare system in Zimbabwe.

Rohokale et al. (2011) provided substantial motivation for the use of IoT technology in the medical sector. The current study may be seen as an extension of the recommendations in the Rohokale et al. (2014) study by providing a practical implementation of the suggestions made in that study. The use of Zimbabwe as a setting for this practically oriented solution is ideal given the complex challenges that the economy faces such as the abnormal doctor to patient ratio which is averaged at 1:12 000 (Zim Health, 2017). This was aligned to the interview findings and analysis where it was established that medical practitioners are overwhelmed with their work load resulting in a quest to use smart technology to reduce this workload. According to WHO (2017) there is a substantial deterioration of the healthcare system in Zimbabwe that will lead to a humanitarian crisis of epic proportions. This was supported through the interview findings where doctors emphasised the need for a self-sustaining and profitable IoT framework of implementation for the healthcare sector that will contribute towards an alleviation of the medical crisis. Another important outcome from the study is that many of the respondents in the study indicated that it was important to identify

factors that will lead to greater acceptance of technology based interventions in the healthcare sector because these factors will enable the successful integration of technology into the health sector. The general perception is that many of the factors are oriented around social norms and belief systems that was hindering technological progress in Zimbabwe and Africa in general.

The literature review also focused on the technological infrastructure and highlighted important aspects that need consideration when building IoT systems. In a study on the implementation of IoT technology in the health sector, Garrity (2015) made specific reference to factors such as operational efficiency, system integrity, security and standardisation as pivotal in ensuring that the technology was successful in handling the demands imposed by the health system. This was also supported by in a similar IoT based case study by Hughes (2017) that was conducted in the Congo. In this study, Hughes stressed upon the importance to design systems and devices that are robust, self-recharging and scalable so that it handles the most extreme of conditions. The findings from the current study resonate with those from the Hughes study and once more, the pivotal factors that emerged are system security and ethical and confidentiality concerns, scalability and robust designs that will be able to withstand compromising conditions that are invariably found in Zimbabwe and the African continent in general.

Another significant outcome from the empirical analysis is that the intervention of technology should be done in a subtle manner that does to have too much of a disruptive effect. According to Garrity (2015), such an approach will ensure greater acceptance. It is also imperative for the technology to yield positive results as soon as it is implemented so that it creates a positive precedent and a positive perception that enables greater participation with

the technology. This outcome resonates with technology acceptance theoretical theories proposed in Davis (1985), Venkatesh (2003) and Roger (1985).

### 6.2.2 The IITA Framework

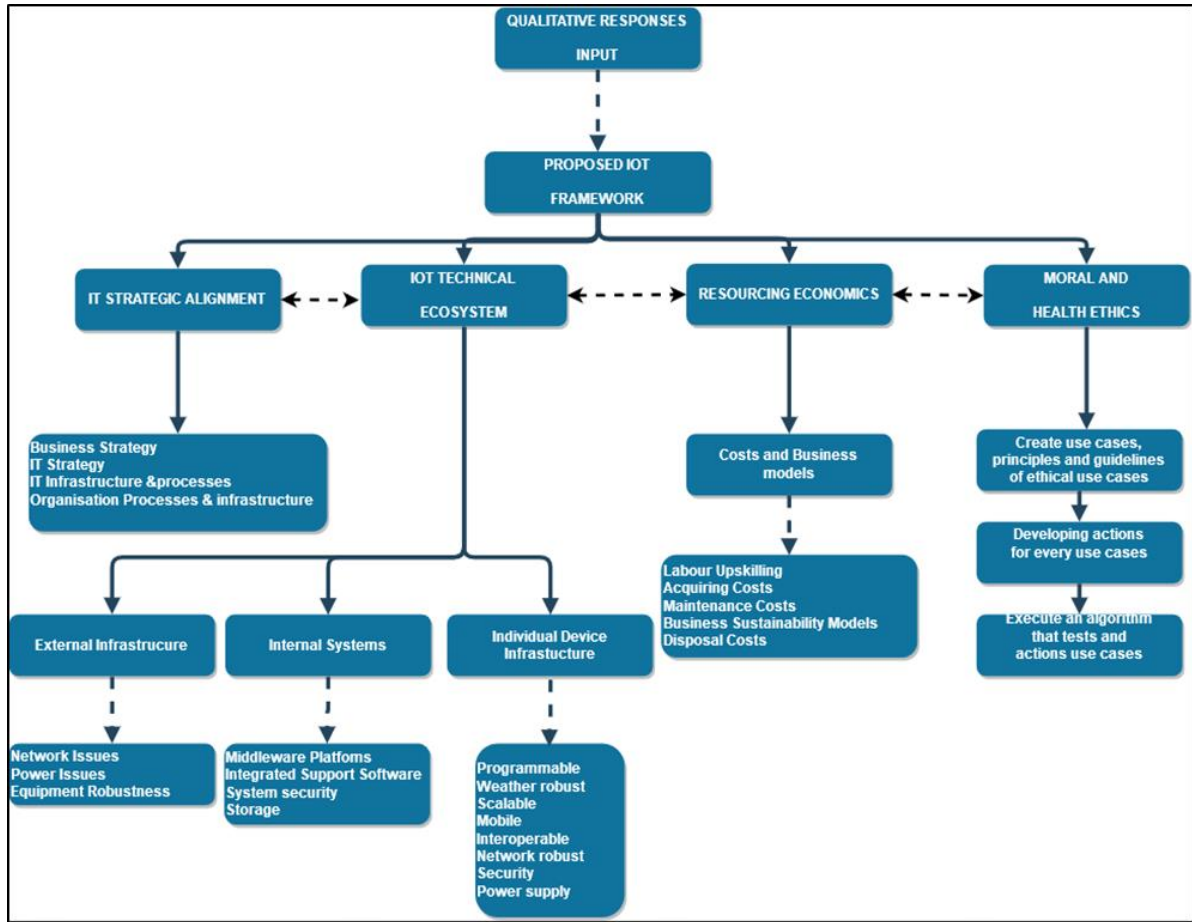


Figure 51 IoT Technology Transformation Alignment (IITTA) model

Figure 51 provides an illustration of the architecture of the proposed framework. It's design is based on the information obtained from the empirical analysis, technology acceptance theory and IT based knowledge of networks and connectivity of devices.

The ITTA framework consist of four major themes. These are: IT Strategic alignment, IoT Technical ecosystem, Resourcing Economics and Moral and health ethics. Each component covers an array of sub themes that enable all key issues that emerged in the findings of this paper.

The strategic alignment construct guides the development of an IoT ecosystem (Henderson and Venkatraman, 1999). It provides a path that could be followed using business intensive terms and logic to implement technology for a humanitarian purpose. In the current context, the business case is that of patient monitoring. The process and “actors” involved in this business case are elaborated in Figure 51. Another key business strategy that has to be highlighted is the implementation of a model that is sustainable and adds a revenue stream to the healthcare practitioners that will cover basic costs of implementing the system. The next step in the sequence is the formulation of an IT Strategy that will drive the delivery of healthcare services (e.g. identification of what technologies meet the business need). The strategy will result in an identification of the resources and the capability of the system in terms of areas of applicability and the range of coverage.

The second key theme that emerged was that the “IoT Technical ecosystem” should have a technical infrastructure that was compatible with the current medical records system as well as the internet technology that was currently in use. The overriding opinion was that although the current infrastructure is lacking in sophistication, it did contain historical records that needed to be preserved for future reference. Any new system will have to be cognisant of the standards and the technology used for the development of the previous system. A subtheme that emerged was that the new system should be energy efficient given the challenges faced by Zimbabwe from an energy usage perspective. The model proposed in the current study consist of a solar based remote charging system that used a network consisting

of Low Radio Frequency technology (LoRa). This strategy enhances the affordability robustness of the proposed solution and is ideal for implementation in Zimbabwe and the African continent. The proposed solution abides by the requirement to be centered around a single remote database thereby enabling access to patient records from any given location. While the use of Cloud Computing has been touted as a viable option, the researcher has resorted to the use of a centralised, in-house database model that could be scaled to the Cloud if the situation demands such an action. The decision to opt for a localised solution rather than cloud based one is based on security concerns as well as cost considerations. The final technical component is the actual IoT device that acts as an information source. The requirement was that these devices should be programmable, robust (climate/network), scalable, mobile, secure and self-powered (solar/ kinetic).

### **6.3 Reflection on the Key Research Questions**

*What are the perceptions of Zimbabwean healthcare professionals of the current implementation of IoT technology as an enabler to provide quality healthcare in the public healthcare system in Zimbabwe?*

The part of the study was conducted qualitatively and consisted of 10 interviews that consisted of two sets of interviews that were analysed to answer questions of this section: one set from three IT specialists and another set for seven medical specialists. The key topics that emerged were condensed into themes and enabled defining of the following trends.

IT specialists suggest that the implementation of IoT in Zimbabwe may be affected by lack resources to purchase or maintain the technology such as lack of foreign currency to fund the Technology. This is mainly attributed to the current poor economic environment in Zimbabwe. Additionally there are not enough complementary skills locally to support the main

stream operations of IoT services. The factors that emerged around resourcing resonates with a similar study that was conducted by Hughes (2017), in the Democratic Republic of Congo where technologies had to be modified according to economic and environmental constraints. This situation is similar to Zimbabwe where concerns about the state of the IT infrastructure in Zimbabwe became a focal point of much of the interviewee discussions. The lack of IT capacity in Zimbabwe manifests in the form of poor network quality, coverage and bandwidth. The responses in this regard are similar to a study conducted by Mpondi (2018) with regards to the capacity of the IT infrastructure in Zimbabwe to accommodate enhancements that will provide a better general service by the Government to its citizens. The outcome from the Mpondi study and the current study is that a bleak picture is painted with regards to the integration of technological enhancements into the Zimbabwean public infrastructure. Based on this knowledge, the technical infrastructure requirements of the proposed ITTA model is not very complex, sophisticated or expensive.

Another concern expressed by the respondents was that many technological devices were not resilient to the harsh climate conditions experienced. In response, the proposed ITTA model was developed to factor in climatic fluctuations so that it was able to handle extreme changes to humidity, pressure, heat, wind and rain.

In a majority of the interviews, there was a reference to the issue of the need to craft a solution that enables the IoT based intervention to align with current system in terms of compatibility and well as the processes that are usually followed for healthcare delivery. In response to this, the proposed ITTA model has been carefully crafted so that it does not cause too much of a disruption to the current systems that are in place. The ITTA has been designed so that it is compatible and interoperable with different medical platforms of the current medical operations and processes.

The further concerns that were raised was the issue of ease of use and security. From an ease of use perspective, the data suggests that the proposed model has been perceived to be

highly usable. A shortcoming of the proposed model is that there has not been a specific focus on the security aspect of the model. However, security does provide an interesting dimension from which to extend this study.

A further aspect that became discernible was the observation that the medical practitioners exhibited a reluctance to embrace the introduction of technology into the medical field unless it is absolutely necessary. However, there was a general consensus that technology was a good avenue to resort to in order to obviate the huge doctor to patient ratio gap that exists in Zimbabwe that has serious repercussions if there is a medical emergency of scale. A suggestion that did come across is that the Government needs to incentivise the use of technology by medical practitioners if the idea of technology based medical healthcare is to gain any sort of traction.

The availability of the appropriate skills to install, support and maintain these systems is vital for the IoT ecosystem to function. Medical practitioners indicate the need for programs and educational workshops for up-skilling them to use IoT which may have a positive bearing on the acceptance of technology. Economically, there is a need to lower import taxes, ease the importation process and avail foreign currency for the institutions that implement IoT products.

From an overview perspective, the interview-based engagement with the medical experts made the researcher aware of the main concerns with regards to the current state of the medical healthcare system in Zimbabwe and the potential for technology to help improve the situation. While the proposed ITTA has factored many of these concerns into its design, the financial constraints may compromise the feasibility of currently using the model.

***How can the experience of current usage of IoT technology by IT healthcare professionals in Zimbabwe be leveraged to develop a “best practices” framework for***

***the implementation of IoT technology to enhance the delivery of public healthcare services in Zimbabwe?***

This research question is a reference to the synthesis phase of the study that comprises of a model that has been derived as an output of the qualitative analysis conducted on the interview data. It proposes a framework of best practices given the key issues and trends identified in the interviews. In this section the proposed model was developed and named the IoT Technology Transformation Model (ITTA) that was synthesized from various perspectives that emanated from the study's findings.

From a technical perspective, the ITTA model was designed to alleviate the technical challenges that impede the functioning of IT based systems. The first technical aspect was the physical technical and network challenges faced in harsh environments. Given the arid, remote and under developed regions in Zimbabwe it was proposed that the system should consist of renewable energy resources such as a solar source to be able to supply a sustainable means of energy to the ITTA components. Another key trend that was identified under the physical technical aspect was the under developed state of the mobile network infrastructure in Zimbabwe. Therefore the ITTA model incorporates the Low radio frequency (LoRa) technology to be able to solve issues to do with the poor network coverage in Zimbabwe. This technology is affordable and is effective in transmitting IoT data. The second technical aspect that the ITTA model attempts to solve is the organizational technical systems. One of the key outcomes that came from the study was that there is a significant discord among systems currently being used in the public healthcare systems in Zimbabwe. Therefore the proposed model proposes an enterprise-wide robust healthcare system that consists of administration, operational, decision support, billing and adequate security that are all synchronized in such a manner that it presents itself as a seamless, coherent system. The last technical aspect the ITTA model advocates is the proposed design nature of the individual IoT devices that can be



able to withstand different elements that may affect it to perform its functions given the extreme environments experienced in various parts of Zimbabwe. The ITTA model proposes the design of the individual devices to consist of characteristics that they are easily re-programmable, serviceable, secure, robust, scalable, compatible, interoperable and mobile in order to be compatible in a dynamic environment.

The second primary trend that the ITTA model attempts to solve is the business strategic alignment model in the healthcare system. This model has been brought up by Henderson and Venkatraman (1999), suggesting that in an introduction of a system it is important to align the key business elements that is; Hospital strategy, IT Strategy, IT Processes and Infrastructure and the Organizational Processes & Infrastructure. This study proposes adopting the Technology Transformation framework which defines the ITTA model as a critical enabler of the Healthcare transformation with capabilities to deliver the organization absolute advantages. The model also aligns with general healthcare imperatives such as monitoring of patients with chronic ailments such as high blood pressure and sugar diabetes.

***What is the intention of medical healthcare professionals in Zimbabwe to adopt a framework for the implementation of an IoT strategy to enhance the quality of healthcare service delivery in Zimbabwe?***

The study sample consisted of 46 participants who were purposively identified and invited to participate in the qualitative phase of the study. The sample for this phase of the study was selected purposively based on the requirement that all respondents had to have at least 3 years of experience as a professional worker in the public healthcare sector in Zimbabwe. Members from the sample were selected based on their familiarity with the current

use of IoT based systems as well as routine hospital systems and processes. The questionnaire was designed to align with the main constructs of the study's conceptual model that consisted of a combination of TAM, DOI and the Technical construct model. The questions that were aligned to each of these constructs are widely recognised in the research community as standard questions. This strategy ensured the validity of the questionnaire.

The analysis that was conducted consisted of descriptive statistics that were designed to provide an overall indication of the respondents' perceptions towards the proposed ITTA model. The main constructs from the TAM model "behaved" in accordance with previous TAM based empirical studies where PU was identified as the strongest predictor of the behavioural intention to use the ITTA model. PEOU was also identified as a significant predictor of the intention to use the ITTA model. The remaining constructs did not achieve the desired levels of significance. However, this outcome was not entirely unexpected, given the small sample size. Another discerning outcome was the negative contribution made by the Technical Infrastructure factor where the majority of the respondents felt that the technical infrastructure in Zimbabwe would render the proposed model to be ineffective. This construct also impacted negatively on the constructs from the Diffusion of Theory model. Because of the infrastructure constraints, issues such as observability, trialability and Relative Advantage have been somewhat obfuscated in the multi-variate statistical analysis (evidenced by low confidence values) thereby compromising the validity of the statistical analysis procedures. However, each of these constructs were strongly positive when it came to the univariate analysis. This outcome is certainly a convincing endorsement of the proposed ITTA model.

## 6.4 Contribution to Practice

The ITTA model tested in this study may be of interest to health institutions wishing to adopt IoT in healthcare systems. There are various stakeholders whom have direct benefit in the model, governments, healthcare practitioners and patients especially in disadvantaged backgrounds.

First, from a practical point of view, this study may help the healthcare system in Zimbabwe and other developing countries uncover areas that are vital for the implementation of Iot in healthcare. Therefore, the main implication of this research is for healthcare practitioners and government institutions to become aware of what factors influence the success of IoT systems they may need to develop.

With these factors in mind, the Healthcare practitioners and IT experts involved in the implementation of IoT are then able to include the key factors identified into the design of their business models and systems such factors as IT strategic alignment, technical designs quality, Moral and ethics handling in IoT and the resourcing economics of the model. This research enables the various stakeholders in the IoT industry to understand the consequences of IoT implementation and the motives why adoption can be challenging, therefore taking a more proactive approach when such systems are been developed.

Secondly, the findings of the research may contribute towards the academic body of knowledge were they may benefit from the understanding of IoT success factors.

Finally, the study premises to educate companies who have already implemented IoT systems, by giving them means to benchmark their systems and to identify areas to concentrate their product designs and business models.

## 6.4 Concluding Remarks

The current study's objective was to contribute towards an improvement in the quality of healthcare delivery in Zimbabwe, a country that may be viewed as a microcosm of the many developing countries in Africa. The contribution was mainly to leverage the efficiencies of IoT technology to assist the healthcare sector. Similar studies have been previously done across the world in attempt to either theoretically or experimentally implement IoT technologies in the healthcare system. However none of the studies have attempted to assess the viability of implementing IoT in an African country with a balanced view on both the technical and social element. Thus, the current study leveraged the opportunity to engage in a unique study in the African context. Ideally, the study's outcome would be applicable to many other countries on the African continent. However, due to time and cost limitations the study was confined to the case of Zimbabwe. Based on the methodologies and research tools that were manipulated throughout the research process key factors and learnings were captured and analyzed. The study has drawn out key trends and issues that affect the implementation of IoT technology in the healthcare systems in an African environment and has suggested an IoT based framework that would contribute towards an improvement in healthcare service delivery in Zimbabwe.

The findings and the solutions that were suggested in the study may enable academics in future studies or implementers of technology to understand the current state of perceptions, systems and resources that are in place in order to create an incremental body of knowledge and implement better and more efficient systems. The study has achieved its objectives in understanding issues that would influence the implementation of an IoT based intervention in Zimbabwe, developing an IoT based model to help improve healthcare service delivery and finally validate the model via empirical data that attests to the willingness of respondents to

use/accept the model as a possible solution towards alleviating healthcare challenges in Zimbabwe.

### **6.5 Limitations and Recommendations for Further Study**

The main limitation arises from the study's design where purposive sampling was used extensively. However the researcher has adopted an exploratory demeanour towards the study and prioritised the acquisition of meaningful data. A recommendation that can be made in this regard is that the ITTA model could be validated with a wider audience and possibly in a country where the IT infrastructure has better capacity.

The lack of focus on the security of the proposed system is also seen as a limitation. The system is critically dependent on the transmission and preservation of secure data and a subsequent study could enhance the proposed ITTA by integrating security protocols into the system.

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## APPENDIX A- SEMI STRUCTURED INTERVIEW GUIDE

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### UKZN HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE (HSSREC)

#### APPLICATION FOR ETHICS APPROVAL For research with human participants

#### Information Sheet and Consent to Participate in Research

Date: 31 August 2018

Greetings,

My name is Kudakwashe Antony Motsi (Student No. 209540571) and I am currently studying for a Master of Commerce in Information Systems and Technology degree at the University of KwaZulu-Natal (UKZN), in the School of Management, Information Technology and Governance. The discipline of my study is in Information Technology (IT). The contact details for myself as well as my supervisor and the academic department at UKZN are listed below:

Researcher Name: Kudakwashe Motsi; e-mail: 209540571@stu.ukzn.ac.za ;  
Mobile Contact Number: +263777222755

Supervisor Name: Dr Sanjay Ranjeeth; e-mail: [ranjeeths@ukzn.ac.za](mailto:ranjeeths@ukzn.ac.za) ;  
Office Contact Number: +27 33 260 5641

You are being invited to consider participating in a study that involves research to understand the influencing factors that affect the creation of a framework for IoT Implementation in the Public Healthcare System in Zimbabwe. With the objective of evaluating healthcare professionals' perceptions of the current status of the public healthcare system in Zimbabwe

#### ***A Framework for IoT Implementation in the Public Healthcare System in Zimbabwe***

The current aspect of the study is directed at obtaining an insight into your perception or experiences towards IoT implementation in the public healthcare system in Zimbabwe. This insight will be guided by a semi-structured interview that will be used to add structure to a conversation regarding your perceptions or experience of IoT Implementation in the public healthcare system in Zimbabwe. A significant part of your contribution towards this research effort will be in the form of interviews to understand your perceptions or current experiences regarding the use of IoT in the health care system. The duration of your participation if you choose to participate and remain in the study is expected to be approximately 40 minutes.

We envisage that the information that you provide will be pivotal in developing a framework for IoT Implementation in the Public Healthcare System in Zimbabwe. It is also envisaged that the outcome of the study will make an academic and practitioner-based contribution to the general discourse on IoT usage in Zimbabwe.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number\_\_\_\_\_).

In the event of any problems or concerns/questions you may contact the researcher by making use of any of the contact details provided above, or by contacting the UKZN Humanities & Social Sciences Research Ethics Committee. The contact details are as follows:

*HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION*  
*Research Office, Westville Campus*  
*Govan Mbeki Building*  
*Private Bag X 54001*  
*Durban 4000* *KwaZulu-Natal, SOUTH AFRICA*  
*Tel: 27 31 2604557- Fax: 27 31 2604609*  
*Email: HSSREC@ukzn.ac.za*

Your participation in the study is voluntary and by participating, you are granting the researcher permission to use your responses. You may refuse to participate or withdraw from the study at any time with no negative consequence. There will be no monetary gain from participating in the study. Your anonymity will be maintained by the researcher and the School of Management, I.T. & Governance and your responses will not be used for any purposes outside of this study.

All data, both electronic and hard copy, will be securely stored during the study and archived for 5 years. After this time, all data will be destroyed.

If you have any questions or concerns about participating in the study, please contact me or my research supervisor at the numbers listed above.

Sincerely

*Sanjay Ranjeeth*

-----

**CONSENT TO PARTICIPATE**

I ..... (Name) have been informed about the study entitled *A Framework for IoT Implementation in the Public Healthcare System in Zimbabwe* by *Kudakwashe Motsi*.

I understand the purpose and procedures of the study.

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

I have been informed about any available compensation or medical treatment if injury occurs to me as a result of study-related procedures.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at the details provided in **Page 1** of this document.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

*HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION  
Research Office, Westville Campus  
Govan Mbeki Building  
Private Bag X 54001  
Durban  
4000  
KwaZulu-Natal, SOUTH AFRICA  
Tel: 27 31 2604557 - Fax: 27 31 2604609  
Email: HSSREC@ukzn.ac.za*

I hereby provide consent to:

Audio-record my interview    YES / NO

\_\_\_\_\_  
**Signature of Participant**

\_\_\_\_\_  
**Date**

\_\_\_\_\_  
**Signature of Witness**

\_\_\_\_\_  
**Date**

(Where applicable)

**General Instructions for the Interview**

During the interview, you are at liberty to request clarification or repetition of the question. There is no time limit set for answering a particular question or for the duration of the interview session. It is advisable to complete the interview in a single sitting.

**Demographic & Background Information:**

Job Title/Position						
Job Description						
Department						
Gender	<i>Male</i>			<i>Female</i>		
Qualification(s)	<i>Under_graduate Degree/ Diploma</i>	<i>Post_graduate Degree</i>	<i>Honours</i>	<i>Masters</i>	<i>PhD</i>	<i>Others- (please specify)</i>
Approximately how long have you been a practitioner in the healthcare sector in Zimbabwe?						
Approximately how long have you been involved in the use/installation of IoT technology for the healthcare sector?						

**Context for the Interview with Medical Health Practitioners (Parts A and B only)**

In this part of the interview, the questions are directed at your general perception of the **use of IoT devices such as RFID tags** in the medical sector to monitor and transmit patient data on a real time basis to medical experts for diagnosis and response of medical conditions.

**PART A – PHENOMENOLOGICAL KNOWLEDGE OF IoT Usage in the Medical Healthcare sector in Zimbabwe – A Bracketing Approach**

1.	Please provide some detail regarding your experience(s) of the use of technology to enhance medical healthcare service delivery in the public healthcare sector in Zimbabwe.
2.	What is your view of the use of technology as an enabler in the quest to improve medical healthcare service delivery in Zimbabwe?
3.	How can technology contribute towards improving the delivery of medical services to the citizens of Zimbabwe?

Context for **PART B** of the Interview (Knowledge & Practice):

In this part of the interview, the questions are directed at your perceptions of the generic benefits or drawbacks that will be introduced by the use of technology to enhance medical healthcare services in Zimbabwe

<b>PART B – based on <i>Technology Acceptance and Diffusion of Innovation Theory</i></b>	
1.	<p><b>Perceived Usefulness/ Relative advantage</b> What are the possible advantages and disadvantages of using IoT Technology for you as medical practitioner, and for your patients?</p> <p>Do you think that the IoT intervention in the medical healthcare sector is one that will be of benefit to the practitioners and the patients?</p>
2.	<p><b>Compatibility</b> How is using IoTs in healthcare systems compatible with your current practice in medicine in the local environment?</p> <p>Do you think that IoTs will cause too much of a disruption and it will distract medical professionals from exercising their expert medical opinion or does the use of technology provide much needed empirical support for medical diagnosis?</p>
3.	<p><b>Perceived Ease of Use/ Complexity</b> Do you think that it is easy/difficult to leverage the benefits of using IoT technology in the public healthcare sector in Zimbabwe?</p> <p>What are the challenges that you are facing / have faced when using IoTs in healthcare during your medical practice experience?</p> <p>Are you as a medical healthcare professional intimidated by the extensive use of technology in the medical healthcare sector?</p>
4.	<p><b>Trialability</b> Do you think that the use of technology to provide critical healthcare information will result in too much of reliance on technological devices with only a minimal focus on actual physical monitoring of the patient's well-being?</p>

	<p>If the technology fails, how can backup systems be put in place so that the quality of healthcare is not compromised?</p> <p>Have you received any training in relation to the use of IoTs in healthcare (such as training sessions, workshops, online training etc.)?</p>
5.	<p><b>Observability</b></p> <p>What is the extent of use of IoTs in your medical practice and healthcare environment (i.e. times of use, type of content you gather / process /produce, sources at the internet or intranet, and programs)?</p> <p>Do you carefully consider the use of IoT as an effective tool for your patients?</p> <p>Do you access patient's information using technology/ IoT technology during your practice in healthcare? If yes, would you consider this strategy as an enhancing or delimiting one? If no, why not and would you want to have a better engagement with technology driven healthcare systems.</p> <p>In your opinion what are the factors that promote or limit the use of technology/ IoT technology for healthcare in Zimbabwe? As a point of reference, the response can be linked to factors such as the <i>technological infrastructure, management commitment, and knowledge of the use of technology</i> by healthcare practitioners, concerns regarding <i>confidentiality of patient healthcare data</i> and environmental concerns such as the <i>reliance on power supply systems as well as guaranteed network connectivity</i>.</p>

Context for the Interview with IT Professionals working in the Healthcare Sector in Zimbabwe (Part C only)

<b>PART C – The Technology Infrastructure</b>	
	<p><b>The Sensor Layer</b> (<i>The Sensor layer consists of the devices that are used to collect data that has been transmitted from the patients</i>)</p>
1.	<p>What type of technologies do you use for data collection e.g. remote sensors and actuators</p> <p>What are the technical requirements that affect the functionality of the Sensor layer in your environment?</p> <p>What are the challenges that currently affect the implementation of an IoT strategy for medical healthcare at the Sensor layer?</p>
2.	<p><b>The Network/Communication Layer</b> (<i>The Network or communication layer ensures data security at access points where data is collected from the perception layer and is transferred to respective central systems via the use of Wi-Fi, 2G/ 3G/ 4G technology</i>)</p>

**Thank You!**

	<p>What type of Network technologies are used by your access point to transmit data?</p> <p>What are the technical structures and requirements that affect the transmission of data?</p> <p>What are the current challenges that affect the network layer?</p>
	<p><b>The Middleware Layer</b> (<i>The middleware layer ensures a seamless integration of protocols and different service management systems to process, retrieve and compute data</i>)</p>
3.	<p>What type of middleware technologies are used to combine, process and output data from their access points?</p> <p>What are the technical structures and requirements that affect the processing of data at this layer?</p> <p>What are the current challenges that affect the middleware layer?</p>
	<p><b>The Application Layer</b> (<i>responsible for inclusive applications management based on the processed information in the Middleware layer and includes smart health applications used by practitioners and patients</i>)</p>
4.	<p>What type of applications are used to by the end users to interact with the system?</p> <p>What are the technical requirements that affect the applications functionality?</p> <p>What are the current challenges that affect the application layer?</p>
	<p><b>The Business Layer</b> (<i>after data has been gathered information is now fused to produce analytics, for example, the use of decision support systems is used at this stage</i>)</p>
5.	<p>What type of technologies are used to compute, analyse and report information at the business layer</p> <p>What are the technical requirements that affect the business layer</p> <p>What are the current challenges that affect the business layer?</p>



## APPENDIX B – FIRST PHASE ETHICAL CLEARANCE

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2 November 2018

Mr Kudakwashe Antony Motsi (209540571)  
School of Management, IT & Governance  
Pietermaritzburg Campus

Dear Mr Motsi,

Protocol reference number: HSS/1592/018M

Project title: A framework for IoT implementation in the Public Healthcare System in Zimbabwe

### Approval Notification — Expedited Application (Phase 1)

In response to your application received on 22 October 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted APPROVAL for the {PHASE 1}.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years. The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

.....  
Dr Shamila Naidoo (Deputy Chair)  
Humanities & Social Sciences Research Ethics Committee

/pm

cc Supervisor: Dr Sanjay Ranjeeth  
cc Academic Leader Research: Professor Isabel Martins  
cc School Administrator: Ms Debbie Cunynghame

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Humanities & Social Sciences Research Ethics Committee

Dr Shenuka Singh (Chair)

Westville Campus, Govan Mbeki Building

Postal Address: Private Bag X54001, Durban 4000

Telephone: +27 (0) 31 260 3587/8360/4557 Facsimile: +27 (0) 31 260 4609 Email: [ximbap@ukzn.ac.za](mailto:ximbap@ukzn.ac.za) / [snvmanm@ukzn.ac.za](mailto:snvmanm@ukzn.ac.za) / [mohunp@ukzn.ac.za](mailto:mohunp@ukzn.ac.za)

Website: [www.ukzn.ac.za](http://www.ukzn.ac.za)



Founding Campuses: ■ Edgewood ■ Howard College ■ Medical School ■ Pietermaritzburg ■ Westville

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## APPENDIX C – SURVEY QUESTIONNAIRE

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### UKZN HUMANITIES AND SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE (HSSREC)

#### APPLICATION FOR ETHICS APPROVAL For research with human participants

Date: 9 November 2018

Greetings,

My name is Kudakwashe Antony Motsi (Student No. 209540571) and I am currently studying for a Master of Commerce in Information Systems and Technology degree at the University of KwaZulu-Natal (UKZN), in the School of Management, Information Technology and Governance. The discipline of my study is in Information Technology (IT). The contact details for myself as well as my supervisor and the academic department at UKZN are listed below:

Researcher Name: Kudakwashe Motsi; e-mail: 209540571@stu.ukzn.ac.za ;  
Mobile Contact Number: +263777222755

Supervisor Name: Dr Sanjay Ranjeeth; e-mail: [ranjeeths@ukzn.ac.za](mailto:ranjeeths@ukzn.ac.za) ;  
Office Contact Number: +27 33 260 5641

You are being invited to consider participating in a study to ascertain acceptance of a framework named *IoTMed* that guides the implementation of an Internet of Things (IoT) based strategy to enhance public healthcare in Zimbabwe. The *IoTMed* framework is an outcome of 1<sup>st</sup> part of the study that I am currently engaged with. The study's title is:

#### ***A Framework for IoT Implementation in the Public Healthcare System in Zimbabwe***

The *IoTMed* framework is a convergence of empirical data that was gathered as part of the first phase of the study. The “first phase” empirical data consisted of interviews with experienced healthcare professionals in Zimbabwe who have provided their insight into aspects relating to

the use of electronic devices to transmit real time data thereby enabling a dynamic public healthcare system in Zimbabwe.

The current phase of the study consists of a survey that is aligned to a theoretical framework that guides knowledge on the acceptance by healthcare professionals in Zimbabwe of the proposed *IoTMed* framework. The duration of your participation if you choose to participate in this phase of the study is expected to be approximately 15 minutes for the filling-in of the survey questions.

We envisage that the information that you provide will be pivotal in developing a framework for IoT Implementation in the Public Healthcare System in Zimbabwe. It is also envisaged that the outcome of the study will make an academic and practitioner-based contribution to the general discourse on IoT usage in the healthcare system in Zimbabwe.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number\_\_\_\_\_).

In the event of any problems or concerns/questions you may contact the researcher by making use of any of the contact details provided above, or by contacting the UKZN Humanities & Social Sciences Research Ethics Committee. The contact details are as follows:

*HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION*

*Research Office, Westville Campus*

*Govan Mbeki Building*

*Private Bag X 54001*

*Durban 4000*

*KwaZulu-Natal, SOUTH AFRICA*

*Tel: 27 31 2604557- Fax: 27 31 2604609*

*Email: HSSREC@ukzn.ac.za*

Your participation in the study is voluntary and by participating, you are granting the researcher permission to use your responses. You may refuse to participate or withdraw from the study at any time with no negative consequence. There will be no monetary gain from participating in the study. Your anonymity will be maintained by the researcher and the School of Management, I.T. & Governance and your responses will not be used for any purposes outside of this study.

All data, both electronic and hard copy, will be securely stored during the study and archived for 5 years. After this time, all data will be destroyed.

If you have any questions or concerns about participating in the study, please contact me or my research supervisor at the numbers listed above.

Sincerely

**CONSENT TO PARTICIPATE**

I ..... (Name) have been informed about the study entitled ***A Framework for IoT Implementation in the Public Healthcare System in Zimbabwe*** by Kudakwashe Motsi.

I understand the purpose and procedures of the study.

I have been given an opportunity to ask questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

I have been informed about any available compensation or medical treatment if injury occurs to me as a result of study-related procedures.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at the details provided in **Page 1** of this document.

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

***HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION***

*Research Office, Westville Campus*

*Govan Mbeki Building*

*Private Bag X 54001*

*Durban*

*4000*

*KwaZulu-Natal, SOUTH AFRICA*

*Tel: 27 31 2604557 - Fax: 27 31 2604609*

*Email: HSSREC@ukzn.ac.za*

I hereby provide consent to:

\_\_\_\_\_  
**Signature of Participant**

\_\_\_\_\_  
**Date**

**Demographic & Background Information:**

Job Title/Position	
--------------------	--

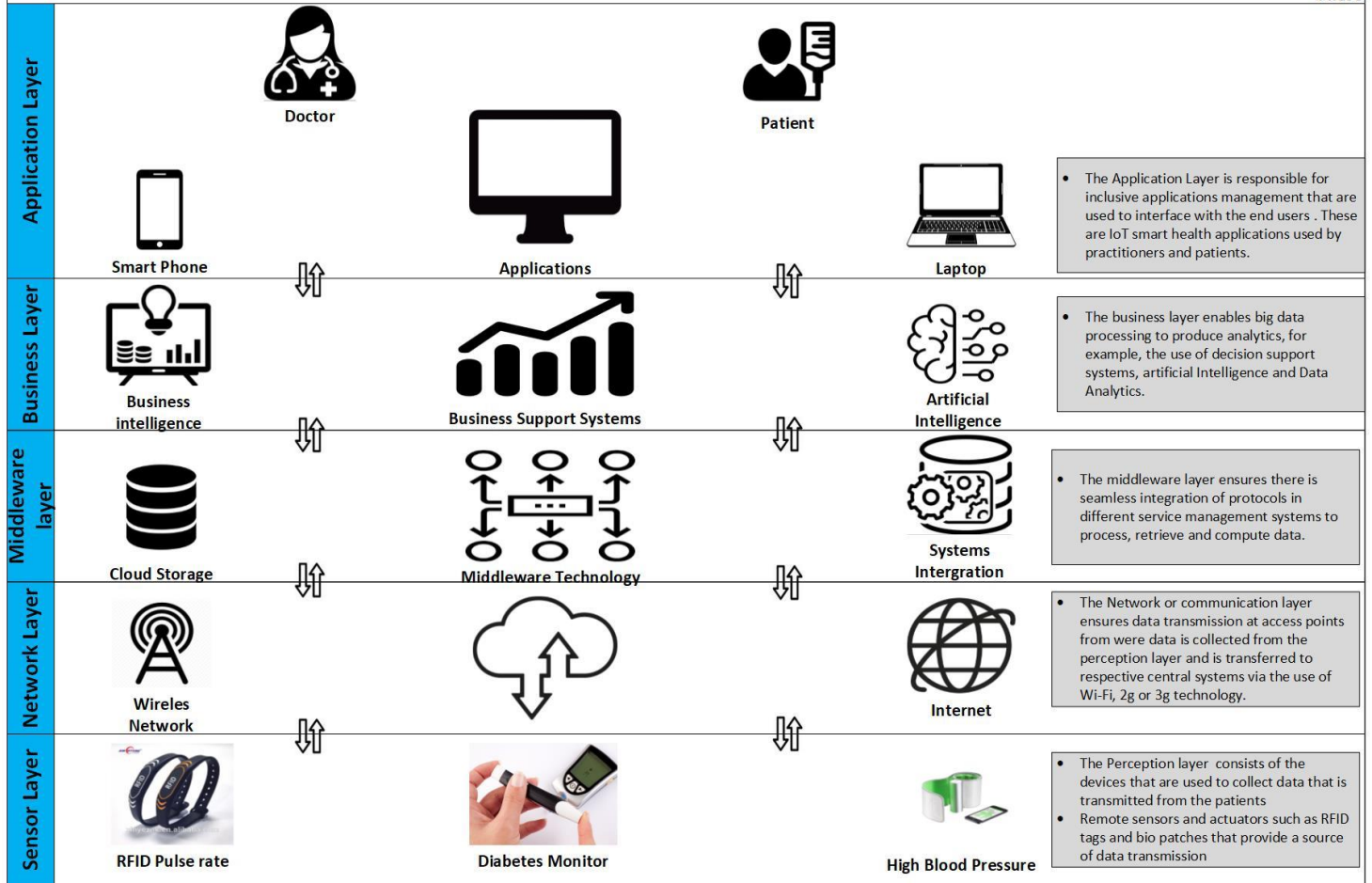
Job Description						
Department						
Gender	<i>Male</i>			<i>Female</i>		
Qualification(s)	<i>Under_ graduate Degree/ Diploma</i>	<i>Post_ graduate Degree</i>	<i>Honours</i>	<i>Masters</i>	<i>PhD</i>	<i>Others- (please specify)</i>
Approximately how long have you been a practitioner in the healthcare sector in Zimbabwe?						
Approximately how long have you been involved in the use/installation of IoT technology for the healthcare sector?						

## Introduction

This questionnaire has been developed in order to obtain feedback on the degree of acceptance of the proposed framework/model for an Internet of Things (IoT) based intervention in the public healthcare sector in Zimbabwe. The proposed model, which has been named ***IoTMed*** has been developed by the researcher based on feedback from healthcare professionals in Zimbabwe. An overview diagram of the proposed model is presented below.

# IoT Med Architecture

Phase



Please place an "X" in the appropriate box to rate the following items

## Section 2- Technology Acceptance Criteria

### Perceived usefulness of the proposed IoTMed

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
<b>PU1:</b> Using IoTMed will help health practitioners to <b>improve their work efficiency</b> by tracking patients' health conditions					
<b>PU2:</b> Using an IoTMed based approach in delivering healthcare allows the health practitioners to <b>support critical decisions</b> through using technology in tracking the patients' information from outside the hospital					
<b>PU3:</b> IoTMed would improve my <b>performance</b> in tracking my patient conditions					
<b>PU4:</b> IoTMed will improve the <b>quality</b> of patient care and management					
<b>PU5:</b> IoTMed will enable patient tasks to be done more <b>accurately</b>					

### Perceived ease of use of the proposed IoTMed

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree
<b>PE06:</b> Learning to use IoTMed applications would ease my task on <b>tracking</b> of patient progress?						
<b>PE07:</b> My interaction with IoTMed applications on tracking of patient progress system is <b>clear and understandable</b>						
<b>PE08:</b> The IoTMed framework is flexible and easy to work with						
<b>PE9:</b> It would be easy for me to become <b>skillful</b> at using IoTMed health care applications for tracking my patients' medical conditions						
<b>PE10:</b> I believe using IoTMed in healthcare does not require <b>a lot of mental</b> effort						

### Behavioral Intention of the proposed IoTMed

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree
<b>BE11:</b> I intend to use IoTMed Technology to <b>perform my job</b> .						
<b>BE12:</b> Given the <b>opportunity</b> , I would use IoTMed						
<b>BE13:</b> I have every intention to use IoTMed technology when it becomes <b>available</b> in my hospital						

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**Relative advantage of the proposed IoTMed**

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree
<b>RA14:</b> Using the IoTMed enables me to do my work <b>faster</b>						
<b>RA15:</b> Using the IoTMed gives me greater <b>control</b> over my work (e.g.: better interaction with and control of my patients' monitoring)						
<b>RA16:</b> Using the IoTMed improves the <b>quality</b> of my work						

**Compatibility of the proposed IoTMed**

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree
<b>C17:</b> Using the IoTMed can be compatible to the manner which health practitioners work						
<b>C18:</b> Using the IoTMed is entirely friendly with my current work routines						
<b>C19:</b> Using the IoTMed is compatible with every aspect of my work (e.g.: evaluation, planning, <i>diagnosis</i> )						

**Observability of using IoTMed**

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree
<b>O20:</b> The results from using the IoTMed is clear and <b>evident</b> to me						
<b>O21</b> I would not have any difficulty in <b>explaining</b> why the use of the IoTMed may or may not provide benefits						
<b>O22:</b> I can tell others about the implications (e.g.: results or benefits) of the use of IoTMed						

**Trialability of the proposed IoTMed**

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree



<b>TR23:</b> I have had several <b>opportunities</b> to try <b>IoTMed</b> without compromising my job performance						
<b>TR24:</b> <b>IoTMed</b> must be tried for a <b>sufficient</b> period of time before rolling it out in scale						
<b>TR25:</b> <b>IoTMed</b> must be used for <b>testing</b> purposes for a sufficient amount of time enabling me to understand its use						

**TECHNOLOGY INFRASTRUCTURE**

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Strongly Disagree
<b>TR26:</b> The public healthcare system in Zimbabwe has sufficient <b>Network coverage</b> to capacitate <b>IoTMed</b> use						
<b>TR27:</b> The current technological equipment in Zimbabwe may be easily adapted to enable <b>IoTMed</b> implementation						
<b>TR28:</b> The technological <b>support / skills</b> for IoTMed in Zimbabwe is sufficient to support the use of <b>IoTMed</b>						
<b>TR29:</b> The <b>regulatory</b> environment affects the progress to adopt <b>IoTMed</b>						
<b>TR30:</b> The <b>cost</b> of <b>IoTMed</b> devices shall heavily impact its adoption in Zimbabwe						
<b>TR31:</b> Zimbabwean <b>environment</b> (eg climate) is conducive not to affect the devices data collection						

**Comments/Feedback/Suggestions on the IoTMed**


*Thank You!*

## APPENDIX D- PHASE 2 ETHICAL CLEARANCE



14 February 2019

Mr Kudakwashe Antony Motsi 209540571  
School of Management, IT and Governance  
Pietermaritzburg Campus

Dear Mr Motsi

Protocol Reference Number : HSS/2169/018M (Phase 2) Linked to HSS/1592/018M  
Project title: A Framework for IoT Implementation in the Public Healthcare System in Zimbabwe

### Full Approval – Expedited Application

In response to your application received 4 December 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

**PLEASE NOTE:** Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

.....  
Dr Rosemary Sibanda (Chair)  
Humanities & Social Sciences Research Ethics Committee

/pm

Cc Supervisor: Dr Sanjay Ranjeeth  
cc Academic Leader Research: Professor Isabel Martins  
cc School Administrator: Ms D Cunynghame

Humanities & Social Sciences Research Ethics Committee  
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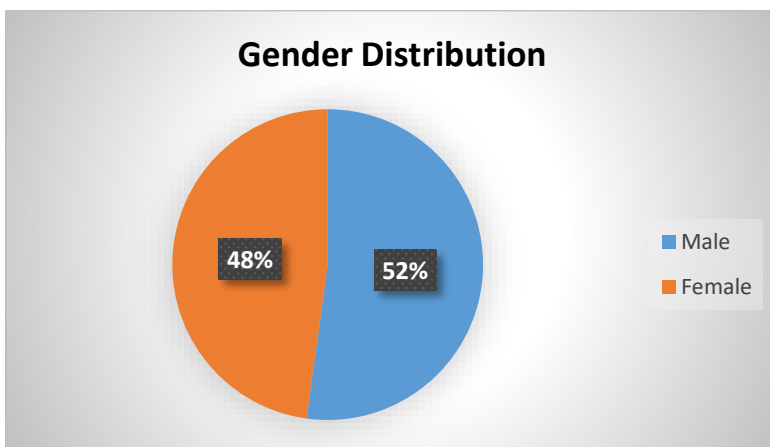
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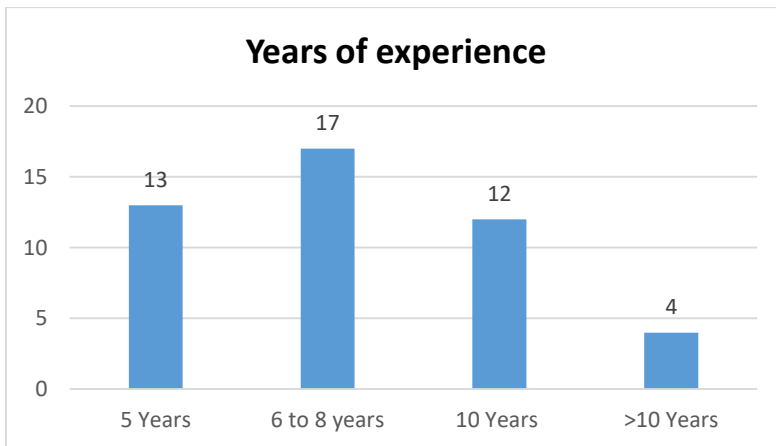
Founding Campuses: ■ Edgewood ■ Howard College ■ Medical School ■ Pietermaritzburg ■ Westville

## APPENDIX E- DEMOGRAPHICS OF THE RESPONDENTS

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**Gender Distribution**



**Years of experience distribution**