PLANNING CONSIDERATIONS FOR SMART METER IMPLEMENTATIONS IN SOUTH AFRICA

By

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DECLARATION

I, Tonderai Muchenje 214372197, hereby declare that the thesis for PhD in Information Technology *to be awarded* is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

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ABSTRACT

Smart meter implementations are still in their infancy in many African countries. This is evident by the lack of research on the subject in the African context. Most of the research studies are either Euro-centric or US-centric. Although these studies are important and informative, they might not address the African challenges in context. Hence, South Africa was chosen as the testbed for an investigation that addresses the apparent knowledge gap. This study set out to formulate a framework for planning considerations in the implementation of smart meter technology within South Africa.

Through extensive literature review and analysis, the technology acceptance model (TAM) was chosen as a foundational framework for this study. Although TAM is widely used for researching technology acceptance and use, its applicability was found to be inadequate in explaining customer-centric factors in smart metering. Therefore, it was supplemented with factors from the theory of reasoned action (TRA), the theory of planned behavior (TPB), privacy calculus theory (PCT), as well as the unified theory of acceptance and use of technology (UTAUT). A total of 11 consumer-centric factors were identified, and these were statistically analysed using the structural equation modelling technique (SEM). Ten (10) consumer-centric factors was found to be significant. These were attitude, perceived value, monetary cost, privacy risk, perceived ease of use, perceived usefulness, facilitating conditions, social norms, trust in technology and behavioral intention.

Hypothesis testing confirmed that, not one acceptance model could adequately be used to identify and explain the consumer-centric factors that can be incorporated for planning considerations for smart meter implementation in South Africa. It was further observed that the consumer-centric factors such as environmental issues, security, reliability and health issues that were important in developed countries were not deemed so in South Africa. From a methodological perspective, the study attests to contextual localised application as opposed to universal meaning and measurement invariance when incorporating planning consideration for smart meter implementation in South Africa as compared to European countries and the United States of America.

Finally, the findings hold some practical implications, as they showed the practical utility of the model in predicting the consumer-centric factors that can be incorporated for planning considerations. In support, the Business Model Canvas (BMC) was found to be a useful tool in deriving and reporting on the formulation of planning consideration guidelines. Using the BMC, five planning consideration guidelines were derived: customer segmentation, partnerships, benefits

communication, value identification and customer attitude. These planning considerations will allow smart meter providers to identify their customers, partners and value propositions they might need to offer consumers to facilitate a higher smart meter acceptance and use. The proposed planning consideration guidelines can practically be used by policymakers and regulators for several aspects for future pervasive technology acceptance studies.

This research has, therefore, created a platform for further research in the smart technology domain while providing a usable predictive framework for the identification of consumer-centric factors and formulation of planning considerations guidelines for smart meter implementation within the South African context.

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CHAPTER 1:
INTRODUCTION

To get the bad customs of a country changed and new ones, though better, introduced, it is necessary first to remove the prejudices of the people, enlighten their ignorance, and convince them that their interests will be promoted by the proposed changes; and this is not the work of a day.

Benjamin Franklin (1781)

Chapter 1 begins with a discussion about pervasive computing technologies in the context of smart meter technology (Section 1.1). This is followed in Section 1.2 with a general consideration of why smart meters are needed, including their benefits and challenges. Sections 1.3 to 1.9 present the research problem, objectives, research validity and significance of the study as well as its limitations. Chapter 1 concludes with a discussion of the thesis chapter organisation (Section 1.10).

1.1 Pervasive computing technologies

The speed at which modern technologies are developing, and the demand for more human-centric computing technologies has made traditional computing environments, associated with wired computers, ineffective and inefficient in many ways. Modern advances in making computers smaller, wireless, mobile and smarter enables them to communicate and collaborate anytime and anywhere with traditional systems and infrastructure. These innovations have provided organizations with strategic advantage by increasing productivity, speed and customer service, a concept referred to as pervasive computing. According to Giordano and Puccinelli (2015), the pervasive vision has been dominated by two paradigms: (1) The human-free paradigm centered around wireless sensor networks and (2) the human-centric paradigm accelerated by the rise of mobile personal smart devices.

Satyanarayanan (2001) posits that pervasive computing technology simply represents a further step in technology evolution which dates back to the 1970s and is characterized by distributed systems and mobile computing. The need to access information anytime and from anywhere has provided the stimulus for mobile computing which has, in turn, enabled the existence of the pervasive computing concept. Distributed computing's seamless access to remote information resources and communication with fault tolerance and high availability and security creates the platform on which pervasive computing applications can interoperate (Saha & Mukherjee, 2003). Kurkovsky (2007) suggests that pervasive computing technologies are already in place, the only challenge is to find the best and most efficient methods to integrate them into the current environments. In his understanding, pervasive computing systems emerge at the unification of embedded and mobile devices and system, wireless communications, and distributed, mobile and context-aware computing.

Satyanarayanan (2001) has examined pervasive computing technologies based on applications characteristics and outlines the following common basic elements:

(i) *Ubiquitous access* – A situation in which users are surrounded by a great number of interconnected, embedded systems which are commonly invisible and weaved into the background of the surroundings such as furniture, clothing and rooms that sense the settings and state of physical objects via a multiple of sensors. Sensors become the key drivers that input information from the physical world to the virtual world while operating in a time-driven or event-driven way.

(ii) *Context awareness* – The ability of a system to recognise and localise objects as well as people and their intentions.

(iii) *Intelligence* – The ability of a technology-rich environment to adapt itself to the people that live in it by learning from their behavior, and possibly be advanced enough to show emotions.

(iv) *Natural interaction* – These are advanced modalities such as natural speech and gesture recognition which will allow for a much more human-like communication with digital environments than is possible today.

Based on the discussion above, the need to understand the factors that impact the implementation of pervasive technologies becomes vital. Considering that cost, privacy and security are already difficult subjects in distributed and mobile computing, pervasive computing technologies will even further complicate the situation. This is owing to the ability of pervasive computing systems to employ mechanisms such as location tracking, smart spaces and use of surrogates to monitor user actions on a near real-time, continuous basis.

Pervasive computing systems have become more knowledgeable about a user’s movements, behavior patterns and habits (Ye, Dasiopoulou, Stevenson, & Meditskos, 2015; Gorai & Agarwal, 2012. Saha & Mukherjee, 2003). Henceforth, any exploitation of such information without consent or uncontrolled use of such information can lead to a variety of unsavory activities ranging from unsolicited advertisements to blackmail, energy consumption customer profiling and many others. Certainly, the potential loss of privacy is a serious issue that may dissuade knowledgeable users from engaging with pervasive computing systems. Therefore, there is a need to consider these issues when planning to implement such technologies. This research study has, as its central focus, an investigation about planning considerations in relation to smart meter acceptance and implementation in South Africa. Since smart meters are a pervasive technology, all the points discussed above about the benefits and challenges of pervasive technology are directly applicable to this study.

Section 1.2 discusses the opportunities and challenges associated with smart meter technology, as a form of pervasive technology. In the process, the research gap related to planning guidelines for smart meter implementation in South Africa is delineated.

1.2 Background information about smart meter technology

Section 1.2 contains background information about smart meter technology that provides a general context for this study. The rationale for smart meter implementation, the status of this in South Africa and benefits and challenges of smart meter adoption are considered in this section.

1.2.1 Why use smart meters in managing electricity?

Currently, many countries worldwide are being forced to rethink their electricity infrastructure investment and energy generation, transmission, supply and management in general (Eberhard, Gratwick, Morella & Antmann, 2017) as a matter of urgency. Developed countries, such as the United States of America and Europe, have taken initiatives to replace their ageing traditional electricity infrastructure with electricity grids commonly referred to as smart grids (Kranz, Kolbe, Koo & Boudreau, 2015; Kranz & Picot, 2011; Kranz, Gallenkamp & Picot, 2010). It has been found that many parts of the traditional electricity grids in various countries are many decades old, wearing out and failing to contain the increasing electricity demand, monitoring and control needed to support economic growth prospects (Manyika, Chui, & Bughin, 2013; Welsch, Bazilian, Howells, Divan, Elzinga, Strbac &Yumkella, 2013). Therefore, utility companies across the world are investing billions of dollars to upgrade and modernize electricity grids with smarter technologies, aiming to improve electricity usage efficiency, reliability, privacy and security in the digital age (SmartGrid Consumer Collaborative, 2014).

Since the smart grid is defined as "an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" (Cuijpers & Koops, 2013:70). Therefore, the need to conserve electrical energy through modernization of the electricity grid continues to be a growing concern within the electricity industry. The growing demand to share electricity generation with other intermittent sources such as wind and solar has set up a paradigm shift in the energy domain (Barrett, Peters, Wiedmann, Lenzen, Roelich, Le Quéré, , 2013; Fan & Gong, 2013). Thus, smart electric meter implementation and use in various countries, including South Africa, becomes a strategic focus. Wang et al. (2011), further suggest that smart grids using smart meter technology will modernize the existing electric grid with integral technology that facilitates bidirectional data exchange between utilities companies and consumers in terms of their electricity consumption. Smart meters simplify meter reading for energy billing and enable new services, flexible tariffs and demand response programs on the smart grid. The US Department of Energy report (2010) put forward that smart grids will provide a more interactive, robust and efficient electricity generation, transmission and usage system. The report further emphasizes that smart grids will enable improved reliability, flexibility, power quality, peak demand load limiting capabilities and quick response to repair outages. Kranz et al. (2010) posit that smart grid infrastructure can easily integrate renewable energy (such as wind, solar and gas) feeds into the electricity grid thereby buffering unforeseen spike demands.

According to Karlin (2012) and NIST report 7628 (2010), smart meters are the most important component in the smart grid as they have replaced traditional manual meters in order to communicate information for billing and other operational matters. Smart meters are electric devices that allow for two-way wireless communication between the customer and the utility company in near real-time at an interval of fifteen minutes per hour (NIST 7628 report, 2010). Wang (2011) further outlines that smart meter technology is a combination of electric meters with two-way communication technology that will help the smart grid with information, monitoring and control abilities. Smart meter technology implementation aims at improving power grid reliability and promoting energy efficiency and demand control while providing better services to customers. Although smart meter technology implementation benefits both the energy companies and their clients (customers), various concerns have been raised. The NIST 7628 report (2010) outlines these concerns, ranging from energy billing accuracy to security and privacy issues, smart meter integrity, communication and the impact of these challenges on the legal system.

1.2.2 Smart meters status in South Africa

At the 64th Association of Municipal Electricity Utilities (AMEU) Convention in 2014, it was discussed that, although the legislative drivers for implementing smart meters may differ in various countries, legislation was noted to be a major factor in determining smart meter implementation. This was evident from the experiences of the smart meter deployment forerunners, the US and Europe. In the case of South Africa, the South African government through the Department of Minerals and Energy, published a regulation (R773 of the Electricity Regulation Act of July 2008) to address shortages in electricity generation capacity in the country. The Regulation notice R773 stipulated that all electricity consumers or customers with a monthly consumption of 1000 kWh and above must have a smart meter installed and be on a Time of Use (ToU) tariff not later than 1 January 2012. The Regulation notice R773 further authorized the licensee (utility company) to remotely monitor and control the use of all electric geysers, heating systems, cooling and ventilation systems, swimming pool pumps and heaters in all customer premises. As much as the R773 specified the deadline for smart meter implementation to Eskom and municipalities, the regulation was not well received and accepted as municipalities found it unrealistic to fully comply with the set date, given the complexities of, and investment required to implement smart meter technology on a large scale. (Sustainable Energy Africa, 2015).

Furthermore, in order to allow smart meters to collect, transmit and store electricity consumption data on the meter as total register values as well as half-hourly, a National Smart Metering Standard, NRS049:2008 was developed and published to specify the Advanced Metering Infrastructure (AMI) needed in South Africa. The NRS049:2008 specified that smart meters may be permitted to record tampering, supply outages, load limiting capabilities and effect discontinuity commands to cut the supply of electricity to a particular consumer's premises (Eskom, 2008).

With all the legislation around smart meter technology, many municipalities and Eskom, as smart meter providers, are experiencing teething problems with smart meter implementation, particularly in relation to customer satisfaction, energy efficiency, revenue management, cost saving and accuracy of billing. This is largely owing to a lack of proper planning and implementation roadmaps. Utility companies and municipalities have ventured into this complex technological project without proper stakeholder engagements and planning and have ended up with a low rate of smart meter adoption and deployment. Although the US has installed about twenty-five million smart meters to date, about sixty-five million smart meters are projected to be installed by 2020 (Karlin,2012), The USA has not had a smooth smart meter implementation process owing to various issues raised with regard to security and privacy, potential risks , billing, and environmental concerns that emanate from smart meter technology. If a country like the USA, with high access to electricity, good infrastructure and technical support faces smart meter adoption challenges, what can be expected in South Africa with only 50 to 75 percent of the country electrified and with a lack of technical skills and a high unemployment rate?

Although the USA and Europe are ahead in smart meter installation in comparison with South Africa, a survey by Boston Consulting Group (2010) showed that, of about 1678 participants in the USA from both smart meters deployed and non-smart meter deployed areas, 66% of the respondents reported that they will like more communication from their smart meter providers while 30 % have can remember getting any addition information apart from their monthly bill. These data suggest that, even in these countries, cost-and-benefit information sessions to educate potential smart meter users were lacking. In the same report, Canada was identified as a country on its way to a 100 percent coverage in smart meter deployment, while Europe is moving towards 80 percent deployment of smart meters by 2020. As for South Africa, smart meter technology implementation is in its early stages and major cities like Cape Town, Pretoria, Johannesburg and Port Elizabeth are the places where utility companies and municipalities are currently working towards effective smart grid implementation programmes.

1.2.3 Benefits and challenges of smart meters

Though many research studies outline the benefits that smart meters offer both consumers and utility companies, most of this research has been skewed in favor of the utility companies. This bias is evident from the findings, most of which outline how smart meters have become a better technological solution for managing power grid reliability, promoting energy efficiency, supporting accurate billing, revenue collection and management, and enabling demand control and customer usage monitoring. Most of these benefits are utility-centric, with only accurate billing and customer usage monitoring being consumer-centric. Whilst there is little confirmatory research on the cost and benefits of smart meter implementation planning from a consumer's perspective, most smart meter research in South Africa has focused on the barriers that government-controlled smart meter providers (for example, Eskom and municipalities) and private smart meter providers are facing in order to effectively install smart meters.

As much as security, privacy and environmental issues have been highlighted as major consumer concerns in the adoption of smart meters, especially in developed countries, these factors are not necessarily priority issues in African countries such as South Africa, especially with regard to privacy and environmental consciousness. Consequently, this research study cannot take a standardized approach and make assumptions that privacy and environmental concerns impact negatively on adoption of smart meters. It should rather seek to verify, in the South African context, some of the smart meter rationale-based factors and assertions put forward in Western and European studies.

Considering the state of economic growth in South Africa and the high levels of unemployment (Statistics South Africa, 2017), the time of use tariffs suggested by the R773 Electricity Act might be perceived to be less affordable in comparison with the traditional monthly billing approach. For example, working class individuals and people on electricity powered life support machines might view time of use billing as costly, because working-class individuals mostly use electricity during peak hours and are usually not at home during off-peak hours when electricity costs would be lower. The same would apply to people on life support. Therefore, accurate billing though smart meters may end up being a utility-centric benefit rather than a benefit for consumers. The capability of smart meters to remotely read electricity usage data from a consumer's home appliances, geysers, heating systems and pumps and send connect and disconnect commands to limit or cut the electricity supply to a consumers' premises could be a conflicting risk and benefit to a consumer, depending on how they view the impact. Considering the high levels of crime in South Africa (even from law enforcing agents), third-party access to electricity usage data poses serious threats to personal identity, privacy and home security if not properly managed. It is imperative that smart meter data be kept secret and accessed only with the consent of the consumer, because, when subjected to further analysis these data can reveal personal details about the consumer such as occupancy of the home, behavioral patterns (such as sleeping habits) and total electricity consumption. Background information about the study topic has been provided in Sections 1.1 and 1.2. Section 1.3 discusses the research problem and identifies the knowledge gap that this study aims to address.

1.3 Research Problem

Despite global initiatives aimed at enhancing electricity energy efficiency, securing supply and mitigating climate change, individual countries should be able to balance their economic growth target with an increasing demand for electricity. Owing to electrification programmes, especially in Africa, supplies of scarce resources used to generate electricity such as uranium and coal are becoming depleted (Ndaba, 2013). Consequently, cost-effective ways to reliably manage the demand and supply of electricity are needed, otherwise access to electricity in the future will be for the privileged only and unaffordable to the poor.

In retrospect, over the decades most electrical grids have not changed in order to meet the energy needs of all the various stakeholders who rely on electricity. Utility companies are failing to effectively and reliably supply stakeholders with their required electricity needs owing to the ailing traditional electricity grid system. Traditional electricity grids can transmit electricity flow only in one direction, making electricity theft, fault detection, near real-time customer feedback, load balancing and dynamic pricing options difficult to achieve. Therefore, in order to address most of the traditional electricity grid challenges, an investment in smart grid technology becomes a viable technological strategy and solution. For smart girds to effectively realize all the potential benefits for all stakeholders in the electricity value chain, the integration of smart meters becomes inevitable in facilitating two-way communication between the customers and the utility companies. Although the implementation of smart meters, as part of the smart grid system, offers many benefits to both consumers and service providers (utility companies), it has been faced with wide resistance in many countries across the world.

Resistance to smart meter implementation is a reality in South Africa, too. From consideration of the challenges mentioned above, several gaps can be identified that should be researched from an African customer perspective, because factors impacting smart meter adoption in Africa are potentially different from those in both America and Europe. Therefore, this research study was delineated to focus only on the South African context.

In South Africa there is a need to understand and explore planning considerations for smart meter implementation and this need became the major motivation for conducting this study. In relation to this, research is needed to support development of a consumer-focused predictive model and planning considerations in smart meter implementation planning projects with specific reference to technology acceptance and use. Therefore, the need to investigate the consumer-centric factors that facilitate high acceptance of smart meter implementation for planning within the South African context can be considered vital research.

The research problem, in particular, that this study deals with is the challenge of how to include consumer-centric factors into the planning considerations of smart meter technology implementation in the South African context. Therefore, the research focus was on how relevant consumer-centric factors can be identified and incorporated into the planning considerations for smart meter implementation projects in South Africa. The main aim of this study was to model these customer-centric factors into tool that show practical utility tool that can be used as a strategic management planning tool (Section 8.4) for both private and public owned smart meter providers to achieve better acceptance of smart meter technology within the South African context. Section 1.4 considers the research questions that relate to the research problem stated above.

1.4 Research questions

In order to scientifically investigate a research problem and discover new knowledge, it is important to express the social enquiry in the form of questions. The central research question to be investigated and addressed in this study is indicated below.

Central research question:

How can consumer-centric factors be incorporated in the planning consideration of smart meter technology implementation in the context of South Africa?

To effectively answer the central research question, several specific sub-questions were put forward and addressed through review of the literature and quantitative research.

- **RQ1:** What are the consumer-centric factors that influence the attitude and intention to accept and use technology?
- **RQ2:** How can these consumer-centric factors be incorporated into a smart meter technology acceptance and adoption model?
- **RQ3:** Which are the most significant consumer-centric factors that are pivotal in the acceptance and use of smart meter technology within the South African context?

Though sub-questions are valuable in directing the train of thought in the process of addressing the social inquiry, it is important to create and align research objectives to the research questions. Section 1.5 presents the research objectives.

1.5 Research objectives

The research objectives in this study represent the specific tasks that were scientifically undertaken in order to discover new knowledge based on the research questions presented above. As for the research questions, a main objective and related sub-objectives were specified.

Main research objective:

Formulate a framework for planning considerations in the implementation of smart meter technology to gain acceptance within the South African context.

En-route to achieving the main objective and answering the central research question, certain sub-objectives must be met. These are listed below.

- Identify and describe the consumer-centric factors that can determine attitude and intention to accept smart meter technology.
- Model and explain the impacts of the consumer-centric factors on smart meter technology acceptance.
- Justify how consumer perceptions can be motivated to enhance increased acceptance of these technologies.

The next section presents a proposed research model outlining all the possible constructs identified from review of the literature that may be relevant to the South African context.

1.6 Research methods and analysis

For this study to achieve its intended goal which was the investigation and validation of a model to be used for formulation of planning considerations for smart meter implementation in South Africa, a quantitative research approach was used (as discussed in Chapter 4). Evaluation of the proposed measurement and structural models was conducted using structural equation modelling (SEM) (as discussed in Chapters 5, 6 and 7 respectively).

In brief, a three-phase research strategy was employed in order to investigate, create and evaluate the model and recommend planning considerations in the implementation of smart meters in South Africa.

Firstly, an extensive literature survey and synthesis (as discussed in Chapters 2 and 3) was conducted in order to identify the relevant technology acceptance models and theories applicable to this research investigation. Models and theories such as the theory of reasoned action (TRA), the Theory of Planned Behavior (TPB), the Technology Acceptance Model (TAM), Privacy Calculus Theory (PCT) and the Unified Theory of Technology Acceptance and Use of Technology (UTAUT) were among those that were considered. At least one of these models was identified as a research framework for this study (Chapter 3). The research model was established in order to assist in identification of the most relevant factors to be considered in this study. Apart from the model selected to support the fundamental research framework, other models and theories were examined to identify supplementary factors that were used to enrich development of the proposed model. Based on the factors identified, research model also assisted in the formulation of a measurable latent variable in the measurement model development.

The sample population for this study was limited to South African residential electricity consumers. Since the target population for this study was approximately 31 million consumers, it was, therefore, important to use quantitative sampling strategies that could accommodate the time and financial resources that were available to the researcher as it was not possible to get responses from all the potential participants (populace of the country). Chapter 4 provides more detail about the sampling methods used and the applicable sample size targeted (Hair, Black, Babin & Anderson, 2010; Krejcier & Morgan, 1970).

In the second phase of the study, the structural equation model was employed to develop a measurement model in order to quantitatively test if the constructs (factors) identified through the literature review and the models mentioned above were valid constructs. Consistent with the approach taken by other researchers in technology acceptance studies and following SEM statistical rules of thumb (Hair, Black, Babin & Anderson, 2010), a minimum of three or four items per construct was deemed the bare minimal for SEM based analyses. A self-administered questionnaire was designed to collect the numeric data that was statistically tested. Thereafter, the identified constructs were pre-tested for content and construct validity. The pre-testing was conducted to check on the language level, identify ambiguities and make sure that the measurement instrument was measuring what was intended (Chapter 5). For constructs to considered valid, the measurement model must have achieved the recommended level of construct validity and reliability. Both the construct validity and reliability should achieve standardized factor loading above 0.7, Average Extracted Variance (AVE) of 0.5 or above and internal consistency above 0.7. Chapter 6 provides detailed discussion about the measurement model evaluation.

The third phase of the study involved testing of structural model validity and goodness-of-fit (Chapter 6). The evaluation of the structural model validity was conducted to verify if the data collected represented a true reflection of the population behavior (Chapter 7). Based on the accepted hypotheses, the research drew various conclusions relevant to smart meter consumers. Thereafter, the Business Model Canvas was used to formulate planning guidelines aimed at enhancing consumers smart meter implementation acceptance (Chapter 8). Section 1.7 discusses the scope and delineation of the study.

1.7 Scope and delineation

This research focused on the planning consideration for smart meter implementation in South Africa. The study aimed to identifying the consumer-centric factors that can motivate a high smart meter acceptance within the South African context. Though there are various stakeholders that may be affected or impacted by the outcome of this research, the study focused mainly on residential consumers with South Africa. Other stakeholders, including business and other institutions that use smart meters were not considered and were eliminated from the study scope. The study used literature reviews and technology acceptance models and theories in the identification of the relevant factors. The choice of South Africa as a developing country, allowed for the gain of in-depth knowledge and understanding of smart meter acceptance from an African perspective. This was important, as most of the smart meter studies are more Euro-centric and US-centric and, therefore, potentially not relevant to the African challenges and environment. An attempt to use domain experts to validate the consumer-centric factors is suggested for future studies. Owing to time and resource limitations, the planning consideration guidelines formulated in this research study could not be practically tested to see if they were relevant in motivating smart meter consumers in relation to smart meter implementation. Therefore, the application of the results from this study must be done with caution, thereby, limiting the generalization of the findings to all African countries.

1.8 Limitations of the study

The main aim of this research study was confined to the investigation of the planning consideration for smart meter implementation in South Africa. As such, there were a plethora of macro-issues related to smart meter and smart grid implementation, such as smart meter legislation, revenue collection, electricity theft, cost reduction on installation and maintenance, energy efficiency use, smart meter security and environmental issues that were likely to form exogenous factors. Owing to the restrictions on time and resources they were not considered in this research study. The factors considered for this research investigation were identified from the literature (Chapter 2) and the theories and models (Chapter 3). Although the aim was to come up with planning consideration guidelines for smart meter implementation in South Africa, the recommendation was generalized using Business Model Canvas as the strategic management planning tool. Considering time and resource constraints, this study explored smart metering implementation by electricity service providers such as Eskom and municipalities in places such as the Johannesburg Metropolitan Municipality and the City of Tshwane Metropolitan Municipality with only secondary data analysis from other private companies and municipalities within South Africa.

1.9 Ethical considerations

This study was conducted within the requirements of the ethics committee of the Nelson Mandela Metropolitan University and all applicable bodies. An ethical reference number: ***H17-ENG-ITe-001***, was obtained (Appendix 6: Ethical approval). A signed request letter for permission to conduct research with individuals within the City of Tshwane was obtained (ref: Appendix 7: Approval Letter from City of Tshwane), and other smart metering technology stakeholders was acquired (Appendix 9: Final questionnaire). The companies and institutions were sent request for permission letters (ref Appendix 10: Sample for a Police Station). All the letters asked for consent for data collection. All the consent responders were given full access to the data and the expert knowledge and insights upon request. All the data and information collected from the surveys, interviews, observations and secondary data analysis of databases was treated as confidential and was used only for the purpose for which it was acquired in order to protect the identities of the individuals and companies. The research did not target vulnerable groups therefore there was no need for explicit ethics approval in this regard. Finally, all data collected during the study was treated as confidential.

1.10 Chapter Outline

The research approach is divided into five sections, this section provides a general overview of the information and steps to be covered in this research.

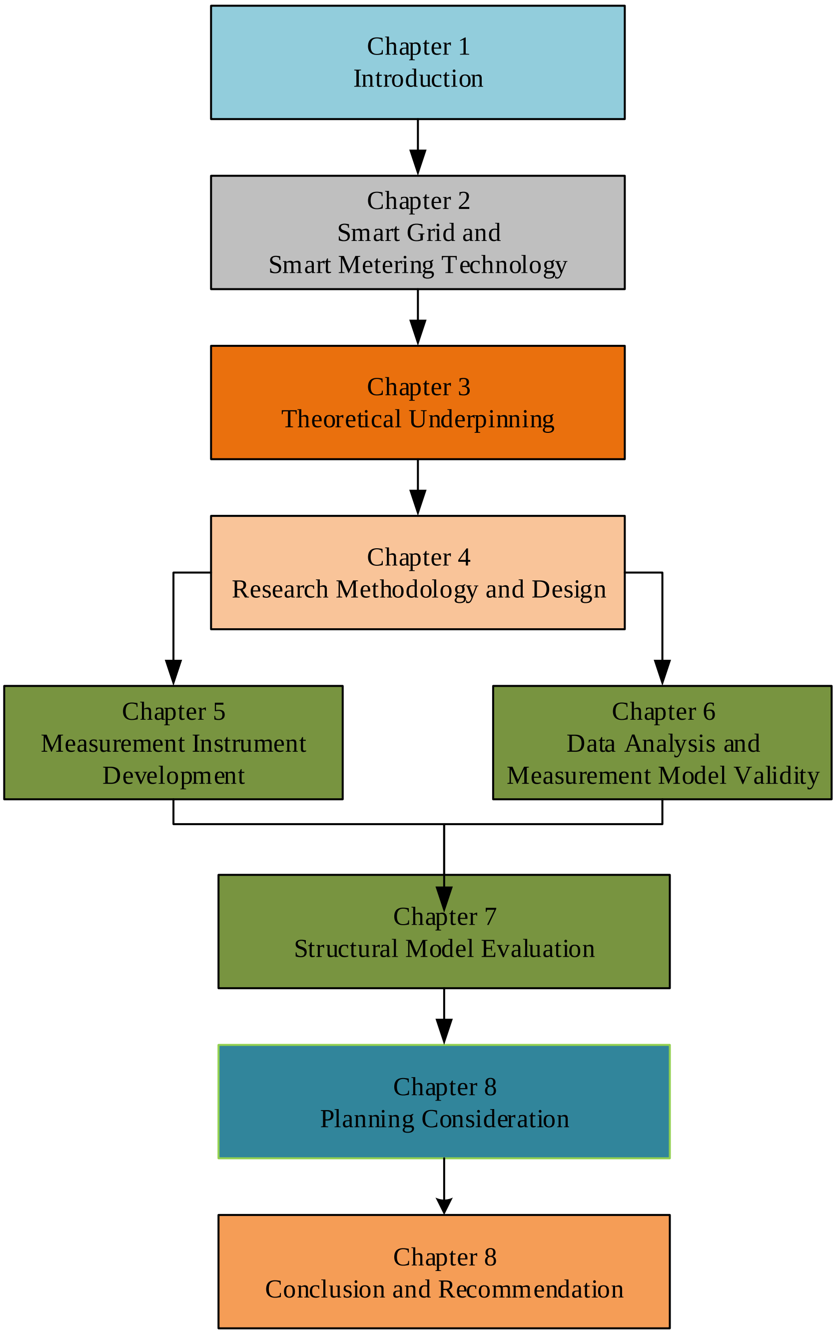


Figure 1.1: Outline of research approach

1.10.1 Section 1: Introduction and background.

A brief introduction to the thesis is provided. Pervasive technology is discussed in the context of smart meter technology implementation planning. The challenges and issues relating to smart meter technology adoption are discussed, focusing on Europe, the United States of America and other countries where smart meter technology has been deployed, or is in the process of deployment to help identify important factors within the context of the study. The research context of this study was South Africa. The research problem, research questions and research objectives under investigation are outlined and the limitations of the research and the contributions to the field of study are communicated. The introduction and background information is contained in Chapters 1 and 2.

1.10.2 Section 2: Theoretical underpinning.

A literature review of the various theories and frameworks that were considered when developing the research framework/model is presented. Since there are no modern models that have been developed to assist identifying the factors that influence technology acceptance on smart meter technology implementation, various behavioral theories and models on technology acceptance are considered and reviewed. The model and theories that were reviewed in order to identify the relevant factors in this research study are the Theory of Reasoned Action (TRA), the Theory of Planned Behavior (TPB), the Technology Acceptance Model (TAM), Privacy Calculus Theory (PCT), the Unified Theory of Acceptance and Use of Technology (UTAUT), and Diffusion of Innovation (DOI).

Detailed discussion of these theories and models is presented in Chapter 3. This process assisted in identifying the most suitable model to be used as the fundamental research framework in this research study. In addition, in cases where the fundamental framework failed to address all the relevant factors for the study, an integration of constructs from other models was considered. The fundamental research framework and the other relevant constructs that influence output of this section are considered.

1.10.3 Section 3: Research process and methodology.

This research study was grounded in the positivism research philosophy, consequently, a quantitative research approach was deemed a suitable scientific inquiry method to uncover the objective, true knowledge. A structural equation modelling technique was employed for this quantitative research process. Therefore, the quantitative data collection method of a questionnaire was used for collecting data for the research study. As mentioned in the previous section, South Africa was the focused population and data was collected mainly in the major metropolitan areas. Chapter 4 briefly discusses how the measurement instrument was designed and developed and assessed for both reliability and consistency using Confirmatory Factor Analysis (CFA) and Co-variance based structural equation model (CB-SEM) to validate the structural model developed.

1.10.4 Section 4: Research, Measurement and Structural Model Evaluation.

This aspect of the thesis deals with the quantitative research techniques, data analysis and findings. The consumer-centric latent variable was identified based on the behavioral intention studies theories outlined in Chapter 3. The six stage structural equation model (SEM) technique was statistically employed to design, develop and evaluate both measurement and structural model. The detailed process is outlined in Chapters 5, 6 and 7.

1.10.5 Section 5: Recommendation and Conclusion.

This section presents a summary of the recommendations based on the findings presented in Chapter 8. The main aim of the chapter is to answer the research question and show how the objectives of this research study were met. It also provides recommendations using the Business Model Canvas (BMC)for technology innovators and policy makers on the implications of consumer-centric factors within the smart meter technology implementation planning in South Africa. Based on the findings, several future research avenues are suggested, and the limitation of the research is also addressed. This section form part of Chapter 9 in this research study.

1.11 Conclusion

In summary, this chapter has provided an overview and related background information for the research work of this study. The research problem section outlined the relevant research gaps and justified the validity of this research in relation to the literature. The research questions and objectives further indicated the significance of this research. In this chapter, the proposed conceptual framework, research methodology and contribution of research was also outlined. Finally, the research ethics and limitation of the study were considered as they set the boundaries in relation to how far this research can extend. A chapter outline concluded the chapter to provide an overview of the structure of the entire research study and of the thesis.

CHAPTER 2:
SMART GRID AND SMART METERING TECHNOLOGY

Opening the 65th Convection of the Association of Municipal Electricity Utilities (AMEU) Southern Africa at Emfuleni Municipality in the Vaal, Minister Van Rooyen said it was important that electricity challenges – from generation to distribution – were looked at with a view to finding better ways to serve customers. – AMEU Report, (2017)

2.1 Introduction

Energy is becoming the "oxygen" and lifeblood of the mass industrialized world and is a critical resource for fostering growth in emerging economies (WEF, 2012). The need to ensure that the increasing electricity demand is met while providing efficiency and security of supply and mitigating the impact of energy generation on climate change remains a global agenda (WEF, 2016). Unfortunately, for many decades, electricity infrastructure has not changed much to adapt to the continual demand for this essential resource. Most components of the traditional electricity grid in various countries are decades old and, consequently, wearing out and failing to meet the requirements of increasing electricity supply, demand, control and monitoring (Manyika et al.2014; Barret et al. 2013). Therefore, utility companies across the world are investing billions of dollars to upgrade and modernize electricity grid infrastructure with smarter technologies to improve its efficiency, reliability, privacy and security, as well as to bring it into the digital age (Schmalensee & Kassakian, 2011). In addition, the need to conserve energy calls for modernization of electricity grid infrastructure, as does harnessing a growing share of electricity supplied from intermittent sources such as wind and solar which has initiated a paradigm shift in the energy domain (Barret et al.2013, 2011; Fan et al.2013).

As part of the modernization of electricity infrastructure, smart meters are currently being deployed in various countries including South Africa. According to Dipleep (2019), smart meter technology is a combination of electric meters and two-way communication technology that will enhance the smart grid with information, monitoring and control capabilities. Fang et al.(2012) and Guo, Bond & Narayanan, (2018) , further suggests that smart grids, utilizing smart meter technology, will modernize existing grids with bidirectional communication and pervasive communication capabilities for smart generation, distribution, management and consumption of electricity. Smart meter technology simplifies the meter reading process for energy utilities and enables new services, flexible tariffs and demand response programs in the context of the smart grid. As the electricity grid becomes “smarter”, it brings in many new data collection, communication and information sharing capabilities related to energy usage, and these technologies in turn introduce new challenges that were not associated with traditional systems. According to Murrill et al.(2012), privacy and security concerns surrounding smart meter technologies arise from the smart meter’s essential functions which include (1) recording near-real time data on consumer electricity usage, (2) transmitting this data to the smart grid using a variety of communications technologies, and (3) receiving communications from the smart grid, such as real-time energy prices or remote commands that can alter a consumer’s electricity usage to facilitate demand.

Murrill et al.(2012) also note that the energy consumption data collected by smart meters contain rich identifiable information about the energy user at a higher frequency than is the case with the traditional system. Without proper protection, real-time or near real-time fine grained metering data may disclose sensitive personal information and expose the energy user to a variety of privacy threats. For example, information about the lifestyle of household occupants can be inferred from high resolution metering data via a nonintrusive appliance load monitoring (NIALM) Murrill et al.(2012) and NIST 7628 Report, (2012). In some cases, privacy sensitive data can be used by third-party companies to profile energy consumption patterns for maximizing revenue or by malicious parties prying on the consumer living pattern and conduct related attacks. Therefore, for the sake of energy customer privacy, personal information and consumption data collected through smart meters should be protected from unauthorized sharing, disclosure, sale and/or storage without consent NIST 7628 Report, (2012).

This chapter starts by defining and describing two key terms, namely ‘smart grid’ and ‘smart meter’, particularly in relation to clarifying their differences. Thereafter, the smart grid adoption drivers that influence utility companies and countries to migrate to smart grid technology will be discussed. This is followed by a comparison of the traditional electricity grid and smart grids and a consideration of their benefits and challenges. Finally, the status of smart meter grids and regulation in South African is discussed as this creates a platform for understanding the issues that can be investigated for planning considerations in relation to smart meter implementation in this country, which is the focus of this research study.

2.2 Smart grids and smart meters

There is often confusion about the terms ‘smart grid’ and ‘smart meter’ and they are consistently used interchangeably. This section provides clarity on the distinction between these two terms by considering various definitions and descriptions of ‘smart grid’ (Table 2.1) and ‘smart meter’ (Table 2.2) and outlining their differences.

Table 2.1: Smart grid definitions

Source	Definitions of Smart Grid
Fang, Misra, Xue & Yang (2012:1)	Smart grid can be regarded as an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable.
Dileep (2019:2591)	“A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it-generators, consumers and those that do both-in order to efficiently deliver sustainable, economic and secure electricity supplies.”
Supriya et al. (2015:529)	A smart grid is referred to as “a modern electric power grid infrastructure for improved efficiency, reliability and safety, with smooth integration of renewable and alternative energy sources, through automated control and modern communications technologies”
Daim, Oliver & Phaal (2018:6)	A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability.
Cuijpers & Koops, 2013:70).	Smart grid is defined as “an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety”
Jenkins, Long, C & Wu (2015:414)	In the article, International Energy Agency describes a smart grid as an electricity network that uses digital and other advanced technologies in monitoring and managing the transportation of electricity from all generation sources to meet the varying end-user demand for electricity. Furthermore, a smart grid can coordinate the needs and capabilities of all generators, grid operators, end users and electricity market stakeholders to operate all parts of the system efficiently, cost-effectively with little impact on the environment at the same time maximizing reliability, resilience and stability of the smart grid.

‘Smart grid’ is a term used to describe an intelligent electricity network system that can control and facilitate various energy sources into one power system (ref Table 2.1 and Table 2.2). Currently there is no single definition of ‘smart grid’ that has been commonly adopted in the smart energy field (Jenkins, et al.2015), and definitions vary between countries, regions, continents and organizations. In order to provide insight and understanding about what constitutes a ‘smart grid’, definitions that were available in the smart energy literature during the time that this research was conducted were presented in Table 2.1.

In order to provide insight and understanding about what constitutes a ‘smart meter’, definitions that were available in the smart energy literature during the time that this research was conducted are presented in Table 2.2.

Table 2.2: Smart meter definitions

Source	Definitions of Smart Meter
Ibhaze et al. (2018:114)	Smart meters are a “type of intelligent electronic device with built in communications capabilities used for power grid measurement”
Edison Energy Institute (2011:7)	Smart meters are defined as” electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems”
Wang et al. 2011	A smart meter is an electricity energy meter that measures consumption of electrical energy and more detailed information compared to a traditional energy meter. The integration of smart meters into smart electricity grids involves implementation of diverse techniques and software, depending on the features that the situation demands.
Sustainable Energy Africa, (2015:2)	A smart meter is referred to as a measurement device that has replaced the traditional mechanical recording mechanism to record electricity usage consumption and communicate between the meter and central systems in near or real-time. The South African Government Gazette, refers to a smart meter as an electricity meter that can allow for: • Measurement of energy consumed on a time interval basis. • Two-way communication between the customer/end-user and the licensee. • Storage of time interval data and remote transfer of it to the licensee. Remote load management.
Atkins (2014)	Describes smart meter is an electric meter that measures energy consumption data over specified intervals, has two-way communications capability, stores metering data in registers, supports a variety of tariffs (e.g. time of use, inclined block, maximum demand, free basic electricity) which can be remotely updated, can switch attached loads on command and interfaces to data concentrators.

Despite the differences in the definitions provided in Table 2.1, it is evident that, in general, a smart grid is described as a system that uses digital technology and smart meters to improve reliability, resilience, flexibility and efficiency to enhance a two-way communication between devices, users and the utility company. Considering all the definitions in Table 2.1, Daim et al.(2018:6) and Cuijpers & Koops (2013:70) were found to provide useful definitions from a customer's perspective, and their definitions make it clear that a smart grid is a network whereas a smart meter is a component of a smart grid. Clarity regarding these key terms is important for enabling understanding and insights about this investigation of planning considerations to enhance adoption of smart meters within the South African context.

Smart grids and smart meters are two technology advancements that have made it possible to transmit real-time data about power transmission (Rausser et al.2018). As a direct consequence of these advancements, energy utilities in Europe and the United States are spending billions on upgrading and modernizing aging components of electrical grids (Toft, 2014). Of the many components available to these utilities, it is the smart meter that connects the utilities with their customers, enabling both to track energy consumption. In Africa, however, owing to the amount of investment required and lack of customer education, implementation of smart meters has experienced some resistance. In contrast, millions of homes already have smart meters installed in Europe and the United States (Supriya et al. 2015 ; Accenture, 2013).

The various smart meter definitions provided in Table 2.2 help to show that smart grids and smart meters are different. Rausser et al. (2018) note that smart meters alone cannot constitute a smart grid but may be referred to as part of a smart grid. In agreement, Daim et al.(2018:6)and Cuijpers & Koops, 2013:70) describe a smart grid as an intelligent network system, while smart meters are referred to as physical electrical devices that are a component of the electricity grid used to record electricity usage information for billing and for communication between the user and utility company in near real-time Sustainable Energy Africa (2015). In addition, the definition provided by Sustainable Energy Africa (2015) states that smart meters are a part of the smart grid that can help better manage electricity concerns in terms of power generation, distribution and demand response.

Smart meter devices are used by utility companies to measure electricity or energy usage and other information relevant to a consumer in order to efficiently and effectively manage consumption. This is made possible with the time of use functionality integrated into smart meters. (Rausser et al. 2018, NIST 7628 report, 2012, Edison Electric Institute, 2011:9). An info graphic that illustrates the distinction between the two terms is provided in Figure 2.2.

2.3 Smart grid adoption drivers

As the demand for better and more efficient energy usage continues to be on the agenda of the World Economic Forum, smart grid adoption seems like the only strategy that can both help to curb the impact of energy generation on climate change and enable countries to reach their economic growth targets (do Amaral et al. 2014).

Table 2.3: Smart grid drivers

Key business drivers in developing countries	**Key business drivers in developed countries**
Reliability	System efficiency
System Efficiency	Renewable energy
Revenue Collection	New products, services and markets
Economic Advantages	Customer choice and participation
Renewable Energy	Reliability
Generation adequacy	Asset utilization

Source: (Nangia et al.2016)

The development of smart grids and integration of smart meters as contributed significantly to the level of automatization of electricity flow from the source to the end users (Dileep, 2019). The current changes taking place on electricity network grids are driven by many factors. These factors or drivers of smart grid adoption are different between developing and developed countries as a consequence of differences in the levels of economic development. (Nangia et al. 2016). A comparison of the key business drivers that are influencing developing and developed countries to implement smart grids and smart meters (IEA, 2015) are shown in Table 2.3. In addition to the drivers presented in Table 2.3, the European Commission has suggested three categories of drivers that are influencing European countries to move to smart grids, namely, internal market, environment and security of supply (Buchholz, Styczynski, Buchholz & Styczynski, 2014; Alejandro, Blair, Bloodgood, Khan,Lawless,Meehan,Tsuji,2014). These three drivers have associated sub-drivers as illustrated in Figure 2.1.

In addition, to the drivers influencing the adoption of smart grids in European communities, technical aspects and policy seem to be the most critical drivers contributing to a move to smart grids in Great Britain (Jenkins, et al.2015). Drivers related to technical aspects include aging electricity grids, operational constraints and reliability of supply whereas policy drivers relate mainly to the legal framework on climate change targets, pollution, competitiveness and other laws that enhance the adoption and implementation of smart grids (Alejandro et al. 2014).

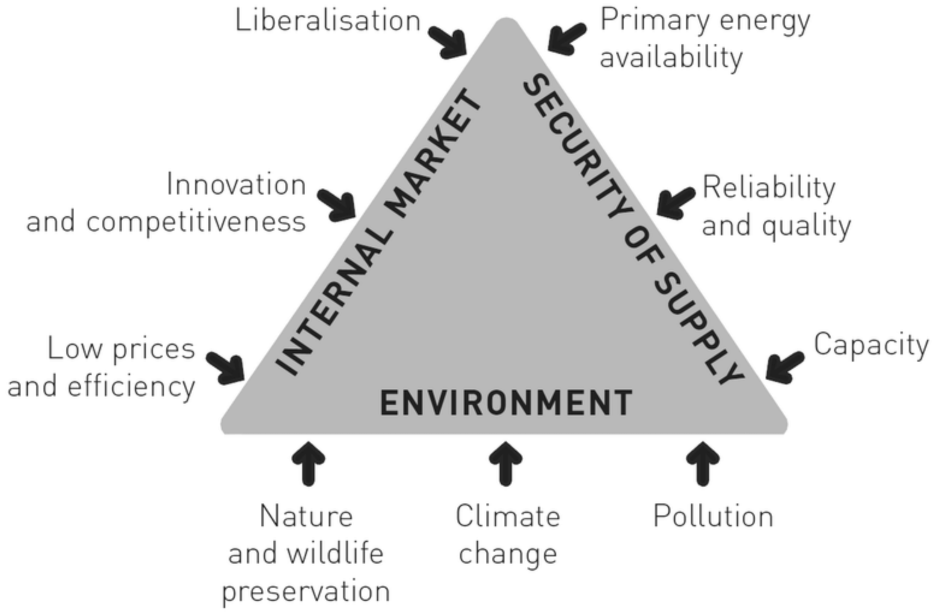


Figure 2.1: Drivers that influence the move to smart grids
(Adapted from Buchholz et al.2014)

The next section provides a review and evaluation of research related to smart grids and smart meters in general.

2.4 Evaluation of smart grid and smart meter research

As considered in Section 2.1, a smart grid is an intelligent electricity network that integrates smart meters to address generation, distribution and demand management of renewable energy resources. It is, therefore, important to identify and evaluate published research related to both smart grid adoption and smart meter integration. A review of the literature on how smart grids and smart meters have been implemented and investigated in various contexts is presented in Table 2.4.

Table 2.4: Published articles on smart meters

Author(s)	Topic	Purpose of study	Significant findings
Jaramillo, Franco and Cordona (2014:221)	Smart meter adoption: recent advances and future trends	This presented a systematic analysis of published literature related to the study of the smart grid from the demand side, it also analyzed the current situation of smart meter adoption and the impact of smart meter penetration in households.	These researchers found that there is no methodology to model and define policies for the entry of a smart grid and smart meters in an electricity system.
Wazeer and Sing Singh, (2018)	Smart Grid	This study investigated and proposed a regional approach to mini/micro grid development that explains the demand for smart grid capability for rural areas in India.	The government of India has not yet demonstrated superior cyber security enforcement, and its standards for security are limited.
do Amaral et al. (2014)	Smart meters as a tool for energy efficiency	This paper introduced the concept of a smart meter and a smart grid, as well as related features, and considered the verified benefits of implementation of these technologies.	There is potential for energy saving when using smart grids and smart meters. There was evidence of better consumption behavior changes in relation to the use of these technologies.
Ponce-Jara et. al (2017)	Smart Grid: Assessment of the past and present in developed and developing countries	This study aimed to compare the success of smart grid power systems in both developed and developing countries. The United States and countries in the European Union were considered developed while India and Brazil were taken to be examples of developing countries.	Developing countries like India and Brazil were found to have numerous challenges such as extreme poverty alleviation, capital investment, power theft and losses and political motivations that slow down the progress of their smart grids. Developing countries are still reliant on technology imports and knowledge from developed countries that further exacerbates their long-term advancement towards smart grid adoption. Developing countries still trying to improve access to electricity, which will require stronger efforts and financial investment.

Author(s)	Topic	Purpose of study	Significant findings
Long et al. (2014)	An Overview of the Smart Grid in Great Britain	This paper provided and overview of the current status of the development of the smart grid in Great Britain.	Currently there is a focus on distribution networks, including real-time flow of information and interaction between suppliers and consumers due to improved ICT, active power flow management and demand management. A transition from a distributed network operator to a distributed service operation is a possible future development for the operation of a smart grid in Great Britain.
Rausser et al. (2018)	Smart meters and household electricity consumption: A case study in Ireland	This study focused on electricity consumption in EU countries and on smart meters that are gaining popularity and being widely used by households and businesses for measuring power consumption and helping to reduce the costs of energy.	Economic benefits have a direct influence on smart meter acceptance. Reduce the cost of smart meters and other related cost in order to improve smart meter adoption.
Liu & Nielsen (2018)	Scalable Prediction-based Online Anomaly Detection for Smart Meter Data	This study proposed a *lambda* system for detecting anomalous consumption patterns, aimed at assisting decision making for smart energy management.	Supports iterative model updates and real-time anomaly detection. Good detection accuracy, and the implemented detection system has good scalability.
Wunderlich et al. (2012)	Examination of the determinants of smart meter adoption: A user perspective.	This study investigated the determinants of smart meter adoption from the user's perspective.	Insights on the role of motivation, incentives, perceived behavioral control and privacy risk in shaping consumers' intentions about adopting sustainable technologies such as smart meter technology. Provides a reference point for future green technology adoption.

The next section outlines smart grid characteristics.

2.5 Smart grid vs. Standard grid

Over the past decades, traditional electricity grids have failed to meet the continual demand for electricity with a reliable and consistent power supply (Saleem et al. 2019). The traditional electricity grid system has mainly been used to transmit electricity generated from a power source by stepping-up the power voltages and then gradually stepping-down the power distributions at consumer premises (Elmabet et al.2013; IEC, 2011). From power generation to power consumption, the flow of electricity and information has been one-way, which has made it difficult for utility companies to detect faults, manage energy wastages, integrate various renewable energy sources and deal with worn-out infrastructure problems while trying to achieve a reliable energy supply and a secure grid (Saleem et al. 2019).

The introduction of smart grids in the early 2000s, was aimed at addressing issues challenging the traditional electricity grid. The smart grids concept, through the integration of information and communication technologies (ICTs), focused on intelligently delivering electricity via smart meters which facilitate two-way communication between the utility company and consumers. The integration of ICTs on the traditional grid was to improve its effectiveness, efficiency, reliability, security, sustainability, stability and scalability (Emmanuel et al. 2018; Abrar et al. 2018). A detailed comparison of the functional differences between the smart grid and traditional grid is presented in Table 2.5 and Figure 2.3 provides an overview of how the flow of information and electricity from a traditional one-way power flow compares to the smart grid two-way flow.

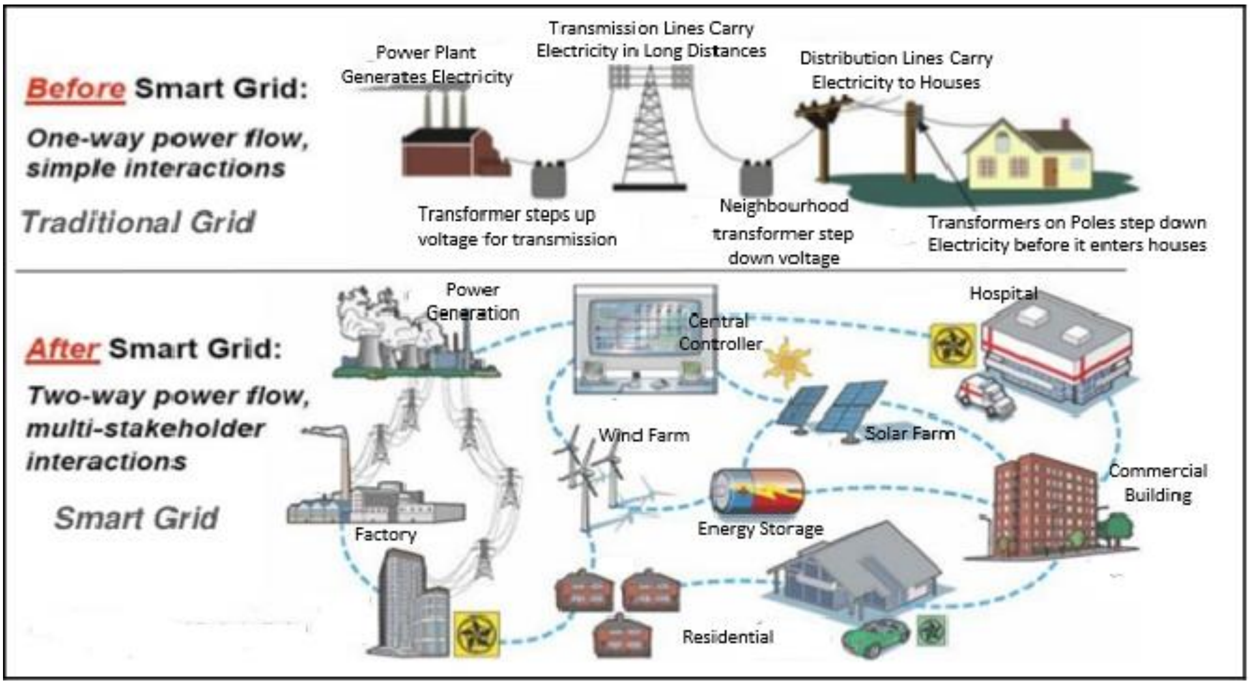


Figure 2.2: A comparison of a Standard Traditional Grid and a Smart Grid (adapted from NIST Standard 2008)

Figure 2.2 shows that the traditional electricity grid only allows power flow to move from a power generation plant, producing only one energy type such as coal generated power or hydro-power through transmission lines that carry electricity for long distances to neighboring transformers that step down the power to be distributed to consumer houses (Saleem et al.2019; Ramezy et al. 2017). These traditional grids cannot manage, monitor and control reliable electricity supply and support information flow feedback from consumers to utility companies efficiently. In addition, traditional grids cannot integrate other renewable energy sources (Abrar et al. 2018). Utility companies using traditional electricity grids have found it difficult to forecast future projected electricity demands as they rely on the monthly manual collection of meter readings which need to be further analyzed for decision making purposes. In contrast, smart grids, with the integration of smart meters and various sensors and communication technologies, enable information and power flow to and from consumers in a near real-time manner that makes it easier for utility companies to collect, manage, monitor and distribute accurate meter readings and billing (Saleem et al.2019, Abrar et al. 2018, Ramezy et al. 2017, NIST Report 7628, 2010).

Based on the discussion above, it is evident that traditional electricity grids differ from smart grids in many ways. Table 2.5 presents the differences in characteristics of the two electricity grids

Table 2.5: A comparison between traditional and smart electricity grids

Characteristic	Traditional grid	Smart grid
Equipment	Electromechanical	Digital control
Information flow	One-way communication	Two-way communication
Communication	Not in real-time	Near real-time
Power Generation	Centralized generation	Distributed generation
Sensors	Few or limited sensors	More sensors throughout the grid
Recovery	Manual	Automatic
Monitoring	Manually monitored	Self-monitoring in real-time
Restoration	Limited	Adaptive and islanding -self-healing
Consumer Preference	Limited choice	Variety of choices
Billing Cycle	Limited to monthly posts	15 minutes intervals
Control Devices and Appliance	Manually	Remotely
Network Grid Topology	Radial	Interconnected network
Environment	High pollution	Low pollution
Consumers	Passive involvement	Active participation
Reliability	Prone to failures and outages	Pro-active, real-time protection and islanding

Source: Adapted from Abrar et al. (2018)

From the consumer's perspective, there are some important functional differences between the two electricity grids. For example, the smart grid provides a two-way communication flow between consumers and the utility company as compared to the one-way communication flow associated with the traditional grid. This smart grid function allows consumers to monitor and change their consumption behaviors and also allows them to use electricity efficiently and save money as compared to the traditional grid where consumers have to wait until month-end to get information about their energy consumption from their monthly bills. Another important aspect of the smart grid is the integration of smart meters through advanced metering infrastructure that is able to detect tampering, electricity theft detection, remote load balancing, accurate billing, fault tolerance capabilities and electricity fault detection and recovery which are all difficult to detect in the traditional grid.

2.6 Communications technologies in a smart grid

As discussed above, smart grid deployment is not aimed at replacing the traditional electricity grid but rather at modernizing the generation, transmission, distribution and utilization of energy. Revamping of the traditional grid includes using new sensing devices, measurement functions and control and automation technologies (Saleem et al.2019; Güngör et al. 2011). Ramezy et al. (2017) put forward that the integration of information and communication technologies into the traditional electricity grid has facilitated a new power generation, transmission and distribution system to maximize the use of various renewable energy sources and add energy efficiency to the smart grid. Hence, in order for the smart grid to achieve its objective, communication technologies become a vital component of the smart grid network (CCST, 2010).

In order to understand how the smart grid has been revamped with the integration of ICTs, Ramezy et al. (2017) put forward their suggested smart grid communication architecture. They have proposed that the smart grid consist of three main layers, namely: an application layer, communication layer or system and power system or control layer. The Figure 2.3 below illustrate the layout.

With reference to Figure 2.3, first the application layer aims to facilitate and enable interoperations among various applications that include demand response management, advanced metering systems, theft and fraud detection and monitoring, and many others service and applications relevant to the smart grid.

Secondly, the communication or system layer is a key component of the smart grid as it enables communication among all the application systems and devices. Telecommunication technologies are used in the communication layer to enable automation of the energy and information flow, intelligent functionalities and reliability. In addition to telecommunication technologies like 3G, GPRS and GSM, ICTs have also offered an alternative communication channel to remotely control and monitor the smart grid.

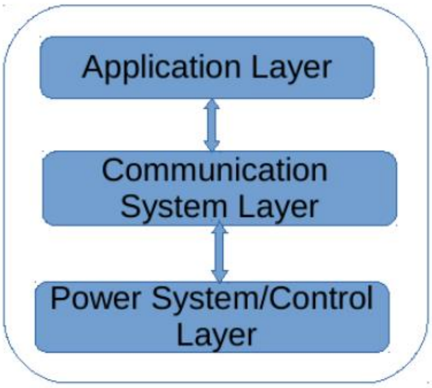


Figure 2.3: Smart grid communication technology (Ramezy et al. 2017)

Secondly, the power system or control layer (Figure 2.4) functions as the most important part of the smart grid as it supports the interaction between power generation, transmission, distribution and utilization by consumers. This layer allows the integration of various energy sources and changes the one-way manual communication system through use of an advanced smart metering system that facilitates a two-way communication interaction between the consumer and the utility company. On principle, the changes effected on the layer affect every stakeholder in the smart grid, for example, changes in the approach to billing will affect consumer participation in an active way.

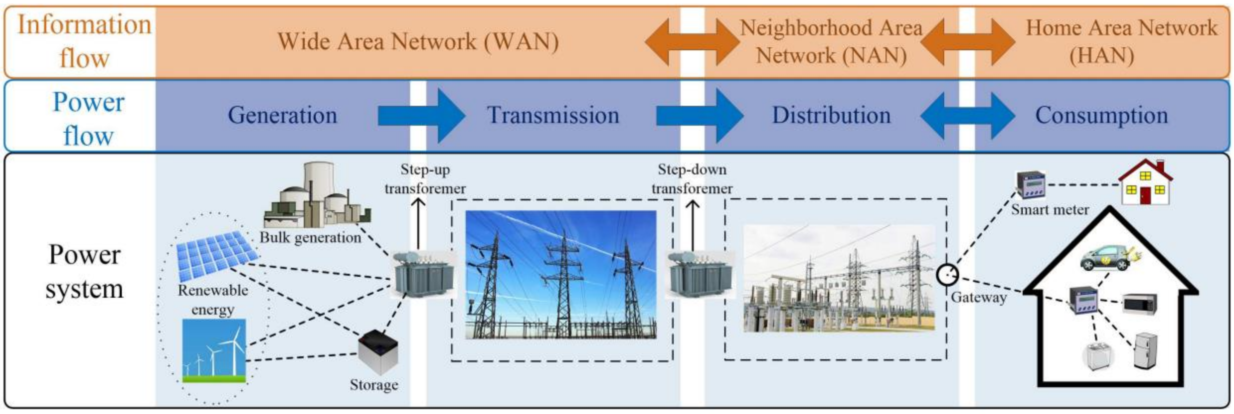


Figure 2.4: The three communication infrastructures of a smart grid (Adapted from Saleem at al. 2019)

As illustrated in Figure 2.4, Saleem et al. (2019) suggest that a smart grid comprises of three communication infrastructures, namely, a wide area network (WAN), a neighborhood area network (NAN) and a home area network (HAN). In their explanation, the HAN manages the communication about the flow of electrical energy and other relevant information between the utility company and the consumers. The installation of HANs in residential and commercial premises enables the connection of home appliances, electric vehicles and renewable energy sources within the home environment to smart meters and, in commercial premises, smart meters are connected to electrical appliance and industrial plants. To facilitate information flow between consumers and utility companies in a smart grid there needs to be connection between two communication platforms, the HAN connected to the smart meter and the utility company data center connected to the smart meter.

The NAN is composed of smart meters that are connected to various HANs. The NAN is responsible for collecting electrical usage data and other relevant information from the HANs and communicating it to utility company data centers. In addition, NANs act as an interface between the distribution and transmission substations in the power distribution network (Figure 2.5).

The third type of area network, the WAN, functions as the backbone for the smart grid communication network gateways and enables ease of interaction between power transmission systems, bulk generation systems, renewable energy sources and control centers. The communication technologies that are applicable to each of the WAN, NAN and HAN are shown in Figure 2.6.

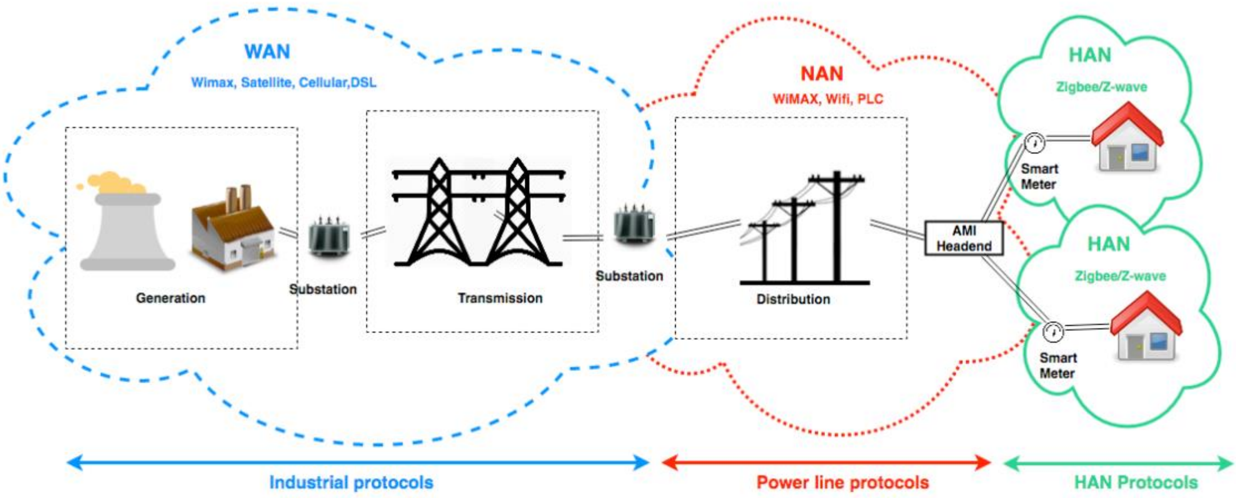


Figure 2.5. Communication technologies included in a smart grid as applicable to the wide area network (WAN), neighborhood area network (NAN) and home area network (HAN): (Adapted from Saleem et al. 2019; Abrar et al. 2018)).

Details about the smart grid WAN, NAN and HAN communication technologies are provided in Table 2.6. Saleem et al. (2019) confirm that communication technologies and networks are important components of smart grids as they are integral to smart grid functions such as controlling, monitoring and reliably managing the utilization of electrical energy. Though both wireless and wired communication technologies can be used to enable smart grids to sustainably and cost effectively manage demand and supply of electricity, Abrar et al. (2018) assert that wireless networks are more cost-effective in supporting smart grid applications than wired networks. According to Abrar et al. (2018), optical fiber, copper cable and power lines are examples of components of wired networks while WiFi, Bluetooth, ZigBee, satellite, WiMAX, and cellular network technologies such as 3G, GSM, and GPRS are technologies used in wireless networks. Details about these wireless communication technologies in relation to their application to facilitate energy and information flow in smart grid network architecture are provided in Table 2.6.

Table 2.6: Wireless communication technologies used within a smart grid

Technology	**Spectrum**	**Data Rate**	**Coverage**	**Application**	**Limitations**
GSM	900- 1900Mhz	Up to 14.4kbps	1-10km	AMI, Demand Response HAN	Low data rates
GPRS	900- 1900Mhz	Up to 170bps	1-10km	AMI, Demand Response HAN	Low data rates
3G	1.92 -99GHz 2.11 -2.17GhZ	Up to 384-2Mbps	1-10km	AMI, Demand Response HAN	Expensive spectrum
WiMAX	2.5Ghz, 3.5Ghz 5.8Ghz	Up to 75mbps	10-150km (LOS) 1- 5km (NLOS)	AMI, Demand Response HAN	Not widespread
PLC	1-30Mhz	2 -3mpbs	1-3km	AMI, Fraud detection	Harsh noise environment
ZigBee	2.4Ghz, 869 – 915Mhz	250kbps	30- 50m	AMI, HAN	Low data rates Limited range

Source: Adapted from Saleem et al. (2019) and Ramezy et al. (2017)

Considering the overview of communication technologies provided in Table 2.6, it is evident that wireless communication networks are the most commonly deployed communication network technologies in smart grid communication. Wireless communication technologies contribute to the success of smart grids, the benefits of which will be considered in the next section.

2.7 Benefits of smart grids

Saleem et al. (2018) suggest that the smart grid has become a promising solution to improve traditional electricity grid functioning, particularly in relation to areas traditionally prone to failure. The adoption of smart grid functionalities has modernized the traditional grid with intelligent monitoring, control and communication capabilities to provide stability, efficiency and reliable supply and management of electricity (Souran et al. 2016; Durand, 2013). Key benefits of smart grid adoption for both utility companies and consumers are detailed in Table 2.7.

Table 2.7: Major smart grid benefits for both utility companies and consumers

Utility Company	Consumers
Improving power reliability and quality	Opportunity to become prosumers (producers and consumers)
Maximizing facility usage and averting construction of back-up (peak load) power plants	Improved quality of power supply
Enhancing capacity and efficiency of existing electrical power networks	User-friendly and transparent interface with utilities
Improving electricity grid resilience and stability	Save money through the use of time of use tariffs
Enabling predictive maintenance and self-healing responses to system disturbances	Opportunity to interact with the electricity markets through home area networks and smart meter connectivity
Facilitating extended deployment of renewable energy resources	Provide opportunity for consumers to purchase energy from clean resources
Accommodating distributed power sources	Allow consumers to be active participants in managing their own consumption
Automating maintenance and operation	
Reducing greenhouse gas emissions by enabling electrical vehicles and new power resources	
Reducing oil consumption by reducing the need for inefficient generation during peak usage periods	
Presenting opportunities to provide better grid security	

Utility Company	Consumers
Enabling new products, services, and markets	
Providing more information to consumers and increasing consumer options	

Source: Adapted from Saleem et al. 2018; Souran et al. 2016

In relation to smart grid benefits, a noteworthy consideration is the cost of energy to the consumer. Seemingly relentless electricity price increments can surely be, at least in part, attributed to the numerous inefficiencies associated with traditional grid infrastructure. Since smart grids will certainly address many of these inefficiencies and bring additional enhancements, it is envisaged that the consequent reduced operational and management costs incurred by utilities will ultimately drive energy costs down for the end consumer (Saleem et al. 2018; Souran et al. 2016).

Despite the many benefits associated with smart grid adoption, there are challenges that need to be considered. These will be discussed in Section 2.8.

2.8 Challenges and issues associated with smart grids

This section discusses barriers that smart grids have introduced in relation to electricity power demand and supply. Various challenges or concerns that impact stakeholders (the utility company and the consumer) are summarized in Table 2.8 and discussed in more detail below.

Table 2.8: Summary of the stakeholder challenges associated with smart grids

Challenge or concern	Impacted stakeholder (utility company or consumer)
High initial cost	Utility company
Security	Consumer
Consumer opposition	Utility company
Health issues	Consumer
Privacy	Consumer

Source: Adapted from Rahman et al. (2013)

For the past decade, the smart grid has shown to be a technological innovation that can provide a sustainable strategy to manage electricity generation, transmission, distribution and utilization, and. if implemented correctly, smart grid benefits outweigh the challenges (Saleem et al.2019; Abrar etal.2018; Abu, Yunus, Majid, Jabar, Aris, Sakidin & Ahmad, (2014). However, there are issues and concerns associated with smart grid implementation. These have been highlighted most vocally by public consumer groups and include the challenges and concerns summarized in Table 2.8 which are discussed below.

High initial cost – The initial costs associated with the adoption of smart grids are quite high. Costs can be lowered using strategies like cost sharing among stakeholders and potential beneficiaries. However, the high initial costs can negatively impact adoption of smart grids by the general populace.

Security – Smart grids are not immune from the cyber security vulnerabilities that exist owing to the need of an online presence. Data of millions of consumers has to be protected and dealing with security risks is one of the areas of smart grid adoption that needs to be prioritized.

Consumer opposition – Acceptance of Smart meter is slowly increasing but generally, concerns about health issues and data privacy have generated the most resistance to smart meter adoption from consumers in both the USA and Europe.

Health issues - There has been overwhelming public resistance to deployment of smart meters in many developed countries owing to the fact that smart meters, which uses wireless technologies in transmitting information between devices, are perceived to expose humans to radio frequency radiation and possible carcinogenic effects similar to those caused by cellphones. Though this perception has contributed to consumer smart meter resistance, scientific studies have established that smart meters operate below radiation levels harmful to human beings (California Council on Science and Technology, 2010). There is, therefore, a need to consider public education of consumers to change this perception, otherwise it might continue impacting the future use of technologies in the same spectrum ranges.

Privacy - Smart meters use advanced metering infrastructure (AMI) that collects consumer consumption data hourly or less while monitoring other relevant services and communicates these data to the utility company with little or no human interaction as compared to the traditional metering system (Abrar et al.2018; Yesudas, 2016; Gungor et al.2013). This has led to consumers feeling unsafe and violated with regard to their personal privacy as smart meters can potentially be used to monitor their absence and presence at home, and what appliances are used and therefore available in their homes. There is also a concern about third party access to personal information without consent. Therefore, there is a need for utility companies to educate consumers about their privacy rights, especially about how data is used, shared and accessed by third party partners. In addition, smart metering policies should be made available to consumers in order to reduce complaints.

Since this research study focuses on adoption of smart metering in South Africa, the next section provides a brief discussion about smart meters and their benefits.

2.9 Smart meters and their benefits

As discussed, in Section 2.1, smart meters are a key component of the smart grid that has helped modernize the traditional electricity grid to achieve sustainable energy efficiency and reliable energy supply. This section briefly discuss what smart meters are and their potential benefits to various stakeholders in the value chain.

Verticale et al. (2017) suggest that smart meters are a vital component of the smart grid system and, therefore, they play an important role in the generation, transmission, distribution and consumption of electrical energy and of information flow. Without the use of smart meters, the recording of electricity consumption and two-way communication between the consumer and the utility company would be difficult to achieve. A smart meter can be defined as an electronic device that is used to measure the physical flow of electrical usage data, record events and automate and transmit information to the utility company for billing and other operations (Verticale et al. 2017; Jaramillo et al. 2014; do Amaral et al. 2014).

Smart meters, through the use of sensors on the smart grid network, collect energy flow, power and voltage measurements at the consumer premises and communicate these data to the utility company. The utility company, in turn, uses such information for managing electricity demand, billing and other customer value-added feedback services. In addition, while communicating feedback to consumers, smart meters can gather data remotely and notify the utility company about power outages and power quality issues in near-real time. These actions are not possible with the use of traditional electronic meters. A combination of smart meters and two-way communication technology between a consumer and the utility company for information monitoring and control is referred to as advanced metering infrastructure (AMI).

Murrill et al. (2012) pointed out that smart meters are the key component of the AMI as they enable the smart grid to facilitate the two-way flow of both information and electricity. In brief, AMI is a two-way communication technology that can provide various functions to the smart grid by integrating sensors, smart meters, monitoring systems software and hardware systems in order to collect and disseminate information between smart meters and utility companies and consumers

(Ramezy et al.2017, do Amaral et al. 2014, Edison Energy Institute, 2011). In addition, the AMI allows for real-time dynamic pricing, collection, storage and analysis of information. Considering the key role of smart meters in solving traditional electricity grid challenges, it is important to identify the benefits that can be realized from implementing smart meters. Table 2.9 lists possible benefits of smart meter implementation.

Some of the benefits associated with the implementation of smart meters presented in Table 2.9 are of particular relevance to this study because South Africa has been challenged by a shortage of electricity owing to theft, poor network management and lack of technical skills in relation to implementing cost saving strategies and power and load management.

These particular issues, in relation to the benefits of smart meter implementation are discussed below in the subsections 2.9.1 to 2.9.4 below.

Table 2.9: Smart meter benefits for both electricity consumers and utility companies

Stakeholder	**Benefits**
Electricity consumers	• Better access to data in order to manage electricity use • More accurate and timely billing • Improved outage restoration • Power quality data
Utility company	• Reduced cost of meter reading • Reduced trips for off-cycle reads • Eliminates handheld meter reading equipment • Reduced call center transactions • Reduced collections, rebilling and connects/disconnects • Early detection of meter tampering and theft • Reduced estimated billing and billing errors • Improved transformer load management • Improved capacitor bank switching • Data for improved efficiency, reliability of service, losses and loading • Improved data for efficient grid system design • Power quality data for the service areas • Reduced costs for collecting load research data

Source: Adapted from Edison Electric Institute (2011) and Abu et al.(2014)

2.9.1 Electricity theft

Electricity theft severely affects genuine customers and utility companies worldwide. According to Louw (2019:), “the non-technical losses (NTL) are quantified as losses, which are incurred because of poor administration, fraud, non-paying customers, and corruption, with the largest component attributed to electricity theft" These non-technical losses are from across all sectors of the economy. The integration of smart meters helps utility companies to detect unauthorized consumption and electricity theft, not only for billing issues but also for improving distribution efficiency, power quality and load balancing. Smart meter monitoring of consumer electricity usage that shows unusual sharp increases might suggest electricity theft.

2.9.2 Distribution network management

Verticale et al. (2017) suggest that smart meters can provide a number of important opportunities for Distribution System Operators (DSOs) to manage and plan low-voltage networks and reduce electricity network losses. Moreover, smart metering data helps to identify more profitable customers to provide optional value- added services. However, this imposes many challenges in collecting, managing and analyzing large quantities of real-time smart metering data.

2.9.3 Appliance scheduling

Smart meters can be used to monitor and control the use of all households' appliances and electric devices including lights, heaters, air conditioners and washing machines. They can be programmed to maintain a schedule for appliance usage that best benefits a particular household in order to achieve cost savings, and/or to work off renewable energy sources and/or storage units. A smart meter could be programmed by the household and/or it can be connected to a central control station at the utility company that directs the smart meter to control the households' appliances based on a preselected schedule for operation (Qayyum et al. 2015)

2.9.4 Power and load management

Smart meters can analyze and control fluctuations in low voltage grids caused by unbalanced load. Information about the load at the customer end and control of the maximum load demand helps utility companies to maintain a flat voltage profile on the power supply and improve system stability. For instance, using the data obtained from the meters, smart inverters can be triggered to compensate reactive energy and voltage drops instantaneously. Moreover, using smart meters, the maximum load demand of a customer during peak load can be controlled.

Despite the benefits outlined above, there are a number of consumer concerns that have significantly negatively impacted the adoption of smart meters (Table 2.10). Of these concerns. health, security and privacy have been identified as major barriers to the adoption of smart meters.

The importance of the consumer concerns outlined in Table 2.10 provides an insight into the factors that might need to be considered in achieving the primary objective of this research study.

Table 2.10: Smart meter consumer concerns

Functionality	Consumer concern	Consumer asset affected
Storage of electricity consumption data	Detection of consumer behavioral living patterns and identification of the appliances used within a consumer premises	Personal privacy Safety and security
Two-way wireless		Data integrity
communication through smart meters	Modification of power flow data due to interception	Data availability and power supply privacy and security
	Exposure to radio frequency waves causing electro- hypersensitivity	Health problems Safety concerns
Time of use tariff	Working consumers unable to benefit from the time of use tariffs owing to inflexible working hours	Comfort Convenience More costly
Remote connection and disconnection of supply	Disconnection errors or activist hacking for social justice	Safety and security Control
Energy export and calculation of net usage	System destabilization due to failure to detect energy injection	Availability of power Safety

Source: Adapted from Yesudas (2016)

The following sections provide a consideration of the status quo of smart meters in South Africa and of current regulation relating to their implementation within the South African context.

2.10 Current smart meter regulations in South Africa

The South African government, through the Department of Energy, published Regulation 773 of the Energy Regulation Act for electricity reticulation services in the Government Gazette of 18 July 2008 which states that all electricity consumers with a monthly electricity consumption of 1,000kWh and above must have a smart meter installed and be billed on a time of use tariff (TOU) by not later than 01 January 2012. If implemented, this regulation would give the utility company or licensee power to remotely control all electrical appliances such as geysers, heating and cooling systems and swimming pools pumps in all households.

For consistence, the Department of Energy defined a smart metering system as an electricity meter that is able to do the following:

- Collect and measure of electrical energy consumed on a time interval basis.
- Enable a two-way communication between the customer and the smart meter service provider.
- Store time interval data and communicate it wirelessly to the smart meter provider.
- Remotely effect power and load balance management.

The intention of Regulation 773 of the Energy Regulation Act for service providers to maintain good electricity quality of supply, stability of the grid and to minimize load shedding and blackouts was not realized. This is because the implementation was not accepted as its requirements seemed unfeasible for South African smart meter service providers like municipalities and the set deadline could not be met by a large majority of the municipalities. Revision of the regulation is yet to be adopted and municipalities are, therefore, still expected to look at technology solutions that address both load management and revenue collection challenges, although how this is to be done remains unspecified.

2.11 Status of smart metering in South Africa

Although smart metering is in its infancy in South Africa, municipalities are increasingly focusing on customer satisfaction, revenue collection, reliability, energy efficiency and cost savings. As a strategic response, there are municipalities that are turning to smart metering, although this is not happening at a large scale. Municipalities implementing smart metering pilot projects include the City Power Smart metering project in the City of Johannesburg, the City of Tshwane, and the Nelson Mandela Bay area (Sustainable Energy Africa, 2015).

The national energy utility Eskom, as well as the South African National Energy Development Institute (SANEDI) have piloted smart metering. The success of pilot smart metering rollouts has been mixed, which is unsurprising given the level of complexity involved in such programmes. Municipalities risk not realizing the expected benefits from smart meter projects through being held back by project planning and implementation issues. In order to develop planning considerations for implementation of smart meters within the South African context, which is the purpose of this research study, the various benefits of smart meter implementation have been considered. Most of the benefits considered, however, are Europe and America centric and hence may not be perfectly fit South Africa’s geo-economics and political landscape.

2.12 Conclusion

McKinsey (2019) notes that total energy consumption grew by 2.3 percent in 2018, solely driven by rapid economic growth and increased demand for heating and cooling. In the growth projection, electricity consumption is projected to be double by 2050 and renewable energy sources are projected to make up 50 percent of the energy generated by 2035. Alongside the increasing demand for energy are the aging electricity grids that need to be upgraded and modernized. In addition, the heavy dependence of countries on fossil fuels for their electricity generation will not be changing in the near future. Therefore, in order for countries to meet increasing energy demands, they will be forced to build more coal, natural gas and/or nuclear power stations. The environmental impact of energy generation is well documented in the literature and includes the effects of increased carbon emission (estimated to rise by 59 percent by 2030) and radioactive waste. In order to counter environmental impacts such as these, adoption of smart grid systems becomes a solution for creating smarter ways to efficiently and effectively manage energy usage. Smart grids are groups of technologies, standards and practices, that, when correctly implemented, provide an innovative and reliable power grid that efficiently uses the energy being generated. Park et al. (2017) found that the deployment of smart grids changed consumer roles in the electricity grid system as smart grids allow electricity consumers to move from being passive consumers to active stakeholders in the electricity value chain, with a role in making decisions about how their data is being used. Gone are the days where consumers would simply receive monthly bills for their energy consumption and pay. The deployment of smart grids allows electricity consumers to become active stakeholders whose roles are expanding. As smart grid technologies are developed and diffused, consumers become active prosumers (producers and consumers) and are able to receive and send information to their utility company and get feedback within a matter of minutes or hours as compared to the slow transfer of information associated with traditional manual systems. Consumer market participation has increased through demand response, renewable energy production and electric vehicle to grid as smart grids are deployed. With an increase in demand for efficient management of electricity in South Africa, the impact of regulation, policy, education and skills development becomes vital to the successful implementation of a smart grid. Currently, as smart meter deployment in South Africa is in its infancy stages, the need to understand benefits and barriers to adoption becomes critical to planning consideration for smart meter implementation. The next chapter will investigate various behavioral intention consumer-centric factors that impact on the adoption of smart meters within developing country like South Africa.

CHAPTER 3:
THEORETICAL UNDERPINNING

To get the bad customs of a country changed and new ones, though better, introduced, it is necessary first to remove the prejudices of the people, enlighten their ignorance, and convince them that their interests will be promoted by the proposed changes; and this is not the work of a day.

Benjamin Franklin (1781)

3.1 Introduction

As technology innovations continue to develop faster than the human rate of adoption, there is a need to create business models that are responsive to consumer-centric perceptions about technology adoption. Gone are the days when consumers occupied a peripheral position in the decision to adopt technological innovations that impact their day-to-day lives. In the past, organizations and companies have often advanced technological applications that were opportunistic and neglected the consumer-centric factors which later affect the rate of adoption, or even lead to resistance to new technological innovations. Governments are injecting huge sums of money into introducing technologies which are intended to impact positively on citizens, but the lack of proper diffusion mechanisms and understanding of determinants of technology acceptance results in citizens being reluctant to adopt new technologies to the expected levels. Therefore, a major challenge of many governments, organizations and companies is how to increase the rate of diffusion of a new technological innovation without neglecting the consumer-centric factors.

In light of the low rates of adoption of new technologies, this chapter provides an extensive review and synthesis of literature that is aimed at discovering theoretical underpinning of the consumer's attitude and behavioral intention towards technology acceptance. Since smart meter technology modelling, implementation planning and acceptance is still in its infancy in the electricity industry, this study relied on extant technology acceptance models and theories in explaining the consumer adoption of smart meter technology. The first section of the chapter presents the various technology models and theories that have been used to explain technology acceptance. Thereafter, a justification of the choice of the TAM as the research framework for this study will be provided. Since the TAM was developed over 30 years ago, a complete reliance on it to explain consumer-centric factors of smart meter technology acceptance in the 21st century might not be adequate. Hence, the second section presents other consumer-centric factors from other models and theories to assist understanding and explain the decision to accept smart meter technology. It is evident in the literature that technology acceptance is not limited to technical aspects such as perceived ease of use and usefulness as proposed in the TAM because there are now more complex evolving processes that might relate to a user's attitude and personality. In light of this, trust in technology, facilitating conditions, perceived value, monetary cost, privacy risks and social norms were identified as relevant in explaining consumer-centric factors influencing the acceptance of smart meter technology implementation and were integrated into the TAM and then presented in the proposed research model for this study.

3.2 Technology acceptance and behavioral theories

The need to understand user acceptance factors that are critical in the adoption and acceptance of new and future technologies is important if businesses and governments expect high levels of acceptance for the millions of dollars invested in smart technology projects. Otherwise, their huge capital investment will end up not realizing the benefits intended owing to a very low rate of adoption and leading to a low return on investment (ROI) (Dillon & Morris, 1996). Hence, over the past 60 years, practitioners and academia from various disciplines have been interested in comprehending organizational and individual factors that drive a user's decision to accept or reject a technology (Taherdoost, 2018; Sharma & Mishra, 2014). Apart from the research interest that user technology acceptance has generated over the past decades, Taherdoost (2018) posits that technology acceptance can be seen as a function of user involvement in information system development. Therefore, technology innovators, policy makers and other decision makers are obligated to consider the issues that influence a user's decision to accept and use a specific technology in order to take them into account during technology design and development stages. Since technology acceptance and use has some degree of fuzziness between what the consumer's actual usage will be in relation to what has been planned, technology acceptance theories and models assist in reducing the deviation by modelling user acceptance for the purpose of predicting future usage (Dillion & Morris, 1996).

A review of the literature shows that technology acceptance is an extensively researched area in the information system domain (Taherdoost, 2018, Lai, 2017, Sharma & Mishra, 2014, Dillon & Morris, 1996). Nonetheless, understanding user behaviors has always been one of the most difficult areas in relation to information systems (Silva & Dias, 2007). In the past, researchers have investigated a variety of issues related to user acceptance and adoption ranging from user characteristics to internal beliefs and their impact on user behaviors (Davis et al. 1989). However, understanding human behavior and attitudes in the rapidly changing smart technology space makes it even more challenging and more interesting to practitioners and academia to investigate technology acceptance and its related issues. As such, behavioral studies then shift the research focus from technical requirements of information systems/technology to the need to comprehend user behavior in relation to use of the system (Gu et al. 2009).

3.3 Interchangeable terms and definitions: Diffusion, adoption and acceptance

In light of the literature about behavioral and technology acceptance studies, most researchers have used the terms: *diffusion* and *adoption* and *adoption* and *acceptance* interchangeably (Lai, 2017, Sharma & Mishra, 2014, Renaud & van Biljon, 2008), even though they are different in meaning. Distinguishing between the three terms is important since this research study focuses on developing a predictive model that incorporates consumer-centric factors in the acceptance of smart meter technology within the South African context. Also, the correct use of these terms' aids understanding of the limitations of this research study in relation to the models that are applicable in formulating the research study predictive model.

An adaptation of the information technology (IT) implementation stages used by Kaldi et al.(2008) in their investigation of knowledge management systems adoption in organizations is used to aid clarification of these terms (Figure 3.1).

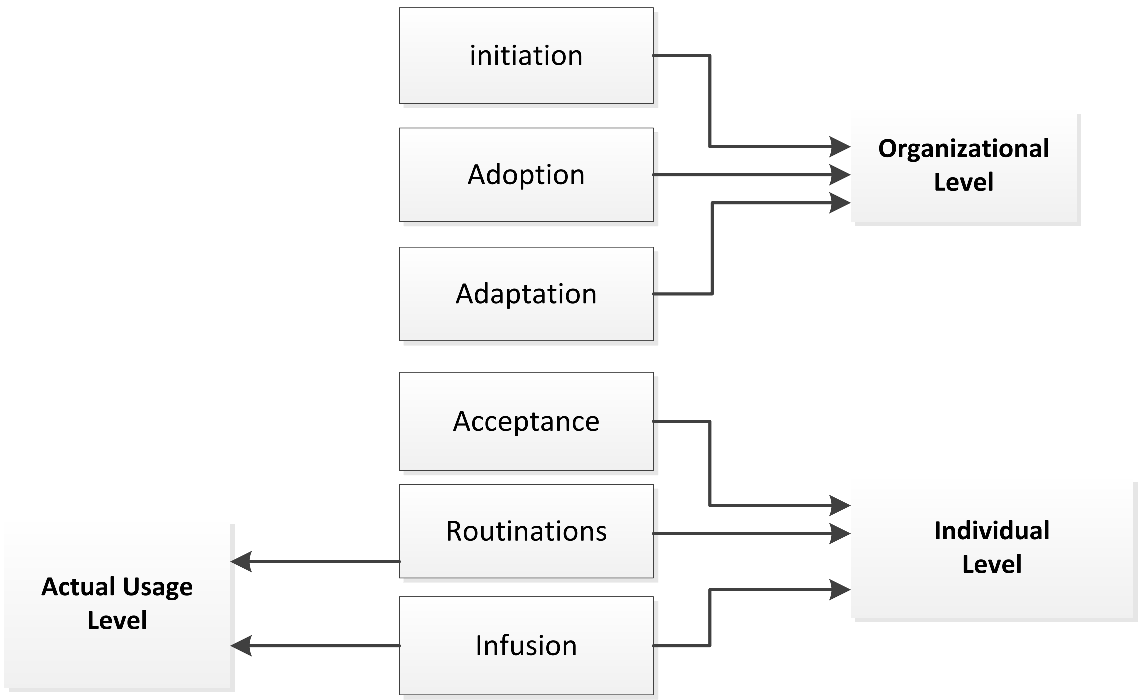


Figure 3.1: Information technology implementation stages: (Adapted Kaldi et al. (2008))

The IT implementation stages diagram in Figure 3.1 shows the stages through which each of the terms is practically applied in the diffusion of a technology within a particular social system. In line with this, Kaur & Kaur (2010), suggest that initiated new ideas are termed innovations only once they have been adopted in a particular social system. Thereafter, the innovation idea is tested commercially, and then adoption and acceptance of the technology by targeted users subsequently leads to diffusion and infusion of that technology into the social system. As such, the acceptance of innovations is intended to improve and make things easier for individuals or organizations of a particular social system.

3.3.1 Adoption and diffusion

Sharma & Mishra (2014) define *adopting* as a stage of selection of a technology for use by an individual or organization while *diffusion* is referred to as a stage during which technology spreads to general use and application. They further suggest that adopting happens at an individual or organizational level whereas diffusion happens at the global level of a social system. In agreement, Kaur & Kaur (2010) point out that adopting and diffusion are two important aspects to consider as they provide insight about how individuals or organizations perceive the innovation, their behavior towards it and their intention to use it. They inherently refer to adoption as a series of evaluations causing the consumer perceptions of the technology to change until the decision to adopt or reject is reached. In contrast, diffusion refers to the process of spreading the innovation across the social system (Bisandu et al. 2019). In relation to the IT implementation stages (Figure 3.1), Kaldi et al.(2008) define adoption as the process of exploration, research, deliberation and decision-making by an organization when considering and intending to introduce a new information system. From the definitions given above, it is evident that diffusion of technology has to do with spreading of technology to individual and organizations within the population whereas adopting is the stage where an individual or organization makes a decision to accept or reject an innovation during its diffusion. In concurrence, Sharma & Mishra (2014) posit that adoption at both individual and organizational level can lead to diffusion of technology to the ultimate users.

3.3.2 Adoption and acceptance

As with the term’s adoption and diffusion, it is important to distinguish between *adoption* and *acceptance* as many researchers confuse the use and application of these two terms and associated concepts. As discussed above, Kaldi et al.(2008), in the context of knowledge management in organizations, provides a distinction between the two terms and defines adoption as a stage of technology diffusion where an organization or individual decides to select a technology for use, while acceptance is defined as the “changes in the individual attitude, perceptions and actions that later lead them to try new practices, activities or innovations which are different from their normal routines or behaviors". Similarly, Reaund and van Biljon (2008) refer to technology adoption as the series of processes starting from individual awareness of the technology to embracing and eventually using the technology. In contrast, acceptance is considered to refer to an attitude towards a technology that can be influenced by various factors. Dillon & Morris (1996) define acceptance in a similar way, that is, user acceptance is a willingness to use information technology to accomplish the function it has been designed to support. In general, Taherdoost (2018), defines acceptance as a positive decision to use a technology.

The discussion above has provided a general understanding of these often interchangeably used terms, while at the same time helping to explain an important boundary of this research study. This study focused on technology acceptance, not on technology adoption since it aimed to develop a predicative model that incorporates consumer-centric attitudes and intentions towards the implementation of smart meters in the South African context. As such, this study focused on the positive changes in attitudes, perceptions and actions towards the use of technology (technology acceptance, as defined by Kaldi et al. (2008)) rather than on technology adoption concepts that refer to the selection of technology for use by individuals and/or organizations. A key outcome of the study was to provide objective insight to decision makers in the smart meter technology domain about how fast electricity consumers can be expected to accept smart meter technology where acceptance rate depends on consumer internal and external beliefs such as usefulness, perceived ease of use, attitude, trust, privacy risk, monetary cost, perceived value, social norms and facilitating conditions.

There are currently no specific technology acceptance models and theories available to explain the behavioral intention to accept smart meter technology, consequently, a number of technology acceptance and adoption models and theories (Figure 3.2) were considered for the purposes of this study, as follows: the Diffusion of Innovation Theory (DOI) (Rogers, 1960), the Domestication of Technology (DoT) (Silverstone & Haddon, 1996), the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1975), the Theory of Planned Behavior (TPB) (Ajzen, 1985, 1991), the Technology Acceptance Model (TAM) (Davis, 1989), the Privacy Calculus Theory (PCT) (Dinev & Hart, 2006) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). An extensive review and synthesis of these technology acceptance and adoption models and theories is provided below. Technology adopting models are discussed in Section 3.3 and technology acceptance models in Section 3.4.

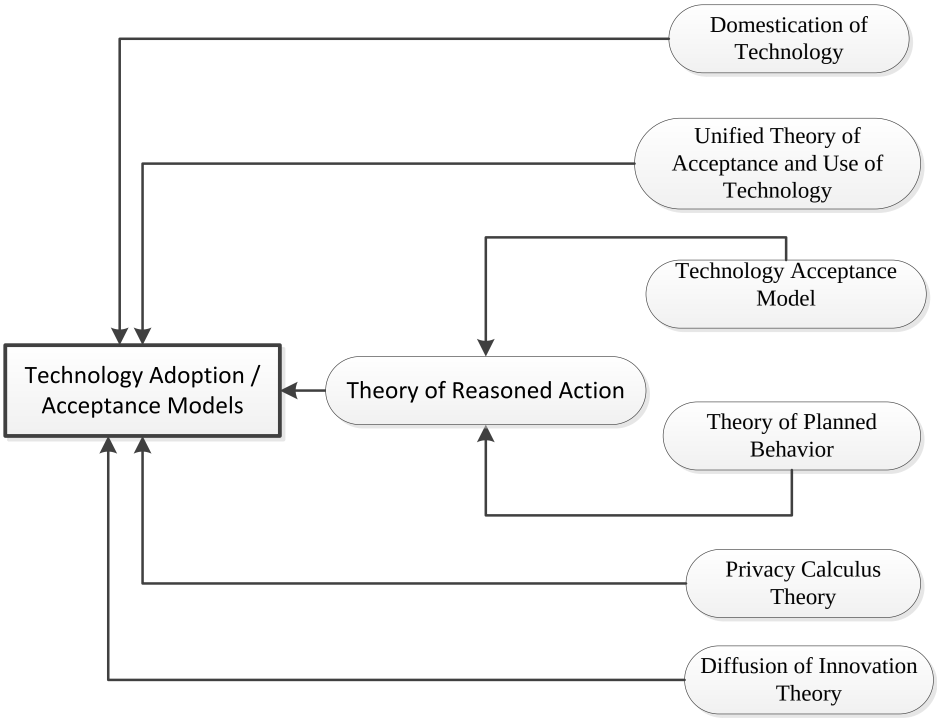


Figure 3.2: Technology adoption/acceptance models (Adapted from Taherdoost, (2018))

3.4 Technology adoption models

Technology adoption models relevant to smart meter technology are discussed in this section. As illustrated in Figure 3.3, there are two models that can be used to explain the smart meter technology diffusion process within the South African context, namely the Diffusion of Innovation Theory and the Domestication of Technology (Taherdoost, 2018, Lai, 2017, Sharma & Mishra, 2014, Renaud & Biljon, 2008).

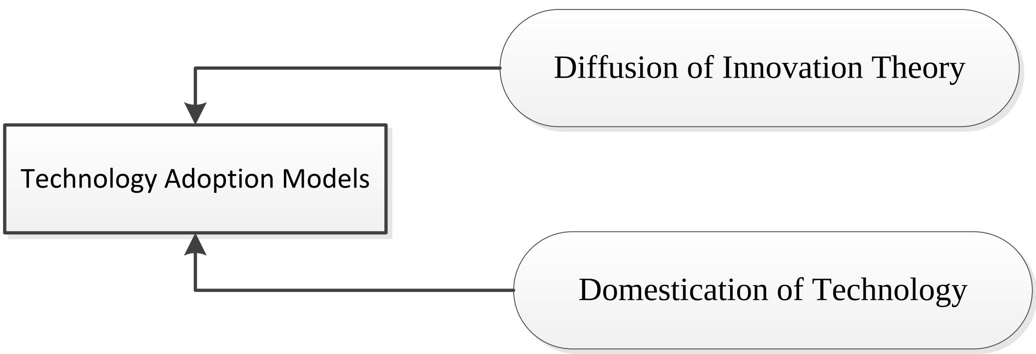


Figure 3.3: Technology adoption models (Adapted from Taherdoost, 2018)

3.4.1 Diffusion of Innovation Theory (DOI)

Wani & Ali (2015) suggest that the DOI was initially introduced by Rogers in 1960, and later modified in 1995. Lai, (2017) further suggests that the DOI was introduced to provide a foundation on which research on technology acceptance and adoption can be conducted. The DOI was developed to examine and explain the factors that influence the spread of new ideas and technologies among members of social systems (Taherdoost, 2018; Lai, 2017; Agag & El-Masry, 2016). Taherdoost (2018) in agreement with Rogers (1962), point out that innovation, communication channels, time and social system are the major factors that significantly influence the spread of a new ideas which can later be adopted or rejected. Though the DOI does not focus specifically on information and communication technologies, it provides a platform to discuss technology adoption or acceptance at both individual and organizational levels (Rogers, 1995), and at global levels (Taherdoost, 2018; Dearing & Cox, 2018; Dillon & Morris, 1996).

Sharma & Mishra (2014), in their review of technology adoption models, suggest that the diffusion of innovation process takes place through various communication channels among members of a group over a period of time and consists of five fundamental stages, namely, knowledge, persuasion, decision, implementation and confirmation. In a review article about technology adoption and acceptance models and theories, Taherdoost (2018) posits that the DOI has three components: the characteristics of the adopter, the characteristics of the innovation and the innovation decision process. In line with most researchers, Kaur & Kaur (2010) and Lai, (2017) further emphasize that the decision to adopt or reject an innovation passes through the five stage process referred to above, moving from knowledge about the innovation that is informed by socio-economic characteristics and that informs attitudes and perceptions towards the new idea, to a decision to adopt or reject the new innovation, to implementation of the idea and, finally, confirmation of acceptance or rejection the new idea (Figure 3.4).

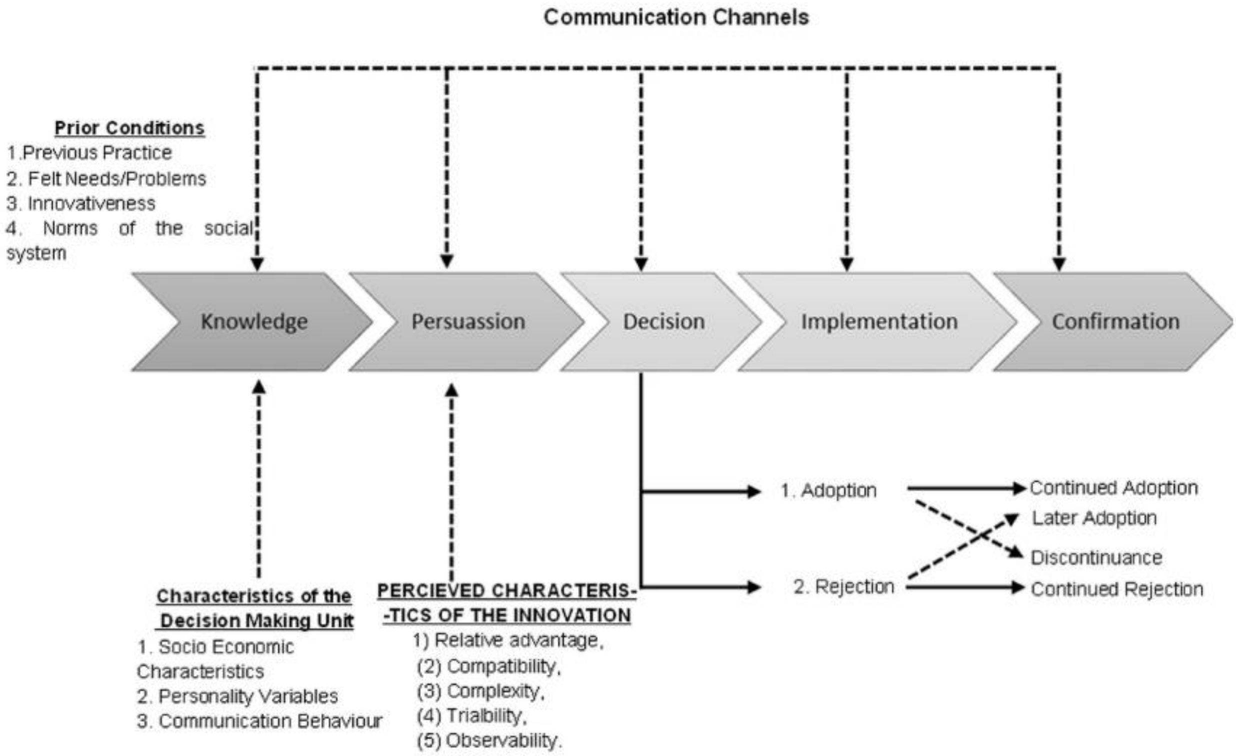


Figure 3.4: The characteristic stages of the Diffusion of Innovation Theory (Adapted from Sharma & Mishra, (2014))

While Sharma and Mishra (2014) have characterized the stages in the innovation adoption process, Kaur and Kaur (2010) have classified innovation adopters into five categories, namely, innovators, early adopters, early majority, late majority and laggards. A brief explanation of the characteristics of each of the adopter categories identified by Kaur and Kaur (2010) is provided in Table 3.1.

Based on the percentage of the likelihood of adoption (Table 3.1), Taherdoost, (2018) and Kaur & Kaur, (2010) suggest that the rate of adoption follows an S-shaped curve (Figure 3.5). The lower part of the curve reflects an initial slow spread of the innovation. The rate of diffusion increases as more people adopt the innovation which spreads exponentially until it reaches a peak-point and thereafter spreads constantly. Kaur and Kaur (2010) suggest that adoption of the innovation eventually reaches saturation when all members who intended to adopt the new idea have adopted it.

Table 3.1: Characteristics of innovation adopter categories as identified by Kaur and Kaur (2010)

Category	Characteristic	Percentage likely to adopt the innovation
Innovators	Venturesome:	
	Individuals that are likely to try new ideas	2.5%
	Acceptable if the risk is high	
	Communicate easily with other innovators	
Early Adopters	Respect:	
	Individuals that are more integrated into the social system	13.5%
	Key leaders within the social system	
	May be referred to as role models in society	
	The individuals to check with before adopting a new idea	
Early Majority	Deliberate:	
	Individuals who can easily adopt new ideas earlier than normal	34%
	Not influential members of the social system but usually are cautious and calculative before adopting any new idea	
Later Majority	Skeptical:	
	Individuals that usually take time to adopt a new innovation	34%
	Adoption of a new idea may be due to social influence or economic necessity	
	The decision to adopt is made with care	
Laggards	Traditional:	
	Conservative individuals who usually are the last to adopt a new idea	16%
	They are always doubtful and distrusting of new innovations	

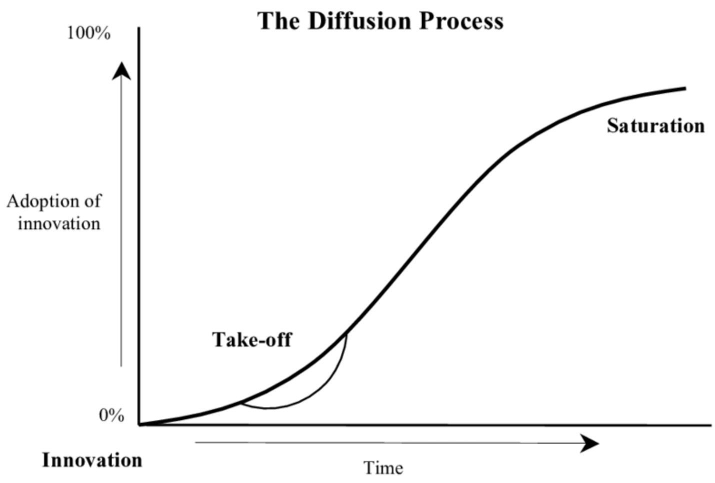


Figure 3.5: S-shaped curve of adoption (Adapted from Gaillard & Ferreira, (2009))

Irrespective of the adopter's characteristics, as outlined above, the characteristics of an innovation have significant impact on the rate of adoption by members of a social system (Wani & Al, 2015; Kaur & Kaur, 2010). Hence, Wani & Ali (2015) emphatically suggest that an individual's decision to adopt or reject an innovation is subject to their perceptions about the innovation. Rogers (1995) identified five characteristic of an innovation that can influence a potential adopter's perceptions and hence influence the adoption of the innovation. These characteristics are: (1) relative advantage, (2) compatibility (3) complexity (4) observability and (5) trialability. Wani & Ali (2015) posit that these five attributes of innovation can determine 49 to 87 percent of variation in the adoption of a new innovation.

In addition to the five characteristics of innovation put forward by Rogers (1995), other researchers have added cost, communicability and divisibility, profitability, social approval, image and trust to the list (Wani & Ali, 2015). Furthermore, found out that although these additional characteristics or attributes were initially viewed as new, there is a view that communicability is similar to observability while divisibility is similar to trialability.

As much as the DOI provides a foundation on which research on technology acceptance and adoption can be conducted, it mainly focuses on system characteristics, organization characteristics and environmental issues. Therefore, it is considered to be ineffective in explaining and predicting the adoption or acceptance of technology as compared to other models. It was included in this chapter as a contribution to a comprehensive literature review about technology adoption and acceptance.

Section 3.2.2 discussed the second of the two technology adoption models, the Domestication of Technology.

3.4.2 Domestication of Technology model (DoT)

According to Gieryn (2002), technologies are becoming interwoven into the daily lives of users through continuous exposure and interaction with technological objects. In brief, the initial application of the domestication concept has enabled researchers to understand media technology use in the complex structures of everyday life settings, with attention to interpersonal relationships, social background, changes and continuities, but also in relation to the increasingly complex interconnection between different media, and the convergence of different media technologies and media texts.

Though domestication of technology forms part of technology acceptance models in general, it does not assist in understanding the factors that can influence the attitude and behavioral intention to accept and use smart meter technology.

3.5 Technology acceptance models

This section discusses the technology acceptance models and theories that are most relevant to this study (Figure 3.6). The first of these to be considered is the Theory of Reasoned Action (TRA).

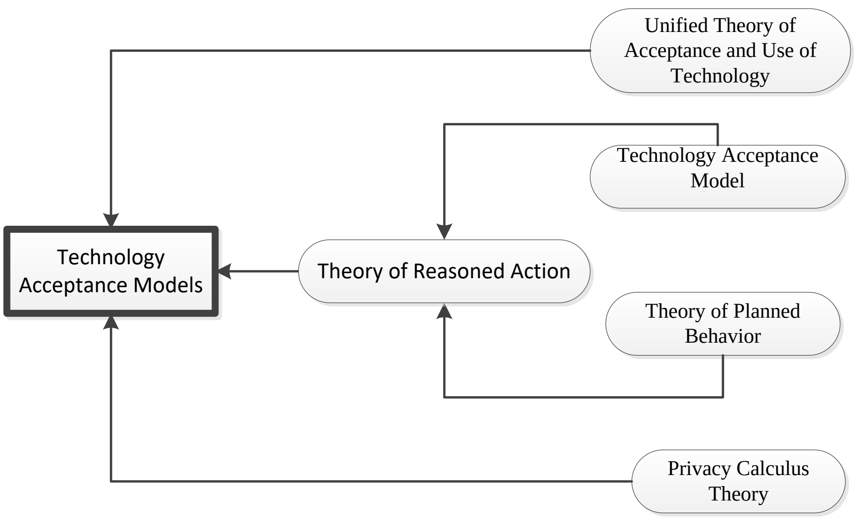


Figure 3.6: Technology acceptance models most relevant to this study (Adapted from Taherdoost, (2018))

3.5.1 Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) is a widely applied model that has been developed for use in the field of social psychology to determine the consciousness in intended related behaviors and effects (Davis, et *al*1989; Ajzen & Fishbein, 1980). According to Ajzen & Fishbein (1980), a person's performance of a specific behavior is determined by his or her behavioral intention (*BI*) to perform the behavior, where the BI is jointly determined by the person's attitude (*Ai*) and subjective norms (*SN*) concerning the particular behavior under inquiry. The BI can also be expressed as a basic algebraic equation, as follows:

$$BI = Ai + SN \qquad (1)$$

Where:

BI = a measurement of strength of an individual's intention to perform a specific behavior

Ai = an individual's positive or negative feelings about performing the target behavior

SN = refers to the individual's perception that most people who are important to him/her think he/she should or should not perform the behavior in question

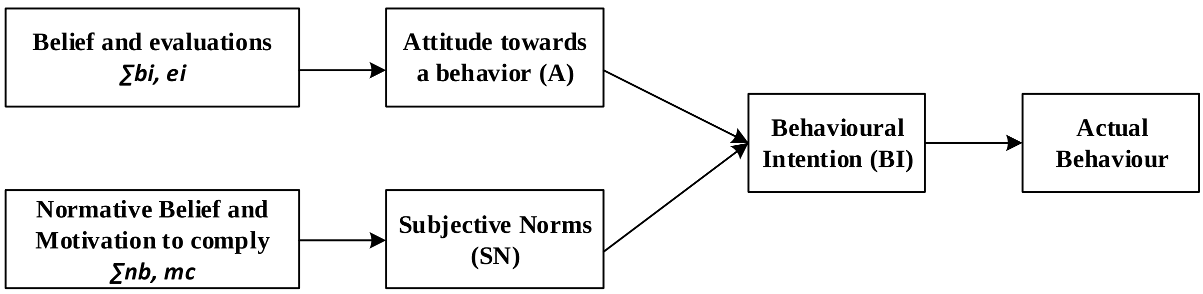


Figure 3.7: The Theory of Reasoned Action (Adapted from Ajzen & Fishbein, (1980))

Though the two major constructs of the TRA are attitude and subjective norm, there are other factors that directly affect them (Figure 3.7). According to the TRA model, a person's attitude towards a behavior is governed by his/her salient beliefs (*b*) and evaluation (*e*) of the consequences of performing the behavior, whereas an individual's subjective norms are determined by the function of normative beliefs (*nb*) and motivation to comply (*mc*) with perceived expectations of a specific referent individual or group. After considering the above factors that directly affect personal attitude and subjective norms, the basic algebraic equation that describes the TRA model can now be expressed as:

$$BI = \sum b,e + \sum nb,mc \qquad (2)$$

3.5.2 Theory of Planned Behavior (TPB)

The Theory of Planned Behavior (TPB) can be expressed as an extension of the TRA; it was designed to predict an individual's intention to engage in a particular behavior at a specific time and place. Ajzen & Fishbein (1991) posit that individual behavior is driven by behavioral intentions, where behavioral intentions are a function of three determinants: (1) a person's attitude, (2) subjective norms and (3) perceived behavioral control (Choen et al. 2012).

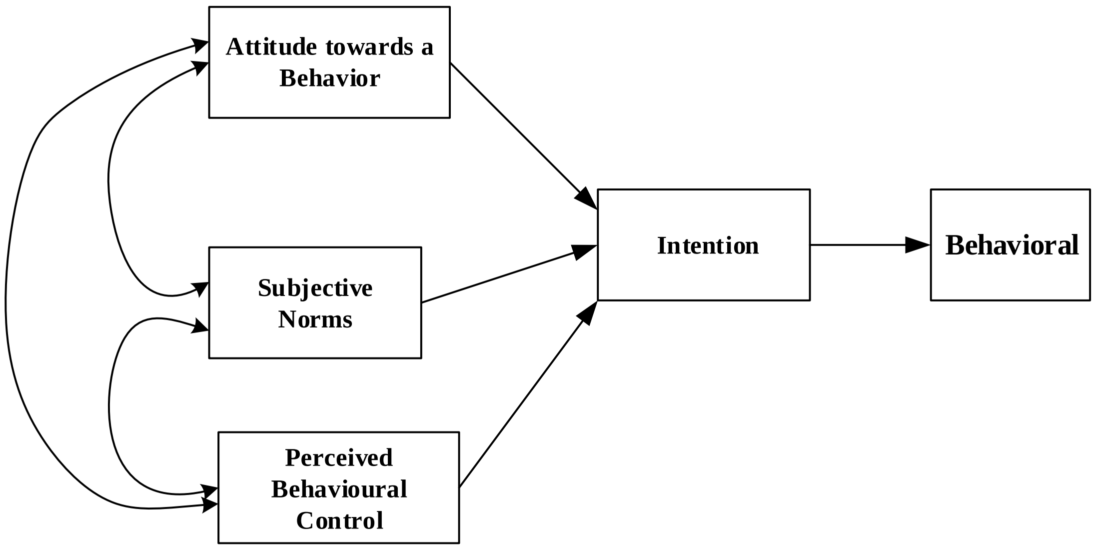


Figure 3.8: The Theory of Planned Behavior model (Adapted from Davis et al. 1989)

In relation to the TRA model, perceived behavioral control (*PBC*) is the only construct that has been added to create the TPB model since a person's attitude and subjective norms will still function the same way. The TPB model can, therefore, be expressed mathematically as an extension to the TRA equation, as indicated below. Perceived behavioral control can be defined as an individual's perception of the difficulty or ease of performing a behavior (Davis & Ajzen, 2002).

$$BI = \left(\sum b,e + \sum nb,mc\right) + PBC \qquad (3)$$

The TPB model (Figure 3.8) can be used to determine individual behavior in various contexts such as adoption of technology, healthcare and politics.

3.5.3 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) is a theoretical model adapted from the TRA and explicitly tailor-made for modeling user technology acceptance and use. This model was developed by Davis in 1986 (Park, 2009; Ajzen & Fishbein, 1980 and Davis, 1989). The initial purpose of TAM was to provide a basis for tracing the impact of the influence of external variables on beliefs (*b*), attitude (*Ai*) and intention (*BI*) in relation to an individual's acceptance or rejection of technology.

TAM is founded on two cognitive beliefs, namely, *perceived usefulness* (*Pu*) and *perceived ease of use* (*Peou*). Perceived usefulness is defined as the prospective user's subjective probability that using a specific application will increase his or her job performance within an organizational context. Perceived ease of use is referred to as the degree to which the prospective user expects the target system to be free of effort.

According to Davis, et al. (1989), a person's actual use of a technology system is influenced directly or indirectly by the user's behavioral intentions, attitude, and perceived usefulness and perceived ease of use of the system. The original TAM proposed by Davis (1989) is illustrated in Figure 3.9.

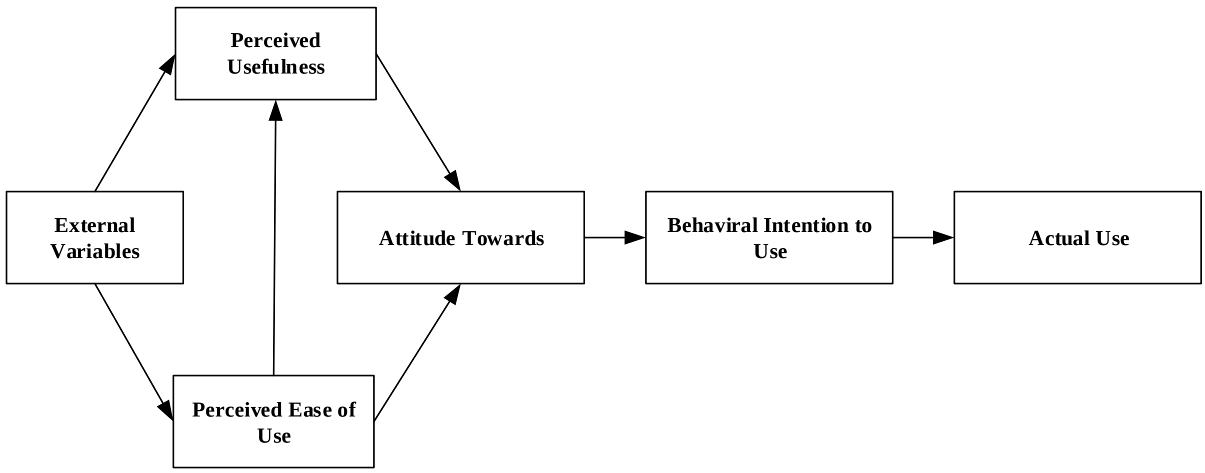


Figure 3.9: Technology Acceptance Model (Adapted from Davis et al. (1989))

Though behavioral intention in both the TAM and the TRA is similar, the TAM determines technology usage behavior as a joint construct that is governed by a person's attitude towards using the system and perceived usefulness. The BI can, therefore, be expressed as an equation, as follows:

$$BI = Ai + Pu \qquad (4)$$

3.5.4 Privacy Calculus Theory (PCT)

The Privacy Calculus Theory (PCT) was developed by Dinev and Hart (2003, 2006) to analyze information disclosure behavior (Sun, et al.2015). It put forward that an individual's ability to take risks is influenced by his or her perception of the benefits (Pb) against the perceived risk (Pr) (Wentzel et al.2014; Keith, et al, 2013; Dinev, et al.2006).

Keith, et al. (2013), points out that privacy calculus is a "rational" theory that aims to explain the attitudes, beliefs, intentions and behaviors of computer users when using technologies, including the cost of perceived risk. The *calculus* refers to an individual's willingness to disclose personal information (privacy) and confidentialities when the perceived benefits outweigh the perceived risk. The resultant of the *calculus* (risk and benefits) is analogously to the perceived value (*PV*) construct. In a privacy context, perceived value can be defined as an overall assessment of usefulness of the information disclosed governed by the perceptions of the privacy risk that will be suffered verses the privacy benefits anticipated to be received (Xu, et al.2011). The PCT can also be expressed as a function, as follows:

$$IID = Pb - Pr$$

$$or$$

$$IID = Pv \qquad (5)$$

The intention to disclose personal information (IID) results from a joint rational assessment of anticipated perceived benefits (Pb) and perceived risks (Pr). Thus, an individual's decision to share information is based on the calculation of benefit and risk perceptions which are negatively correlated (Krasnova & Veltri, 2010; Sun, et al, 2015).

Keith, et al.(2013) further explains the variable constructs relationship and suggests that perceived privacy risks reduce self-information disclosure while perceived benefits increase the likelihood of an individual deciding to share personal information. They further point out that an individual’s unique level of privacy concerns increases their exposure to the context-specific perceived risk thereby decreasing self-disclosure intentions. The PCT model is depicted in Figure 3. 10..

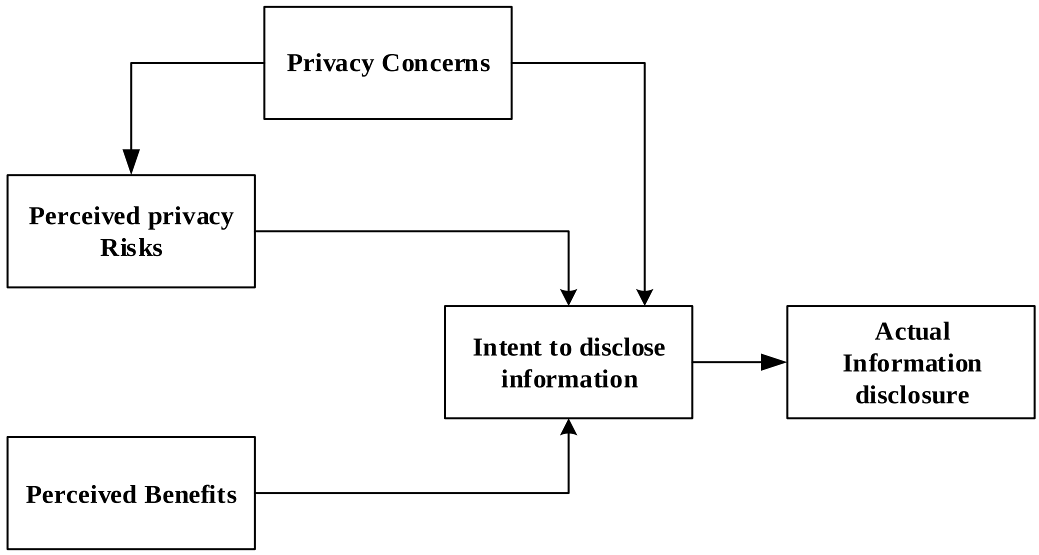


Figure 3.10: Privacy Calculus Theory model (Adapted from Keith et al. (2013))

3.5.5 Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology model (UTAUT) was developed in 2003, with the aim of predicting behavioral intentions in relation to the use of technology and acceptance of technology within the organizational context (Venkatesh, et al.2012). The UTAUT model was developed through the review, synthesis and integration of eight models or theories, namely, the Theory of Reasoned Action (TRA), the Technology Acceptance Model (TAM), the Motivational Model (MC), the Theory of Planned Behavior (TPB), a combined TBP/TAM, the Model of PC Utilization (MPU), Innovation Diffusion Theory (IDT) and Social Cognitive Theory (SCT) (Venkatesh, et al, 2012; William, et al, 2015; Thomas, et al. 2013).

According to Venkatesh, et al. (2012), the UTAUT model has four constructs, namely; performance, expectancy, effort expectancy, facilitating conditions and social factors that have variable influence on the behavioral intention (BI*)* in relation to the use of technology or acceptance of technology. These four constructs can be defined as follows:

- *Performance expectancy:* The degree to which individuals believe that the use of the technology can result in performance gain. This construct is similar to the perceived usefulness depicted in the PCT and the TAM.
- *Effort expectancy:* The degree of ease associated with the use of the technology.
- *Social influence:* The extent to which individuals perceive that significant others (such as family, friends, members of the professional community) believe they should use the technology. Cultural beliefs also exert social influence.
- *Facilitating conditions:* The perceptions of individual as to the extent of organizational resources and technical support available to perform a particular behavior.

Though the four constructs outlined above are the major factors in the UTAUT model, personality differences based on age, gender and experience, and voluntariness of use, moderate various UTAUT construct-relationships. In further research about the context of an individual's use of technology, Venkatesh, et al. (2012) proposed additional constructs to the UTAUT model, such as hedonic motivation, price value and habits. The addition of these constructs and the removal of voluntariness of use from the original UTAUT model lead to the development of the UTAUT2 Model, as shown in Figure 3.11.

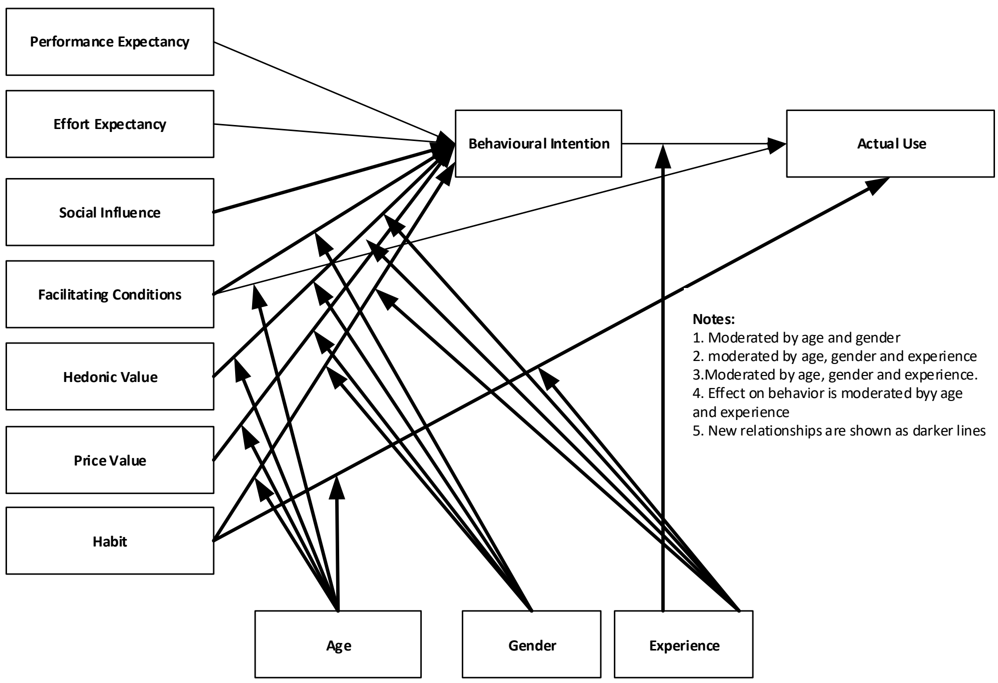


Figure 3.11: The United Theory of Acceptance and Use of Technology 2 model (Adapted from William et al. (2015))

Ever since its inception, the UTAUT model has been widely used in adoption studies as a theoretical lens through which empirical research about behavioral intentions of technology users has been conducted and modelled. (William et al, 2015).

The models/theories discussed above form the basis on which the conceptual research model for this study was developed. The UTAUT2, the Privacy Model and the TAM featured strongly since the objective of this study was to develop a model that can be used by power utility companies to investigate and evaluate the adoption of smart meter technology, while incorporating consumer-centric factors in smart meter technology implementation planning within the South African context. Section 3.5 considers how the various constructs that were identified lead to the development of the conceptual research model for this study.

Table 3.2: Evolution of theories and models of technology adoption

Year	Theory/Model	Developed by	Construct/determinants of adoption
1962	Diffusion of Innovation Theory	Rogers	The innovation, communication channels, time and the social system
1975	Theory of Reasoned Action	Ajzen and Fishbein	Behavioral intention, attitude (A) and subjective norms
1985	Theory of Planned Behavior	Ajzen	Behavioral intention, attitude and subjective norms, Perceived behavioral control
1989	Technical Adoption	Davis	Perceived usefulness and perceived ease of use
1991	The Model of PC Utilization	Thompson et al.	Job-fit, complexity, long-term consequences, affect towards use, social factors, facilitating conditions
1992	Motivation Model	Davis et al.	Extrinsic motivation (such as perceived usefulness and perceived ease of use and subjective norms) and intrinsic motivation (such as perception of pleasure and satisfaction)
2000	Extended Technology Acceptance Model 2	Venkatesh and Davis	Social influence process (subjective norms, voluntariness and image) and cognitive instrumental processes (job relevance, output quality, result demonstrability and perceived ease of use)

Year	Theory/Model	Developed by	Construct/determinants of adoption
2003	Unified Theory of Acceptance and Use of Technology	Venkatesh et al.	Performance expectancy, effort expectancy, social influence and facilitating conditions
2009	Model of Acceptance with Peer Support	Sykes et al.	Behavioral intention, system use, facilitating conditions, network density, network centrality, valued network centrality and valued network density

Source: Adapted from Sharma & Mishra, (2014)

3.6 Justification for using the Technology Acceptance Model as a theoretical model

As the decision to accept and use a new technology depends on uncertain benefits and uncertain costs, understanding the factors affecting choice is vital for both technology innovators and policy makers in relation to future technology developments (WEF, 2017).

Theories that predict how a user comes to accept and use a specific technology have been dealt with extensively in past research, as evident in Table 3.2. These theories suggest a number of constructs that influence a user's decisions about how and when they will use a new technology.

Table 3.3: Technology and user acceptance theories

Model	Constructs	Definitions	Source
Privacy Calculus Theory	Perceived ease of use Perceived usefulness Relevant social groups Institutional privacy assurance Perceived privacy risks	The Privacy Calculus Theory argues that a consumer's ability to take risks (disclosure of personal information) is influenced by the consumer's perception of benefits against risks (the calculus).	Morosan & DeFranco (2015) Sun et al.(2015) James et al.(2015) Keith et al. (2013) Dinev et al.(2006)
Theory of Reasoned Action	Attitude Subject norms	The Theory of Reasoned Action suggests that a person's behavior is determined by a person's intention to perform the behavior and that this intention is, in turn, a function of a person's attitude toward the behavior and a person's subjective norm.	Ajzen (1975) Vallerand et al. (1992) Rehman, et al.(2003)
	Attitude Subject norms	An individual's behavior is driven by behavior intentions, where behavior intentions are a function of three determinants: an individual's attitude toward	Cheon et al.(2012) Davis et al.(2002)

Model	Constructs	Definitions	Source
Theory of Planned Behavior	Perceived behavioral control	behavior, subjective norms and perceived behavioral control. The concept was proposed by Ajzen in 1991 to improve on the predictive power of the theory of reasoned action by including perceived behavioral control.	Notani (1998) Lynne et al.(1995) Ajzen (1985, 1991)
Technology Acceptance Model	Perceived usefulness External variables Perceived ease of use Attitude towards Behavioral intention	The Technology Acceptance Model (TAM) is an information systems theory that models how users come to accept and use a technology.	Sanchez-Prieto, (2016) Miltgen et al. (2013) Davis et al. (1989)
Diffusion of Innovation Theory	Relative advantage Compatibility Trialability Observability Complexity	Diffusion research centers on the conditions which increase or decrease the likelihood that a new idea, product or practice will be adopted by members of a given social system.	Miltgen et al.(2013) Srivastava et al. (2012)
Unified Theory of Acceptance and Use of Technology	Performance expectancy Effort expectancy: The perceived ease of use of the technologies Social factors Facilitating conditions Attitude Behavioral intentions	The Unified Theory of Acceptance and Use of Technology model aims to explain user intentions to use an information system and subsequent usage behavior.	Thomas et al.(2013) Caroline et al.(2013) Venkatesh, et al. (2012)

The TAM has been useful in studying the intent to accept new technologies in a variety of contexts (Table 3.4) It was used as a research model for this study, contributing extensively to the research model. Though the TAM is a widely used model for studies about technology acceptance and use (Table 3.4), it has some weaknesses in that it overlooks certain individual factors that could influence the choice to accept or reject a technology. Such individual factors can either provide additional variables to the TAM or provide an integrative view of the variables needed to explain or predict technology acceptance (Chen et al. 2011). Micheni et al. (2013) posit that, although the TAM provides valuable insights that focus mainly on the determinants of intention, it does not predict how perceptions are formed and how they can be manipulated to enhance user acceptance and increase technology usage. In this study, the motives that drive the acceptance of smart meter technology, in reality, may introduce additional significant constructs such as trust (Gefen et al. 2003; Wu & Chen, 2005), privacy concerns (Zhou, 2011; Keith et al. 2013), price value and facilitating conditions (Venkatesh et al. 2012. 21). These additional constructs cannot be explained or explicitly dealt with in the TAM or in other acceptance models individually.

Table 3.4: Past and present research studies that have used the Technology Acceptance Model

Application domain	Research study context	Source
	Customer acceptance of internet banking	Maduku (2013)
	Clarity of E-stock user’s behavioral intention	Chen & Chen (2009)
Banking	Adoption of internet banking	Lee (2009)
	Adoption of Mobile Money Services	Micheni et al.(2013)
	Electronic toll collection service	Chen et al.(2007)
Government services	Hospital information system acceptance	Lu & Gustafson (1994)
	End users’ reactions to health information technology	Holden & Karsh (2010)
	Online shopping or E-commerce	Lim, Osman, Salahuddin, Romle & Abdullah, (2016)
Commerce	Consumer acceptance of online auctions	
	E-commerce acceptance	Gefen et al.(2003)
	User acceptance of world wide web	Stern et al.(2008)
		Gefen & Straub (2000)
		Moon & Kim (2001)
	Examine Faculty use of Learning Management Systems	Fathema et al.(2015)
Education	Understanding academics’ behavioral intention to use Learning Management Systems	Alharbi & Dew (2014)
	E-learning attitudes	Park et al.(2009)
Privacy and Security	Biometric applications	
	User acceptance of Radio-frequency identification (RFID)	Muller-Seitz et al.(2009)
	Consumer acceptance of location-based services in the retail environment	Uitz & Koitz (2013)

Application domain	Research study context	Source
Geography and environmental service	Examining location-based services usage	
	Investigating the impact of privacy concern on user adoption of location-based services	Zhou (2012)
		Zhou (2011)
General application	User acceptance of interface agents in daily work	Serenko et al.(2007)
	Understanding of self-service technologies	Lin & Chang, (2011)
	Perception about the use of electronic mail	Gefen & Straub (1997)

The proposed research model for this study is illustrated in Figure 3.12. The additional constructs in this model are discussed in Sections 3.6.1 to 3.6.4.

3.6.1 Trust (T)

According to a number of studies, trust has been shown to be a crucial predictor of IT use and adoption (Gefen et al. 2003; Dinev et al. 2006; Zhou, 2011; Joubert & van Belle, 2013). Gefen et al. (2003) and Doney & Connon (1997) agree that trust is a key driver for adoption in the online environment owing to its relevance in dealing with uncertainty and risk vulnerability transactions.

Joubert & van Belle (2013) and Gefen al. (2003) describe trust as a complex and context-dependent construct that is critical in many economic activities that involve undesirable opportunistic behaviors. Over the past decades, various extensive studies have focused on different aspects of trust (Gefen et al. 2003; Papadopoulou & Martakos, 2008). AlHogail, (2018:17) defines trust as “the willingness of a party to be vulnerable to the actions of another party based on the expectations that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party”.

In agreement, Tobergte et al. (2013) and Zhou, (2011) suggest that trust reflects a positive expectation towards another party’s future behavior. It was further noted that trust includes three beliefs: ability, integrity and benevolence. In relation to these three beliefs, the construct of trust in this research study was considered as follows: (1) ability - the municipality as a service provider of smart meters has the necessary skills and knowledge to protect consumers’ privacy, (2) integrity - the municipality keeps its promise to use electricity usage data collected from consumers legitimately and not deceive users and (3) benevolence - municipality smart meter technology will be implemented with the consumer’s interests in mind not just their own. Naturally, consumers with high privacy concerns will doubt the trustworthiness of smart meter technology implementation, which will reduce their behavioral intention to use the technology.

Al-Ghaith et al. (2010) suggest that lack of face-to-face interaction (between service provider and consumer) and dynamicity of electronic service delivery applications have made trust pivotal both in e-commerce and e-government services. Belanche et al. (2012) further outlines that, in uncertain and risk situations, trust reduces the negative impact of vulnerability thereby helping individuals to understand their social environment (Gefen et al, 2003).

There are five trust antecedents that have been identified in several research studies, namely, knowledge-based trust (built on familiarity), institution-based trust (situational normality and structural assurance), calculative-based trust (cost and benefit assessment), cognition-based trust (developed from first impressions) and personality-based trust (individual tendency to trust others) (Gefen et al. 2003; Joubert & van Belle, 2013; Al-Ghaith et al. 2010). Joubert & van Belle (2013) propose another trust antecedent which they referred to as system trust (trustworthiness of the system). Zhou (2011) notes that trust enables mobile users to believe that mobile service providers will provide favorable outcomes in the future, thereby decreasing their perceived risk and promoting usage behavior. Furthermore, other researchers suggest that customer trust has a critical effect on a customer's attitude towards online banking (Liu et al. 2004; Al-Somali et al. 2009; Maduku & Mpinganjira 2012). They also point out that trust plays an essential role in enhancing their behavioral intentions to use or continue to use online banking. In using calculative-based trust, Dinev et al, (2003) concur that, if the cumulative effect of trust and control is higher that the cumulative effect of privacy concerns and perceived risk, the user will more likely make a decision to purchase online. This research study assessed the impact of trust on privacy concerns (perceived risk) and behavioral intention to use smart meter technology.

3.6.2 Privacy Risk (PR)

Tan et al. (2012:214) defines privacy concerns as "a person's awareness and assessment of risks related to privacy violations". They further discussed privacy concerns to include false light, disclosure, appropriation and intrusion. Based on various research studies,, privacy concerns have been found to directly affect a user's behavioral intention in a variety of situations such as ubiquitous commerce, electronic health records, social networking and radio frequency identification-based applications (Angst & Agarwal, 2009; Fogel and Nehmad, 2009; Cha, 2010). Dinev and Hart (2006) posit that a user's internet literacy and social awareness affects privacy concerns which can further determine their intention to transact online.

Though privacy concerns directly affect a user's behavior intention to use technology, it can also indirectly affect a user's behavior through trust, perceived risk and perceived usefulness (Zhou, 2010). Wang & Lin (2017) agrees that privacy concerns affect trust which then influences a users' behavioral intention to use technology. Tan et al. (2012) further outlines studies that evaluate impact of privacy concerns on usage behaviors in social networking. According to Cha (2010) privacy concerns in social networking are negatively correlated with usage behavior. In another study, Tseng, Han, Su & Fan (2017) found that privacy concerns can influence the intention to use a firewall through perceived usefulness. The significance and the impact of privacy concerns on both attitude and behavioral intention to use smart meters was evaluated in the research model developed in this study.

3.6.3 Price value and monetary cost

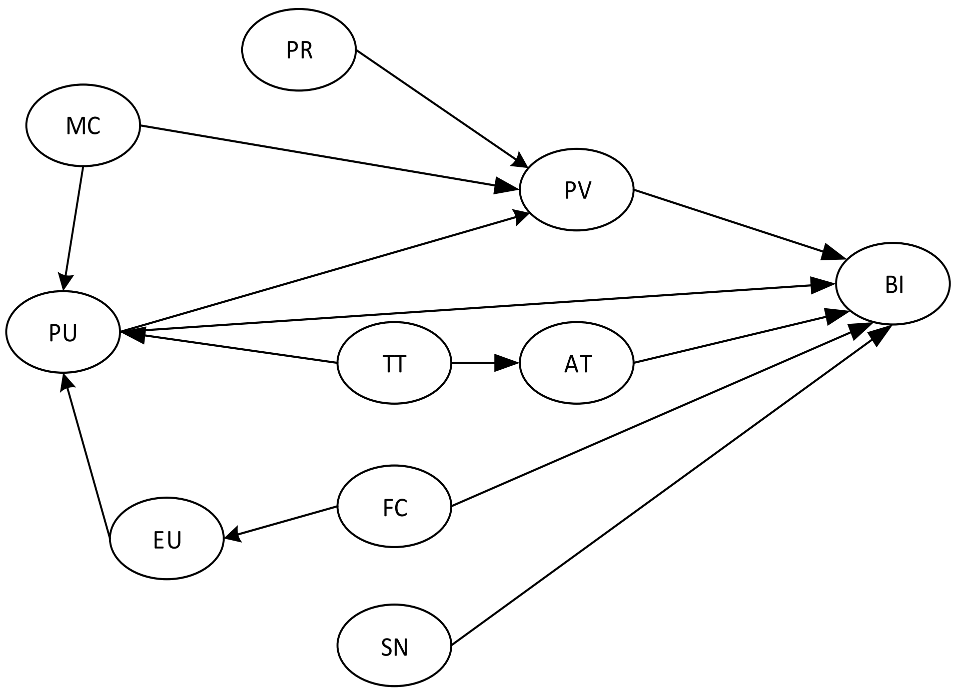
Price value is another important variable that was considered in this research. According to Venkatesh, et al. (2012), cost and pricing structure may have a significant impact on consumers' technology use. Marketing research outlines that monetary cost/price and quality of goods and services is usually conceptualized to determine a user's perceived value of products and services (Zeithaml, 1988). Venkatesh et al. (2012) use this notation and defined price value as a user's cognitive tradeoff between the perceived benefits of application and the monetary cost of using the system. The price value's positivity has a direct impact on intention to use technology. Therefore, the model developed in this research study evaluated and measured the impact of price value on attitude towards use of smart meter technology.

3.6.4 Facilitating Conditions (FC)

Facilitating conditions is another independent construct that may influence the use of technology both directly and indirectly through attitude. Ghalandari (2012) refers to facilitating conditions as the extent to which an individual perceives that the technical and organizational infrastructure required to use the intended system is available. Venkatesh et al. (2012) describe facilitating conditions as training and support given to individuals that is freely available within the organization and practically invariant across users. Micheni et al. (2013) concur and further state that reliable and responsive customer support services, customer education around product features, availability of liquidity and marketing around each of these aspects are key factors in facilitating conditions. In reality, facilitation in an environment that is available to all individuals can vary extensively and facilitating conditions can serve as the proxy for actual behavioral control and can influence behavior directly (Ajzen, 1991). According to Venkatesh et al. (2012), individuals who have access to favorable sets of facilitating conditions are more likely to have a higher intention to use a technology as compared to individuals with lower levels of access. In this study, the impact of facilitation conditions on both the attitude and use of smart meter technology was tested and its usefulness by the municipality evaluated.

3.7 Proposed smart meter technology model (SMTM)

Based on the study objectives, Figure 3.12 shows the structural relationships that have been suggested as the basis of a proposed smart meter technology model.



BI: Behavioral intention, AT: Attitude, PV: Perceived value, PR: Privacy risk, MC: Monetary Cost, PU: Perceived usefulness, EU: Perceived ease of use, TT: Trust in technology, FC: Facilitating conditions, SN: Social norms

Figure 3.12: Proposed Smart Meter Technology Model

3.8 Chapter conclusion

This chapter provided an overview of the most important behavioral intention and technology acceptance theories and adopting models available in the literature that were found to be relevant to this research study and in relation to technology acceptance in general. As discussed above, since there is no specific technology acceptance model and theory available to explain the behavioral intention to accept smart meter technology in general, this research study relied on various technology acceptance and adoption models and theories that have been postulated such as the Diffusion of Innovation Theory (DOI) (Rogers, 1960), The Domestication of Technology (DoT) (Silverstone &

Haddon, 2006), the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1985), the Theory of Planned Behavior (TPB) (Ajzen, 1985), the Technology Acceptance Model (TAM) (Davis, 1989), the Privacy Calculus Theory (PCT) (Dinev & Hart, 2006) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). The extensive review and synthesis of these technology acceptance and adoption models and theories assisted in justifying the selection of the TAM as the research model for this study. Owing to some inadequacies and limitations of the TAM, additional factors from other models/theories were proposed in order to effectively identify relevant factors that may be integrated for planning consideration for smart meter implementation in the South African context. The factors that were proposed for evaluation were trust in technology, privacy risk, perceived value and monetary cost and facilitating conditions. These factors are given further consideration in Chapters 6 and 7.

CHAPTER 4:

RESEARCH METHODOLOGY AND DESIGN

This chapter outlines and justifies the methodology that was employed in this research study. In addition, the research philosophy underpinning this study, the research design and assumptions, and the concepts used in the research process are discussed. Considering the scientific nature of the investigation, a quantitative research approach was deemed relevant. Sections 4.1 to 4.5 consider the research philosophy and research approach with justification of the choices made. The study population and sampling procedure and data collection and analysis methods are considered in Sections 4.6 to 4.9.

4.1 Research Philosophy

Research can be defined as the scientific and systematic search for pertinent information on a particular topic in an effort to gain new knowledge (Bist (2015:34). In support, Tennis (2008) pointed out that all research is based on philosophical assumptions about what constitutes "valid" research and what methods are relevant and appropriate for the development of new knowledge in a given study. The way in which research is conducted may be conceived in terms of the research philosophy to which it subscribed (Saunders et al. 2016; Wahyuni, 2012).

Saunders et al. (2016) refers research philosophy to a system of beliefs and assumptions about the development of knowledge. The term epistemology (what is known to be true) as opposed to doxology (what is believed to be true) encompasses the various philosophies of research approach. The purpose of science then, is the process of transforming things believed into things known ('doxa to episteme'). In agreement, Andriukaitiene, Vveinhardt, & Zukauskas, (2013) suggests that clarification of research philosophy assists researchers to understand the interrelationships between the ontology (what is the nature of reality?), epistemology (what can be known?), and methodology (how can the research uncover what the researcher believes is unknown?) of enquiry.

Creswel, (2008) suggests that two major research philosophies have been identified in science, namely positivism and interpretivism (Cleven, Gubler, & Hüner, 2009). Table 4.1 outlines the difference between these two paradigms (Creswell, 2008). Saunders et al. (2012) suggest two additional research philosophies, namely, realism and pragmatism (Figure 4.1).

Table 4.1: Fundamentals of research philosophies

	Positivism	**Interpretivism**
Independence	The observer is independent of what is being observed.	The observer interacts with the subject being observed.
Value-freedom	The choice of what to study, and how to study it, can be determined by objective criteria rather than by human beliefs and interests.	Inherent biasness is the choice of what to study, and how to study it, as researchers are driven by their own interests, beliefs, skill and values.
Causality	The aim of social science should be to identify casual explanations and fundamental laws that explain regularities in human social behavior.	The aim of social science is to try to understand what is happening.
Hypothetic-deductive	Science proceeds through a process of hypothesizing fundamental laws and then deducting what kinds of observation will demonstrate the truth or falsity of these hypotheses.	Develop ideas through induction from evidence and mutual simultaneous shaping of factors.
Operationalization	Concepts need to be operationalized in a way which enables facts to be measured quantitatively. Static design-categories are isolated before the study.	Qualitative methods are used, and small samples are investigated in depth or over time. Emerging design-categories are identified during the research process.
Reductionism	Problems as a whole are better understood if they are reduced into their simplest possible elements.	Problems as a whole are better understood if the totality of the situation is looked at.
Generalization	In order to be able to generalize about regularities in human and social behavior, it is necessary to select samples of sufficient size. The aim of generalization is to lead to prediction, explanation and understanding.	Everything is contextual. Patterns are identified and then theories are developed for understanding.
Research language	Formal, based on set definitions, impersonal voice, and use of accepted quantitative terminology.	Informal, evolving decisions, personal voice, and use of accepted qualitative terminology.

Adapted from Saunders et al. 2012, Creswell (2008), Easterby-Smith et al. (1991), Hussey and Hussey (1997), and Remenyi et al. (2000)

In agreement with the four research philosophies referred to above, Mohamadi & Al Zefeiti (2015) posit that these research philosophies have an influence on a researcher's philosophical assumptions that serve as the basis for their research strategy and hence that inform their research process. This research study adopted a positivism paradigm as the research philosophy in the investigation of consumer-centric factors that need to be considered when implementing smart meter technology. Brief descriptions of various philosophies are provided later. At this stage, the positivism research philosophy and reasons for the choice of this philosophy are outlined below.

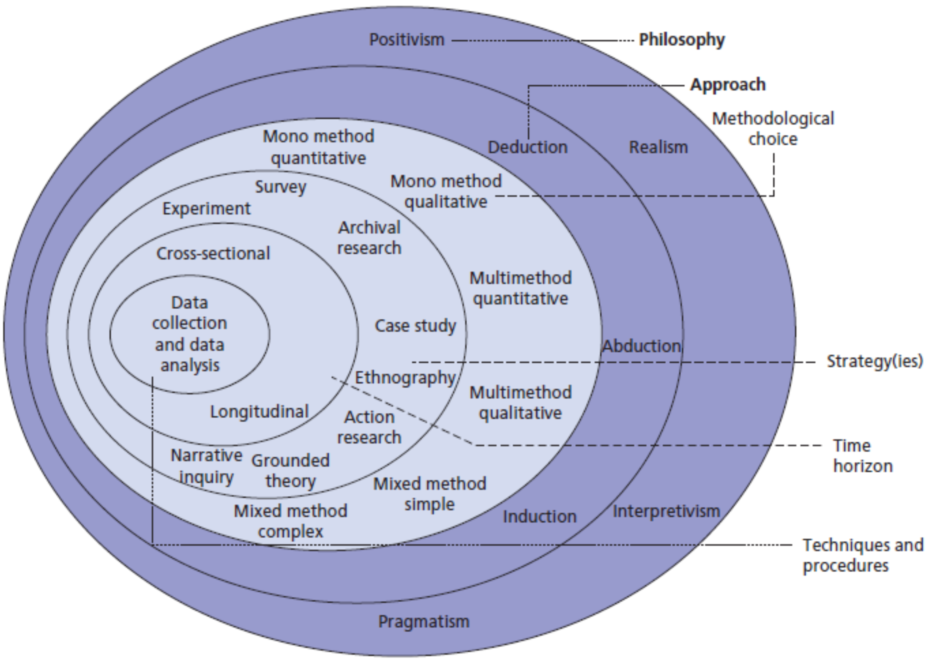


Figure 4.1: Research Onion (Adapted from Saunders et al. 2012))

4.2 Positivism Paradigm

The positivism research philosophy has its roots in the natural sciences and involves empirical testing. It states that only phenomena which can be known through the senses can produce "factual" knowledge that is trustworthy (Creswell. 2008). Positivists believe that reality is stable and can be observed and described from an objective viewpoint (Saunders et al. 2016).

The research process in positivism evaluates artifacts leading to the same objective results, regardless of the individual characteristics of the evaluating person. In this research philosophy the role of the researcher is limited to an observer and neither influences the observed, nor is influenced by it (Saunders et al.2012).

Aliyu, Bello, Kasim & Martin (2014) and Green (2008), suggests that the positivism paradigm is often associated with experiments and observation of facts in the form of quantifiable measurements leading to statistical analysis. The positivist promotes the ideology of experimentation and testing as a way to prove or disprove the formulated hypotheses from the theory. Finally, a positivist makes use of existing theories and models to develop hypotheses which can be tested during the research process (Ramanathan, 2008).

4.3 The choice of research philosophy

A positivist philosophy was adopted for this research study, in line with most Information System (IS) studies (Saunders et al.2012). The aim of this study was to formulate a framework for incorporating consumer-centric factors in the acceptance of smart meter technology implementation planning in the South African context. Therefore, it was essential to analyse existing research on technology acceptance and use. To this end, an extensive literature review of technology acceptance models and behavioral theories was conducted in order to identify a research model for this smart meter acceptance study. Of all the models reviewed, the Technology Acceptance Model (TAM) was identified as a suitable research model.

4.4 Research Approach

This section aims to outline the research methodology paradigm for this study. A paradigm is a perspective based on a set of assumptions, concepts, and values that are held by a community of researchers (Kivunja & Kuyini, 2017). According to Saunders et al. (2012), there are three research methodology approaches that can be adopted, namely, qualitative, quantitative and mixed methods (Table 4.2).

According to Bryman and Bell (2007) and Green (2008), a quantitative research approach entails the collection of numerical data. This approach takes a deductive view of the relationship between theory and research, has a predilection for a natural science approach, and is objectivist in its conception of social reality. In contrast, a qualitative research approach is associated with an inductive approach to generating theory, often using an interpretivist world view allowing the existence of multiple subjective perspectives and constructing knowledge rather than seeking to find it in reality (Green, 2008). Mixed methods research is both a method and methodology for conducting research that involves collecting, analyzing, and integrating quantitative and qualitative research in a single study, MFFRL with the purpose of providing a better understanding of a research problem or issue than would be provided using one research approach alone (Saunders et al.2012).

Table 4.2: Overview of different research approaches (Adapted from Saunders at al.2016)

Philosophy	Interpretivism	Positivism	Pragmatism
Type of research	Qualitative	Quantitative	Mixed methods
Methods	Open-ended questions Emerging approaches Text and/or image data	Closed-ended questions Predetermined approaches Numeric data	Both open and closed-ended questions Both emerging and predetermined approaches Both qualitative and quantitative analysis
Research practice	Positions researcher within the context Collects participant-generated meanings Focuses on a single phenomenon or concept Brings personal values into the study Studies the context or setting of participants Validates the accuracy of findings Interprets the data Creates an agenda for change or reform Involves the researcher in collaborating with participants	Tests verify the theories or explanations Identifies variables of interests Relates variables in questions or hypothesis Uses standards for reliability and validity Observes and measures information numerically Uses unbiased approaches Employs statistical procedures	Collects both qualitative and quantitative data Develops mixing method Integrates the data at various stages of inquiry Presents visual pictures of procedures in the study Employs both qualitative and quantitative procedures

4.5 Choice of the research approach

In this study, the research problem, aims and related questions are all aligned to an objective outcome; therefore, a quantitative research approach was used in formulating a framework to incorporate consumer-centric factors in the prediction of intention to accept and use of smart meter technology within the South African context. The choice of a quantitative approach was based on the need to work objectivity and predictability solutions into the investigation.

Several authors emphasize that a quantitative research approach is viewed as being positivist and uncovers existing reality (Green, 2008; Muijs, 2004). It is further suggested that truth and objectivity about reality can only be achieved if a researcher's role is independent of what is being observed (Green, 2008; Saunders et al.2012; Creswell, 2008). In the context of this research study, an extensive literature review on technology acceptance models and behavioral theories was conducted to identify consumer-centric factors and a suitable research model (Davis, Bagozzi, & Warshaw, 1989; Ajzen, 1975, 1991; Venkatesh et al.2012). According to Wilson (2010), a deductive approach based on existing theory can be used to formulate hypotheses and design a research strategy to test the proposed hypotheses (Ramanathan, 2008). In this study, the TAM, together with constructs identified from existing theories such as trust in technology, privacy risk, price value and monetary cost, facilitation conditions, perceived usefulness and perceived ease of use , social norms, and attitude provided the existing theory on which hypotheses were based to measure their influence on intention to accept smart meters.

In an attempt to meet the research objectives and answer the research questions associated with this study, self-administered questionnaires were used to collect the data. Though data collection by questionnaire has certain disadvantages, this method provides a quick and easy way to collect data, with relatively low or no cost requirements, and higher levels of objectivity than other primary data collection research methods. Objectivity in quantitative research is dependent on the researcher's role being limited to data collection and interpretation only, in order to reduce research bias whereas in qualitative research, the researcher becomes part of the research thereby potentially influencing the research output.

The numeric data was collected through use of the measurement instrument, administered under strict procedures, and prepared for statistical analysis. Structural equation modelling (SEM) was the statistical technique used to analyse complex relationships between Independent Variables (IV) and Dependent Variable (DV). Furthermore, SEM was used conceptually to answer the research questions involving indirect or direct observation of one or more independent variables or one or more dependent variables. The primary goal of SEM, however, is to determine and validate a proposed causal process and/or model, therefore, SEM is a confirmatory technique.

There are a few inherent disadvantages associated with quantitative research approaches. Research findings in these types of studies are only descriptive, thus they cannot provide insight into in-depth issues (Creswell, 2008). Another shortcoming of a quantitative approach is that it relies on experience as a valid source of knowledge and fails to take into consideration other concepts like cause, time and space which cannot be explained in the context of experience. Finally, "quantitative" assumes that all types of processes can be perceived as a certain variation of actions of individuals or relationships between individuals and things (Saunders et al.2016).

Despite the disadvantages, a quantitative research approach was deemed suitable for formulating a framework to support smart meter technology implementation planning. Considering the intended outcome of this research study, the need to be objective about the intention to accept smart meter technology was critical as it is vital for decision making for both technology innovators and policy makers in relation to future developments.

The next section provides a detailed account of the structural equation model research technique used in this study.

4.6 Structural Equation Modelling (SEM)

Structural equation modelling incorporates a family of statistical models used to simultaneously test and estimate complex casual relationships between multiple variables, even when the structural relationships are directly or indirectly linked (Asyraf & Afthanorhan, 2013; Hair et al.2010; Henseler, Ray & Ash, 2015). As an advanced linear modeling procedure, SEM allows the researcher to statistically test the relationship between theory-based latent variables and their indicator variables by measuring directly observable indicator variables (Astrachan, Patel, & Wanzenried, G., 2014). Though Hooper, Coughlan & Mullen, (2008) posit that SEM has become an interdisciplinary statistical analysis technique, they emphasize the importance of its use in social science disciplines. In agreement, Henseler et al. (2015) and Astrachan et al. (2014) put forward that SEM has become the most popular statistical technique used in business and social science research, owing to its ability to model constructs, taking into consideration various measurement errors while testing the research data against the underlying theories to determine if it represents the observed target population.

Even though SEM is similar to multiple regression techniques in its capacity to test relationships between variables, it can simultaneously examine multi-level dependence and multiple dependent relationships within the same analysis (Astrachan et al.2014). As much as SEM is a general term for the family of statistical models used to test relationships between multiple variables, it can be applied through co-variance-based structural equation modelling (CB-SEM) or partial least square structural modelling (PLS-SEM) (Astrachan et al.2014; Asyraf & Afthanorhan, 2013; Hair et al.2010; Henseler et al.2015).

4.6.1 Covariance-based structural equation modelling (CB-SEM).

According to Hair et al. (2010) and Henseler et al. (2015), CB-SEM is referred to as a statistical technique that is used to estimate model parameters by minimizing discrepancies using the observed covariance and the estimated covariance matrix. Even today, CB-SEM is a widely and commonly used SEM technique for testing and confirming underlying theory (Asyraf & Afthanorhan, 2013; Hair et al.2010). There are strict requirements that need to be met before analysis of data using CB-SEM can take place, as follows: (1) data must be normally distributed, (2) the sample must be larger than 200 (Asyraf & Afthanorhan, 2013; Hair et al.2010) and (3) the model must be correctly specified. Many researchers point out that these strict requirements, especially a large sample size and normal distribution of the data have become difficult to satisfy (Astrachan et al.2014; Hair et al.2010; Henseler et al.2015; Amaro et al.2015). In a situation where the sample size is small and the data is skewed, then PLS-SEM becomes the most appropriate SEM approach to use. The next section presents a brief overview of PLS-SEM.

4.6.2 Partial least square structural equation modelling (PLS-SEM).

According to Astrachan et al. (2014), PLS-SEM is a soft-modelling technique with no assumption about data distribution that can statistically analyze data from small to large sample sizes. PLS-SEM is an alternative variance-based structural equation modeling technique to CB-SEM, where constructs are modeled as composites based on factor analysis results with no ability to re-create co-variances among measured variables (Hair et al.2010; Henseler et al.2015). Wong (2013) also emphasizes that PLS-SEM is suitable in situations where (1) there is a small sample, (2) applications have little available theory, (3) predictive accuracy is vital and, (4) correct model specification is not guaranteed. Despite PLS-SEM being used as an alternative CB-SEM technique, Henseler et al. (2015) point out that PLS-SEM is widely used in various behavioral sciences fields of study that include management information systems, strategic management and marketing.

In spite of the different ways SEM can be applied, Hair et al. (2010) suggest that all structural equation models (CB-SEM and PLS-SEM) are classified based on three major characteristics, namely:

- The capacity to estimate multiple and interrelated dependence relationships.
- An ability to represent unobserved concepts in these relationships and account for measurement error in the estimation process.
- Model definition to explain the entire set of relationships.

According to Hair et al. (2010) application of SEM comprises six different stages, as illustrated in Figure 4.2 and described below.

- *Stage 1: Defining individual constructs*

In Stage 1, identifying a good measurement theory is vital as various constructs are identified from previous studies. Considering the underlying theory, and the phenomena under investigation, the researcher chooses a relevant measuring scale type in order to reliably measure the identified construct. In cases where there is no established measurement scale, the researcher either develops a new scale or modifies and adapts measurement items from existing scales to fit the new phenomena context.

- *Stage 2: Developing the overall measurement model*

This stage deals with the development of the measurement model based on the constructs identified and defined in Stage 1. Each construct identified is assigned measurement items. A minimum of three to four measurement items per construct is recommended.

- *Stage 3: Designing a study to produce empirical results*

This stage involves designing the measurement instrument that will be used to collect data. Based on the identified constructs and their associated measurement items, the measurement model is specified. The type of data to be analyses, its impact and methods of handling missing data and sample size are considered.

- *Stage 4: Assess the measurement model validity*

Assuming that sufficient data has been collected, the measurement model is specified and tested for construct validity and goodness-of-fit. There are various construct validity measures such as convergent validity and discriminant validity, and reliability tests are applied to each construct in order to verify if the construct is measuring what it is intended to measure. The Goodness-Of-Fit (GOF) indicates how well the specified model reproduces the observed covariance matrix among the measured items. According to Hair et al. (2010), there are three different types of GOF measures, each one unique. The GOF measures must be examined to confirm model fit.

- *Stage 5: Specifying the structural model*

Stage 5 uses the specified measurement model to specify the structural model by assigning structural relationships between constructs based on the proposed theoretical model. The structural relationships are used to represent specific relationships that exist among identified constructs. These structural relationships in the model can be represented using a path diagram.

- *Stage 6: Assessing the validity of the structural model*

In this final stage, validity of the structural model is tested, and the corresponding hypothesized theoretical relationships are established. This stage evaluates the structural model fit, compares it with the measurement model and estimates all the parameters for all the hypotheses of the structural model for significance.

These six stages can be further combined to form a two-phase approach (Figure 4.2) The first phase includes Stages 1 - 3 (definition, specification and design of the measurement model) and the second phase, Stages 4 - 6 (testing and examination of the measurement model and structural model).

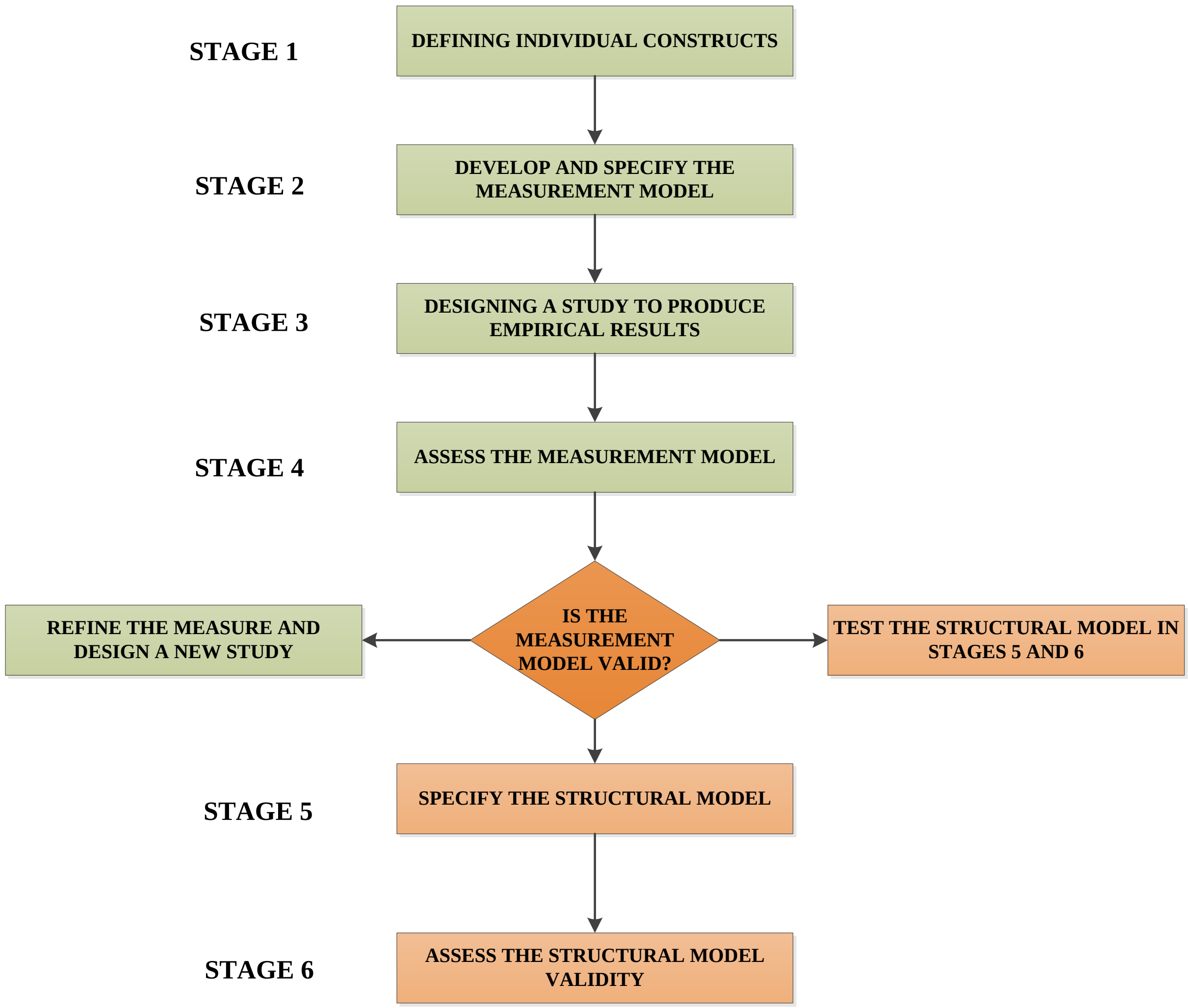


Figure 4.2: The six stages of structural equation modelling (Adapted from Hair et al.(2010))

4.7 Population and sampling procedure

This research study was conducted within the boundaries of South Africa and a sample was drawn from the major metropolitan areas such as the City of Tshwane and the City of Johannesburg. Other metropolitan areas and municipalities such as Nelson Mandela Bay Municipality, Mangaung Municipality and Buffalo City Municipality were also included in the study. Cluster (area) and judgement sampling strategies were applied because it was too time consuming and costly to sample the whole South African population. Cluster sampling (as opposed to random sampling) was selected, as this sampling strategy reduced research time and costs by concentrating surveys only in a selected cluster (Kothari, 2004) such as the City of Tshwane and the City of Johannesburg. Judgment or purposive sampling was used to consider a representative cluster sample of the population. According to Kothari (2004), purposive sampling is used frequently in qualitative research where the intention is to develop hypotheses rather than to generalize to large populations.

4.8 Data collection process

According to Sauter (2012), positivism depends on quantifiable measurements that lead to statistical analysis. In this study, a self-administered questionnaire was designed and used for data collection. The questionnaire was designed for both electronic data collection through QuestionPro version 16 and through manual hard copies for non-internet participants. Since the research aimed to collect data from electricity consumers, both research ethics clearance and relevant permission was requested and granted (ref. Appendix Reference Ethics letter and Appendix City of Tshwane Letter).

Participants who completed the survey electronically were sent an invitation and URL link to enable access to the online version of the questionnaire. With permission from the City of Tshwane, two independent researchers administered hard copy versions of the questionnaire to participants in various suburbs, schools, colleges, government departments and at police stations. During the data collection stage, the researcher’s role was limited to data collection and interpretation only in order to reduce research bias.

4.9 Data Analysis

In this research study, the questionnaire was administered to both smart meter and non-smart meter users in a selection of major metropolitan cities and municipal areas. The study targeted about 500 participants as a representative sample of the general population of 52 million South Africans and focused particularly on electricity consumers (Statistics South Africa, 2018).

The numeric data collected from the survey was statistically tested using CB-SEM. The STATA version 13 statistical software and SEM was used to conduct the two model tests. Firstly, the data collected was examined and validity of the latent variables and reliability of the measurement scale items was tested using various confirmatory factor analysis tests. Subsequently, the measurement model was converted to a structural model and tested for model fit using goodness-of-fit indices and structural relationship significance.

4.10 Conclusion

This chapter considered the research process used in the investigation of a predictive model for implementation planning of smart meter technologies within the South African context. As discussed above, this research study had its theoretical underpinning within the positivism research philosophy, since the research aimed to generate artifacts in the form of guidelines that need to be considered in the planning of smart meter implementation in South Africa. A quantitative research approach was deemed appropriate for meeting this aim. Numeric data that was collected using a self-administered questionnaire, was examined and tested through the application of CB-SEM. Various measurement and structural model fit tests were conducted using SEM in order to verify and evaluate if the constructs were measuring what they were intended to measure. The results of this chapter provided a platform to understand the measurement model evaluation which is explained in detail in Chapter 5.

CHAPTER 5:
MEASUREMENT MODEL DEVELOPMENT

5.1 Introduction

In Chapter 3, various behavioral studies models were presented to provide theoretical underpinnings for this research study. Chapter 5 aims to cover the first part of the two-step structural equation modeling process that deals with defining the individual constructs, specification of the measurement model and, finally, the design of the measurement instrument. Based on the SEM six stage process outlined in Section 4.4, this chapter focuses only on stages 1 to 3. Stage 1 will be considered in terms of the identification and definition of all the theoretical constructs based on extensive literature review of the theory underpinning the study (Chapter 2). In this regard, the TAM constructs and other relevant constructs that provide insight into explaining the behavioral intention to accept smart meter technology within the South African context are defined. Discussion about Stage 2 includes measurement model development. The various items used for construct measurement are outlined with recommendations from previous studies. In the process, the TAM construct items are defined, as well as the other independent construct items that were integrated into the measurement model. While justifying the construct items for the measurement model, the relevant measurement scales are outlined. Consideration of Stage 3 includes how the output from Stages 1 and 2 was used to design the final measurement instrument. The final measurement instrument was used to collect the numeric data required for this study, analysis of which is covered in Chapters 6 and 7.

5.2 Theoretical Constructs for the study: SEM Stage 1

According to Hair et al. (2010), a good measurement theory should always become an important condition that each research study seeks to achieve in order to get statistically significant and valuable results in SEM. Stage 1 of the SEM process aims to identify all the relevant constructs that were used to specify the underlying structural theory of the study. As suggested by Hair et al. (2010), all the constructs used in this study were identified from previous studies relevant to behavioral intention to accept and use technology. In line with most technology acceptance and use research studies, TAM was selected as the research model for the theoretical foundation of this study. Based on an extensive literature review (Chapter 3), TAM stood out as the most universally used theory to understand behavioral intention to accept or reject technology and its use (Ajzen & Fishbein, 1975, 1991; Davis et al.1989).

As discussed in Chapter 3, prior studies have shown the TAM to be one of the most widely used and tested theoretical models for examining the processes and determinants of information technology acceptance and use (Belanche, Casaló, & Flavián, 2012; Gefen et al.2003; Hazen, Overstreet & Wang, 2015; Lin & Kim, 2016; Tan et al.2012). The TAM has been extensively used to explain behavioral intentions to adopt information systems and technologies from both consumer and organisation perspectives (Abdulkadir, Galoji, & Razak, 2013; Davis et al.1989) while at the same time remaining relevant and theoretically justified. As initially proposed by Davis et al. (1989), TAM, exhibits the capability not only to predict behavior, but also to help identify and explain to technology innovators why consumers could not accept the proposed system. By doing so, TAM assists the researcher with a basis for examining the impacts of external factors on the attitude and behavioral intention to accept and use a system. Though TAM suggests two critical factors (perceived usefulness and perceived ease of use) as the primary factors impacting information technology acceptance and use, researchers are encouraged to consult previous studies to identify other factors that cognitively and emotionally determine acceptance. The TAM models the actual use of technology as an outcome of behavioral intention, attitude, perceived usefulness and perceived ease of use (Davis et al.1989). As discussed in Chapter 3, the limitation of the TAM model in explaining smart meter technology acceptance required integration of additional factors to be able to predict the consumer-centric factors in this study. The remainder of this section presents a discussion of both the TAM and the integrated factors thereby proposing an extended consumer-centric TAM model. Firstly, TAM model factors are considered, followed by the integrated factors identified for use in this study, namely, Trust in Technology (TT), Monetary Cost (MC), Privacy Risk (PR), Perceived Value (PV), Social Norms (SN) and Facilitating Conditions (FC).

5.2.1 Perceived Usefulness (PU).

According to the TAM model, perceived usefulness is one of the factors that influence an individual's intention to perform a behavior to accept or reject new technologies (Davis et al.1989). Perceived usefulness is defined as the extent to which an individual believes that using a particular application will increase his or her job performance. In this study, perceived usefulness was defined as the extent to which a consumer believed that using a smart meter would be beneficial and enhance better electricity usage management leading to efficient use of electricity.

In support of the TAM, Hsu and Yen (2012) found that perceived usefulness has a strong influence towards attitude which in turn affects behavioral intention to adopt a Home Energy Information Management System (HEMIS) which is similar to smart meter technology. In their study, Hsu and Yen (2012) suggested that, for consumers to have higher intentions to adopt HEMIS, perceived usefulness should always be a priority. These findings mean that, if consumers find HEMIS to be useful in managing their electricity usage, then their attitude gravitates towards a positive attitude which in turn leads to higher adoption. In addition, Wunderlich, Veit & Sarker (2012) also found that perceived usefulness and perceived ease of use are both significant predictors of smart meter technology adoption.

In validating the construct selection, various contexts where perceived usefulness was investigated in relation to the adoption of technology are presented below. Gu et al. (2009) found perceived usefulness to have a strong influence on the intention to use mobile banking. They identified perceived usefulness as a significant factor, and results showed that users are willing to engage with mobile banking if they find it useful in their work. In the same context of mobile banking, Jeong and Yoon (2013), concur with the studies by Gu et al.(2009), and further suggest that user perception that mobile banking is a more useful and quicker way to do banking in comparison with traditional systems enhances intention to use mobile banking.

Belanche et al. (2012) investigated the adoption of e-government services integrating trust and personal value from a public user's perspective. The findings were in agreement with other studies (Davis et al, 1989; Venkatesh et al.2003) and revealed that perceived usefulness is an important factor that directly affects attitude and intentions to adopt e-government systems. In a similar study, Kaushik, Agrawal & Rahman. (2015) also found that perceived usefulness has an influence on tourist behavioral intention to adopt self-service hotel technology. Though perceived usefulness significantly affected adoption, trust and perceived performance risk were shown to be better predictors in comparison with perceived usefulness.

In the context of mobile technologies, Sanchez-Prieto, Olmos-miguel & García-pe (2016) evaluated acceptance of mobile technology adoption by teachers. In their study, they modelled perceived usefulness and perceived ease of use as direct constructs influencing intention to use mobile technologies and they removed attitude as a construct. The results show that perceived ease of use, perceived usefulness, self-efficacy, mobile device anxiety, subjective norm and perceived behavior positively affect the intention to use mobile technologies. Their study did not indicate which of the significant constructs ranked as the best predictor for intention to perform a behavior.

Though several studies concur that perceived usefulness and perceived ease of use are the most important factors affecting attitude and adoption of new information technologies such as internet banking, Maduku (2013) found that trust has become the most significant factor that affects attitude toward internet banking. In the same context, Tung,Yu, & Yu (2014). Tung et al. (2014)

disagree with the findings of Maduku (2013), as they have shown that perceived usefulness and perceived ease of use have an influence on the behavioral intention to use internet banking. The apparent disagreement in the findings of these two studies may relate to the different countries where the studies were conducted. Maduku (2013) researched the South African population which might have a different set of issues from the Taiwanese population (Tung et al. 2015).

Below various studies where perceived usefulness was investigated, and their context is presented. Based on the internet banking different findings, it is important in this study to evaluate perceived usefulness within the context of South Africa. They have been several studies of smart grid and smart meter adoption in the developed continents America, Europe, Australia with limited if not none in developing and developed countries. Therefore, evaluating the perceived usefulness of smart meter technology within South African context becomes in vital in this study.

5.2.2 Perceived ease of use (PEOU).

Perceived ease of use (PEOU) is the other key determining factor that influences a user's decision to accept or reject new technology. Based on the TAM model, perceived ease of use is defined as "the degree to which an individual expects that using the targeted system would be to be free of effort" (Davis et al.1989). In support, Gefen et al. (2003) outlines the PEOU as an indicator of the cognitive effort needed to learn and use a new system. In this study, perceived ease of use is referred to as the extent to which an electricity consumer believes that using and operating a smart meter will require no cognitive effort.

In determining the factors that affect the adoption of smart meter technology, the findings of Wunderlich et al. (2012) were consistent with the TAM model. Other technology acceptance studies concur that perceived ease of use has a significant influence on adoption or usage of a technology (Al-Somali, Sabah & Gholami, Roya & Clegg, Ben. (2009); Davis et al.1989; Venkatesh, 2000). They further suggest that perceived ease of use can either affect behavioral intention directly or indirectly through perceived usefulness. In agreement, Gu et al. (2009) suggest that self-efficiency as an external variable (Davis et al.1989), is a significant factor that affects perceived ease of use which can either directly or indirectly influence behavioral intention through perceived usefulness. These findings are congruent with the TAM model as put forward by Davis et al. (1989).

In the mobile banking context, for a mobile banking application to be perceived as easier to use, it must enhance self-efficacy. Abdulkadir et al. (2013) and Jeong & Yoon (2013) concur that the perceived ease of use of a mobile banking service increases the acceptance of mobile banking. Jeong and Yoon (2013) posit that perceived ease of use has minimal significance in determining behavioral intention to adopt mobile banking. Their findings suggest that simpler, easier and quicker mobile banking applications enhance behavioral intention to use these on voluntary systems (Davis et al.1989). The findings also showed that perceived ease of use is a better predictor of attitude than behavioral intention to use mobile banking. Their findings indicate that, if the mobile banking service is difficult to learn, perceived ease of use will lead to lower adoption (Jeong & Yoon, 2013). They further suggest that product or service information, guidelines and benefits can also make it easier for consumers to adopt mobile banking. Mobile phone manufacturers designing handsets with bigger screen size, convenient keypads, and better screen resolutions also encourages perceived ease of use .

Sun et al. (2012) posit that perceived ease of use has a significant impact on information disclosure intentions in location-based social networking services. In the context of online trading systems, Roca et al. (2009) emphasize that trust; perceived usefulness and perceived ease of use play an important role in an individual's intention to use an online trading system. This suggests that managers should develop online trading systems that provide current information with an easy to use graphical user interface. Though all three factors can be used to predict behavioral intention, trust stands out as the key behavioral intention factor for encouraging an e-investor to provide personal and financial information without being concerned. Roca et al. (2009) also emphasize that high security perception and the long standing relationship between e-investors and commercial partners becomes critical where trust is concerned.

In view of the discussion above, the perceived ease of use has strong support in prior research in that it both affects attitude and perceived usefulness. Therefore, the need to investigate the perceived ease of use impact on perceived usefulness and attitude toward the acceptance of smart meter technology is proposed for further investigation.

5.2.3 Attitude.

Attitude is another factor of the TAM and is jointly affected by perceived usefulness and perceived ease of use which in turn influences behavioral intention (Davis et al.1989). Though the TAM model suggests that behavioral intention is jointly influenced by perceived usefulness and attitude, Cheon et al. (2012) posit that behavioral intention is a function of three factors: attitude, social norms and perceived behavioral intention. They further suggest that attitude toward a behavior is influenced by an individual's positive or negative feelings about performing that behavior (Ajzen & Fishbein, 1991). According to Sanne & Wiese (2018:3), attitude is defined as the degree to which an individual evaluates the behavior as positive or negative an individual's positive or negative evaluation of performing a particular behavior. In agreement, Ajzen and Fishbein (1980) emphasise that attitude involves an individual's judgment that performing a behavior is good or bad. In the same view, Fazio (1989) suggests that attitude guides a person's behavior by filtering information and shaping perception of his or her world. In this study, attitude is defined as a consumer's positive or negative feeling that using smart meters in managing electricity usage will be favorable.

As discussed by Wunderlich et al. (2012), both perceived usefulness and perceived ease of use are strong predictors of attitude. In the context of most human behavior models, TAM suggests that behavioral intentions depend on attitude and perceived usefulness (Davis et al. 1989). Furthermore, the TAM suggests that perceived usefulness and perceived ease of use affects attitude to using a technology. In the context of Learning Management Systems (LMS), Fathema et al. (2015), found that individuals develop a positive attitude and intention to use a particular technology only if they find it useful. This finding is consistent with prior research, that perceived usefulness and perceived ease of use jointly affect attitude which in turn influences behavioral intention to use learning management systems. Thus, individuals who develop a positive attitude towards technology will eventually develop an intention to use it.

In addition, Wentzel, Diatha, & Yadavalli (2009) found that attitude is the most important factor when investigating technology-enabled financial services adoption in South Africa. Their findings suggest that banks need to explain the benefits of using technology-enabled financial services in order to influence their attitudes positively. In the context of smart phone purchase behavior, Agrebi, Sinda & Jallais, Joël. (2014) concur with the TAM that perceived usefulness has a positive effect on consumer attitude which also has a positive influence on smart phone purchase behavior. Their findings imply that provision of functions and value added service of smart phones are of great benefit to users as aspects that may help in their intention to purchase a smart phone. In line with the discussion above, development of a strong attitude can be affected by a variety of individual and contextual variables.

In the context of smart metering, Hsu and Yen (2012) found that, from the factors investigated, only perceived usefulness showed a positive influence on the actual behavior. These findings were consistent with prior research (Ajzen & Fishbein, 1991; Davis et al.1989; Venkatesh et al.2012). In addition, the findings of Wunderlich et al. (2012) were consistent with the TAM in the sense that both perceived ease of use and perceived usefulness showed significant and positive influence on attitude towards smart meter technology. In this research study, it was proposed that positive attitude towards smart meter technology can be influenced by trust in technology, perceived usefulness and perceived ease of use , which in turn have a significant influence on the intention to accept smart meter technology.

Sections 5.2.1 to 5.2.3 discussed key constructs of the TAM and indicated how they were defined in relation to this study about the acceptance of smart meter technology. Sections 5.2.4 to 5.2.9 consider the addition constructs that were integrated into the TAM that was used as the research framework for this study.

5.2.4 Trust in technology.

Trust is a construct that is not part of the original TAM but can be helpful to explain a consumers' decision to accept or reject new technology in this modern age. Mayer et al. (1195:712) define trust "as the willingness of the user to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party". Similarly, Thatcher, Mcknight, Baker, Erg, & Roberts (2009) refer to trust as a psychological state in which an individual is willing to become vulnerable to another party with the belief that he or she will act favorably with no opportunistic attitudes. They further suggest that consumers may refrain from using new IT systems because of perceived risk and uncertainty about that system.

According to previous studies, trust has been shown to be a crucial predictor of IT use and adoption (Dinev et al. 2006; Gefen et al. 2003; Joubert & van Belle, 2013; Zhou, 2011). Gefen et al. (2003) and Doney and Connon (1997) agree that trust is a key driver for adoption in the online environment owing to its relevance to deal with uncertainty and risk vulnerability transactions. In a mobile service context, Gao, Lingling & Bai, Xuesong, 2014) found that mobile service users feel vulnerable when the technology has the capability to track a user's actions and store personal information outside their control, as this may lead to unauthorized access to personal information through activities such as hacking, accidental disclosures and other criminal activities. In support, Al-Ghaith et al. (2010) indicated that most mobile users are concerned about the security of mobile services and about the mobile service provider's ability to protect unauthorized access to personal information. On the contrary, Gao et al. (2014) posit that mobile service providers may only provide personalized services if they are able to locate a user's position and collect a user's profile. As a result, Al-Ghaith et al. (2010) suggest that security and privacy issues are becoming critical in building customer trust in both internet shopping and mobile services.

In the online context, Al-Ghaith et al. (2010), suggest that online consumers do not only need to trust online vendors but need to trust the web technology itself as a transaction medium.

Furthermore, other researchers (Al-Somali et al.2009; Liu et al.2004; Maduku & Mpinganjira, 2012) suggest that customer trust has a critical effect on a customer's attitude towards online banking. They also point out that trust plays an essential role in enhancing a customer's behavioral intentions to use or continue to use online banking. In support of the notion above, Belanche et al. (2012) outlined that trust is relevant in the development of e-government services. They found that perceived trustworthiness influences the intention to use a variety of e-services such as tax filing, medical information systems or e-voting.

In the context of mobile banking, Xiong (2013) found that perceived value and trust have a positive and significant impact on the behavioral intention to adopt mobile banking. They caution bank managers not to only focus on improving the value experience to banking clients but rather to incorporate ways to increase customer perceived trust in order to help attract new clients at the same time as retaining existing clients. In a similar study, Wentzel et al. (2009) established that an individual's trust in technology-enabled financial services is positively influential on the behavioral intention to use new technology. Therefore, new banks should build trust with the bottom-of-the-pyramid customers to improve acceptance of technology-enabled financial services.

As discussed above, trust, in general, has been dealt with extensively in previous studies. In this study, trust was investigated particularly in relation to its impact on acceptance of smart meter technology. The implementation of smart meter technology will potentially benefit utility companies in the supply and demand management of electricity but will greatly expand the amount of customer data that can be monitored, collected, aggregated and analyzed. Some researchers suggest that the collection of smart meter data from energy consumers raises potential surveillance possibilities that may pose physical, financial and reputational risks (NIST Report 7628, 2010). Hence, the need for service providers to demonstrate the trustworthiness of smart meter technology is vital to increase adoption. Based on the discussion above, the effects of trust in e-commerce, internet shopping, mobile banking and e-government services outlined above has been shown to be critical in the attitude, adoption and continued use of smart meter technology. Therefore, in order to explain the importance of trust in technology in relation to smart meter technology attitude, adoption and use, there is a need to validate its significance.

5.2.5 Perceived privacy risk.

For the purposes of this study, perceived privacy risk is another independent construct that has been added to the original TAM as an external variable to help explain the behavioral intention to accept smart meter technology from a consumer perspective.

According to Wunderlich et al. (2012), perceived privacy risk can be described as the potential loss of control, or disclosure, of personal information without consumer consent. Their findings indicate that perceived privacy risk is an important factor that needs to be investigated when consumers make the decision to adopt new information systems surrounded by uncertainty, discomfort and anxiety. In addition, Taneja, Vitrano, & Gengo, (2014) suggest that privacy risk can be define as the expectation of loss due to information disclosure on Facebook.

The use of smart meter technology has posed privacy risk challenges, including (1) The ability for smart meter service providers to identify a user's behavioral patterns, (2) third party access to personal data without consumer knowledge and (3) the vulnerability of the smart meter technology infrastructure that allows consumer electricity data to be communicated over the internet. In agreement, AlAbdulkarim (2011) point out how serious consumer privacy concerns were in the adoption of smart metering in the Netherlands. Their findings showed that consumer privacy concerns were so strong that the Dutch government was forced to halt rolling out of smart meter technology. Hence, careful consideration of the risks associated with smart meter technology and actions to mitigate them will go a long way in enhancing smart meter adoption.

Cazier, Wilson, & Medlin, (2007) point out that privacy risk is increasingly becoming an important aspect that needs consideration when investigating the factors that impact on information technology adoption. The findings of their research on student registration and schedule management showed that privacy risk factors have a negative impact on behavioral intention to adopt the IT system. Cazier (2008) investigated the privacy risk associated with radio frequency identification devices and found that it has an influence on the intention to adopt the technology.

In this study, perceived privacy risk of information disclosure was expressed as the degree of belief that a high potential for loss is associated with the release of personal information to a smart meter service provider (Agarwal et al. 2007; NIST 7628 report, 2010; Xu et al. 2011;). Previous privacy research has shown that, since personal information has become modern currency (Leman-Langlois, 2008), privacy is violated by organizations that engage in harmful opportunistic behavior such as unauthorized access, insider threats, third party information sharing and selling of personal data to gain competitive advantage (Gefen, 2003; Joubert & van Belle, 2013; Luo et al.2010, NIST 7628 report, 2010).

In the context of location aware marketing (LAM), Xu et al. (2011) found that improper handling of personal information could result in the mining of identity and location data, which may enhance the visibility of consumer behavior and increase the scope for situations that may be personally embarrassing to them.

As evident in previous privacy research, an increase in perceived privacy risk of information disclosure from new mobile applications decreases the intention to disclose information through the application as opposed to intentions related to perceived benefits (Dinev & Hart, 2006; Keith et al.2010; Xu et al.2010). In agreement, Keith et al. (2013), suggest that perceived privacy risk plays a greater role than perceived benefits in determining information disclosure intentions. Despite the general consensus that there is a negative impact of privacy risk on behavioral intention, Wunderlich et al. (2012) found perceived risk to have no influence on the adoption of smart meter technology, despite the controversy around personal information disclosure within the smart meter environment.

Considering the risks of information disclosure associated with smart meter technology, the consumer assessment of the utility of information disclosure will be low if they realize that there is a potentially high risk of invasion of their privacy.

5.2.6 Monetary cost.

Monetary cost is another independent variable that has been added to the model to assist in explaining the behavioral intention to accept or reject smart meter technology. The motivation to include monetary cost was based on prior studies that have tried to explain the impact monetary cost (sacrifice) has on the adoption of new technologies (Chi et al.1991; Chitungo & Munongo, 2013; Tung et al.2014; Venkatesh et al.2012; Xiong, 2016). The term "monetary cost" might not be outlined plainly in these studies but the fundamental aspects of sacrificing monetary resources for a service is evident. Hence, for clarity and consistence in this study, a decision to refer to the construct as monetary cost was agreed upon. Monetary cost was included in the model to represent economic exchange for the product or service.

As Hsu and Yen (2012) assert, when consumers are switching from one service provider to another, there is a once-off transactional cost which they incur. This transactional cost is referred to as a switching cost. Based on the HEMIS adoption research, a switching cost relating to a financial and relational cost showed a positive influence on the behavioral intention to adopt the technology.

This is also evident in the South African context (Department of Economic Development and Tourism, 2014), where most municipalities are adopting smart meters slowly owing to their high cost of implementation. Municipalities indicated that the cost of smart meters is relatively high as compared to prepaid meters. The cost for installing a smart meter ranges from R1500 – R8500 compared to a prepaid meter which is under R1000. Apart from the implementation cost, there are additional charges for the communication units (up to R2000 per meter) and also backend charges for management of the smart meter. Though these costs are explained from the perspective of the smart meter provider, it is difficult to justify the cost to consumers when there are other issues to solve such as access to electricity for all in the country (Department of Economic Development and Tourism, 2014). The findings also point out that, as the cost of smart meters and related communication decreases, the intention to adopt smart metering increases. Most research studies that model consumer adoption were conducted in Europe or America where smart meter adoption costs are not as high as in South Africa, therefore there is a need to further verify the impact that monetary cost has on adoption from a developing country consumer perspective. The section below considers different contexts where monetary cost has been investigated within technology acceptance studies.

Venkatesh et al. (2012) define price value as a user's cognitive balanced assessment of perceived benefits of the application versus the cost of using the system. In their research, the notion of price value was derived from marketing research, where the monetary price is usually conceptualized together with the quality of products or services to determine the perceived value of these products or services (Venkatesh et al. 2012). Their theory suggests that the cost and pricing structure may have a substantial influence on consumer use and value of a particular technology. For example, the popularity of communication via Short Messaging Service (SMS) in China was related to low pricing of the technology as compared to other internet applications. According to Venkatesh et al. (2012), price value has a positive impact on the intention to use a technology when benefits of using the technology are perceived to be greater than the monetary cost. Even though Agarwal et al. (2007) agree on the price value construct, their view of the construct is different. Agarwal et al. (2012) divided the price value into two construct concepts, namely, price and value. They define price as the amount of economic expenditure that a person has to give up in exchange for a particular good or service whereas value represents the consumer's overall assessment of the utility of a product based on the perceptions of what is received and given.

In the mobile banking context, Chitungo & Munongo (2013) define cost as the extent to which an individual believes that using mobile banking will be a costly service. In their study, Chitungo & Munongo (2013) further describe the cost of mobile banking as consisting of transactional, mobile network operator, and mobile device costs. Their findings suggest that cost has a significant influence on intention to adopt mobile banking. In the same context of mobile banking, Xiong (2016) refers to the same term "cost" (Chitungo & Munongo, 2013) and replaces it with "perceived financial cost". In the study by Xiong (2016), it was found that perceived financial cost has no impact on the adopting of mobile banking. In the context of energy management information systems in Taiwan, Hsu and Yen (2012) found that switching cost did not have a positive influence on actual behavior. The findings of both Hsu and Yen (2012) and Xiong (2016) were not congruent with those of most researchers who arguably suggest that high monetary cost has a negative impact on adopting technology (Agarwal et al.2007; Chitungo & Munongo, 2013; Tung et al.2014; Venkatesh et al.2012).

In South Africa, the cost and pricing structure of electronic toll systems has had a significant negative impact on the adoption of technology, even though it provides many benefits to motorists and for traffic management in general (Matsiliza, 2016; AA Report, FIP and E-tolls Report, 2014). It was, therefore, important to consider the potential impact that monetary cost has on the adoption of smart meter technology.

5.2.7 Perceived Value (PV).

This is another independent construct that has been integrated into the TAM to help predict the behavioral intention to accept or reject smart meter technology within the South African context. Perceived value can be defined as a consumer's overall subjective evaluation of the utility of a product or service mainly based on the trade-off between perceived benefits (utility) and perceived sacrifices (cost) (Hazen et al.2015; Zeithaml, 1988). Associated with the construct of value-based adoption, Kim et al. (2007) defined consumer perceived value as the result of a trade-off between quality and monetary price. Kim et al. (2007) related quality to usefulness and monetary price to perceived sacrifice. In another definition, the term "trade off" was explained as the consumer's need to assess the product or service in terms of perceived benefits and perceived sacrifices. In this study, perceived value was defined as the overall assessment of the perceived benefits and perceived sacrifice of the intention to use smart meter technology. This can be expressed mathematically as:

Perceived Value = Benefits (functional benefits + emotional benefits) / Costs (monetary costs + time costs + energy costs + privacy risks)

In agreement, some researchers (Rogers et al.2006; Sun, 2013; Xiong, 2013), suggest that individuals may adopt a new technology if the perceived benefits outweigh the cost of acquiring or using that technology. Monroe (1990) further suggests that an increase in the perceived quality or a reduction in the perceived sacrifice increases customer perceived value, thereby increasing the acceptance of new technologies (Rogers et al.2006). In the context of mobile banking, customers will tend to have a higher perceived value if the perceived benefits of using mobile banking increase while the perceived cost is constant (Xiong, 2013). Taking into account the economic theory of utility (Xiong, 2013), consumers with a high perceived value of mobile banking are more likely to use or accept mobile banking.

Based on the literature, it is vital to consider the balance of perceived benefits and perceived cost of a new system in technology acceptance modelling (Hazen et al.2015; Rogers et al.2006; Xiong, 2013; Zeithaml, 1988). From the discussion above, perceived value is seen to be vital when investigating customer intention to accept or reject a new system. Therefore, this construct was evaluated for significance of influence in smart meter adoption.

5.2.8 Facilitating conditions.

Facilitating conditions can be referred to as the extent to which an individual perceives that the technical and organizational infrastructure required to use the intended system is available (Ghalandari, 2012; Thomas et al.2013). In agreement, Venkatesh et al. (2013) describe facilitating conditions as training and support given to individuals that is freely available within an organisation and practically invariant across users. In the context of mobile money adoption, Micheni et al. (2013) state that reliable and responsive customer support services, customer education around product features and availability of liquidity are key aspects related to facilitating conditions. In reality, facilitation in an environment that is available to all individuals can vary extensively. Ajzen (1991) outline that facilitating conditions in the adoption of a technology can serve as a proxy for actual behavioral control and influence behavior directly. Consumers with a high level of access to information, online tutorials and phones with high data transfer are more likely to use the mobile internet than consumers without these advantages. In the mobile money context, Micheni et al. (2013) suggest that the growth and adoption of a mobile money service can be quicker if appropriate facilitating conditions (such as reliable technology and adequate agent network coverage) are available.

Venkatesh et al. (2012) posit that individuals who have access to favorable sets of facilitating conditions are more likely to have a high intention to use a technology as compared to individuals with lower levels of access. Considering smart meter technology privacy concerns and other security issues outlined in various studies (NIST 7628 report, 2010; DOE, 2012), facilitating conditions can play an important role on the behavioral intention to accept smart meter technology.

5.2.9 Social norms.

Initially, researchers acknowledged that social factors play a significant role in information technology acceptance (Davis et al.1989; Lee, Lee & Lee., 2001), though they focus mainly on social norms. In the TPB model, social norms are defined as an individual's perception that most people who are important to him/her think he/she should or should not perform the behavior in question (Fishbein and Ajzen, 1975). In agreement, Ajzen (1991), Gaffar et al. (2013) and Venkatesh et al. (2012) posit that social norm/influence has perceived social pressure on individuals to perform a behavior.

The review of the literature about smart grid and smart meter technology, indicated that there are very few research studies where social norms have been examined with regard to their impact on behavioral intention to accept smart meter technology in general. In most studies that tried to investigate consumer intention to adopt technology, they either used TRA or TAM as their reference model. According to Hsu and Yen (2012), in their evaluation of social norms on the Higher Education Management Information System (HEMIS) consumer adopting factors, it was found that social norms have no positive impact on attitude towards the HEMIS. These findings were also consistent with original TAM findings. Hsu and Yen (2012) put forward two possible reasons that might have led to this finding. Firstly, HEMIS, during the time of their study, could have been a new technology, meaning consumers were not yet well versed with the technological impact such that they could mobilize against or even have a conclusive understanding of how HEMIS operates, including the risks and benefits. Hence, consumers could not evaluate properly, if their family, friends, colleagues and social group thought they should or should not adopt HEMIS. In their view, those factors could have played a major role in social norm being insignificant in impacting attitude.

In addition, the Department of Economic Development and Tourism (2014), suggests that public groups have expressed their concern about the loss of privacy and security that is introduced by smart meter technology. According to the paper, public groups are not only concerned about their loss of privacy, but also about an increased threat to their security since smart meter technology has the capability to collect detailed knowledge about a user's behavioral patterns such as sleeping time, appliances within the home or even presence or absence at home. Therefore, given this background, the impact of social norms might hamper the intentions to accept smart meter technology.

Though most researchers investigated the impact of social/subject norms on IT acceptance, some studies have found that people's perceptions about social factors are important when examining consumer-centric factors that influence the behavioral intention to acceptance of a technology (Lee et al.2001; ten Kate, Haverkamp & Feldberg, 2010; Willis, 2009).

Section 5.1 provided definition and discussion about the various constructs that have been selected for this study, thus considering SEM Stage 1. Section 5.3 presents Stage 2 of the SEM, which is measurement model development.

5.3 Measurement model development

Based on the TAM and various behavioral studies, a range of constructs were identified and relationships between these constructs were formulated. To meet the research objectives and answer the questions posed in this study, a deductive research approach was used to formulate hypotheses using the construct relationships.

This section presents only the final construct items used in development of the measurement instrument. Other constructs and construct items that were dropped during the pre-testing of the measurement model are not included. Details about these are available in Appendix 5 - Initial pre-testing.

5.4 Choice of construct measuring scale

Selection of an appropriate type of measuring scale for this study was based on what has been used in previous studies about technology acceptance and use (Belanche et al.2012; Davis et al.1989; Fathema et al.2015, Tan et al.2012;Taneja et al.2014; Thatcher et al.2009; Venkatesh et al.2012; Xiong, 2013; Xu et al.2011). Since this study aimed to develop a predictive model for adopting the implementation of smart meter technologies within the South African context, an objective outcome was expected, hence a research method (ref. Section 4.2) was chosen that enabled collection of quantitative data. Though there are various ways to collect quantitative data, Pearse (2011) points out that rating scales are still the most widely accepted way to collect data of the type required for this study.

The Likert scale type was chosen for this study and adapted to measure the smart meter technology acceptance constructs defined above (ref. Section 5.1). The decision to select the Likert scale type was dependent on the fact that the data collected needs to be precise, reliable and valid so that it will be of use to the utilities, policy makers and technology innovators for future technology acceptance and use projects. As much as the Likert scale has now become a widely accepted rating scale, there are various scale types ranging from 4-point to even 100-point scales (Preston & Colman, 2000). The reliability and validity of scale type depends on scale granularity (Pearse, 2011). Likert scales with high granularity tend to produce data that is accurate, reliable and valid with greater power of statistics.

In addition, target sample size and response rate have been suggested as other reasons for the choice of a Likert scale type (Finstad, 2010; Kline, 2011; Pearse, 2011) Likert scales ranging from 4-point (Micheni et al.2013) to 7-point (Davis et al.1989; Kaushik et al.2015; Venkatesh et al.2012; Xu et al.2011,) have been identified as the most common scale types in behavioral intention studies and 7-point and 5-point scales, specifically, were found to be most commonly used for the construct items adapted for this study. The 7-point Likert scale was found to be a better scale type solution for measuring technology acceptance and usability than the 5-point scale (Davis et al.1989; Finstad, 2010; Venkatesh et al.2012,). In support of this choice, Finstad (2010) suggests that the 7-point Likert scale tends to mirror a participant's true subjective evaluation of a usability questionnaire as compared to the 5-point scale that fails to balance sensitivity and efficiency of the participants. In addition, the 5-point scale has high interpolation in comparison with the 7-point scale. Finstad (2010) further posits that the 7-point Likert scale tends to produce results with objective accuracy in relation to high perceived ease of use.

According to Pearse (2011), all Likert scale types must consist of a declarative sentence, followed by the participant's response options indicating the extent to which they agree or disagree with the statement. In previous studies, researchers used various response option labels to assist participants to complete questionnaires. As reported above, 5-point and 7-point scales have been identified as the most used scales. The 7-point scale can provide the following response option labels: *Strongly Disagree (1), Agree (2), Somewhat Agree (3), Neutral (4), Somewhat Disagree (5), Disagree (6) and Strongly Disagree (7)* whereas the 5-point scale eliminates the two extreme options of *Strongly Disagree* and *Strongly Agree* (Pearse, 2011). This approach was used in the Initial questionnaire (Appendix 4 – Initial questionnaire), where response option labels were put on all the response options. Though providing response option labels is helpful to participants in selecting their responses, the inclusion of the mid-point or neutral point label in the Likert scale makes it prone to central point tendency error. Pearse (2011) suggests that the central tendency error is caused by participants who might not recognize the response option that matches their answer, thereby falling back to the mid-point option. This might lead to an inaccurate measure of the latent variable under investigation since the participant's response does not reflect the true subjective evaluation.

In trying to avoid the central tendency error in this research study, the 7-point Likert scale with the following two extreme response options was used: *Strongly Disagree = 1* and *Strongly Agree*

= 7, with numeric labels ranging from *2 – 6* (Appendix 9 - Final questionnaire). This representation of the 7-point scale eliminated the mid-point option, forcing the participants to choose the extent to which they agree or disagree using the numeric labels. For example, in a 7-point Likert scale with declarative statement and response options:

Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

Table 5.1: Example of the 7-point Likert scale

	Strongly Disagree	**2**	**3**	**4**	**5**	**6**	**Strongly Agree**
The smart meter will make it easier for me to monitor and adjust my electricity usage.							

Section 5.4 discussed selection of the construct scale types and their response options. Section 5.5 considers the design and development of the measurement instrument.

5.5 Measurement instrument development

There are various ways through which quantitative data can be gathered for statistical analysis. In this study, a questionnaire was used as a measurement instrument to collect quantitative data based on the 10 constructs identified in Section 5.1. Subsequent to the identification of the constructs, four to six construct items per construct were identified and adapted from previous studies and reworded to suit the smart meter technology context of this study. Thereafter, the choice of a 7-point Likert scale with two extreme response options preset the important processes that precede the design of a valid and reliable questionnaire for data collection. Hair et al. (2010) suggest that the validity and reliability of research output relies on a good measurement instrument.

The questionnaire used in the study had four sections: (1) the invitation and consent letter, (2) a brief explanation of smart meter technology, (3) demographic questions and (4) the measurement model questions (Appendix 9 – Final questionnaire). The first section presented all the relevant ethical declarations needed to conduct this research. The participants were made aware that participation in the survey was voluntary and that they could withdraw from participation at any time. They were also notified that the data collected from the survey would be kept confidential and reported in aggregate. The consent close (in the invitation close) was incorporated using the checkbox (I Agree). Some changes were made to this section and are presented in Appendix 5 - Initial pre-testing.

Section 2 of the questionnaire was provided for clarity and consistent understanding of smart meter technology, as referred to in this study, to avoid confusion amongst participants between smart meters and pre-paid electricity meters. Some changes to Section 2 were made during the pre-testing phase and are presented in Appendix 5 - Initial pre-testing.

The demographic questions section consisted of six questions used mainly to gather information about the target sample population. As in other studies by Micheni et al (2013) as well as Tan et al.2012), social-demographic data such as gender, age, income and educational level was requested, with added questions about the area of residence, the smart meter provider and the current status of smart meter usage. Various changes that were made to Section 3 from the pre-test are presented in Appendix 5 - Initial pre-testing.

The measurement model construct questions (Section 4 of the questionnaire) were also modified as a consequence of pre-testing. Initially, based on the approach used in other studies, 11 constructs, each with a minimum of four items and using a 7-point Likert scale rated from 1 – 7 (Strongly Disagree = 1 to Strongly Agree = 7) were identified and incorporated into the measurement instrument. These constructs included: Perceived usefulness (PU) (Davis, 1989), Perceived ease of use (PEOU) (Gefen et al.2003), Trust in technology (TT) (Belanche et al. 2012), Trust in service provider (TP) (Krasnova & Veltri, 2010), Trust in Legal system (TL) (Joubert & Belle, 2013; Krasnova & Veltri, 2010), Personal Consciousness (PC) (Lee et al.2001; Taneja et al.2014) Community Consciousness (CC) (Taneja et al.2014 ; Lee et al.2001), Monetary Cost (MC) (Agarwal et al.2010), Perceived Value (PV) (Venkatesh et al.2012), Privacy Risk (PR) (Xu et al.2011) and Behavioral Intention (BI) (Venkatesh et al.2012).

In order to increase reliability and validity of the measurement instrument items, the questionnaire was sent to 15 participants including smart meter experts and seasoned researchers for technical and language review. Various comments were received, and changes were made accordingly, as reported in Appendix 5 - Initial pre-testing. A revised questionnaire was pre-tested twice with a sample of 73 and 55 participants respectively, before it was sent for final distribution. The results and changes that were made to the construct items used in the design of the final questionnaire are presented in Appendix - 2 Construct Items. The final version of the questionnaire is contained in Appendix 9 – Final questionnaire.

Section 5.6 discusses the pre-testing process conducted in order to increase the validity and reliability of the measurement instrument.

5.6 Pre-testing of the measurement instrument

The questionnaire was designed using QuestionPro version 16 with the help of a Tshwane University of Technology statistician. The pre-testing of the study was conducted within South African borders with the help of smart meter experts and technicians, fellow researchers, colleagues and friends who were both using and not using smart meter technology. The pre-testing was done to remove ambiguity, avoid sensitive questions and identify and correct grammar and language errors while improving the reliability of the smart meter construct items.

All the participants were given a chance to provide feedback on the questionnaire by commenting on the language and misinterpretations. The electronic version of the questionnaire was distributed to participants on LinkedIn and Facebook, and via email and WhatsApp instant messaging. Hard copies were printed for those who did not have access to the internet. The pretesting was done in three phases with 15, 73 and 55 participants respectively.

5.6.1 Expert judgment pre-testing of the measurement instrument

The initial 15 participant pilot survey was conducted mainly to assist with technical rewording and modification of the statements based on the identified construct items. The reported changes were used to design the initial questionnaire presented in Appendix 4 - Initial Questionnaire.

After consideration and modification of items from the initial pre-test phase, a second pilot survey was conducted with approximately 73 validated participants (Appendix 1 - Construct Items). The main reason for the second pre-test of the instrument was to conduct a basic statistical confirmatory factor analysis (CFA) test of reliability and validity. Since the sample size of the pilot study survey was 73 participants, Partial Least Square Structural Equation Modelling (PLS-SEM) was used as it can accommodate small samples to check for reliability and validity as compared to the conventional Covariance-Based Structural Equation Modelling (CB-SEM) which requires 300 participants or more.

Analysis of the 73 participant pre-test survey showed that Cronbach’s alpha for all the constructs was above the cut-off point of 0.7, indicating that there was internal consistency. The Dillon-Goldstein’s rho for all the constructs was above 0.7 which indicates homogeneity of the constructs. In order to measure unidimensionality, the first Eigen values of the measurement models must be greater than 1 and the second Eigen values must be below 1. After the first assessment of the measurement model, all the first Eigen values were above 1 and the second Eigen values below 1 except for Privacy risk which was above 1. Thereafter, factor loading for each of the constructs was examined to ensure that items with low factor loadings were removed in the process to achieve construct validity. Items with factor loading below 0.7 were removed from the constructs as recommended by Kline (2011) and Büyük Öztürk (2004). Item PR1 from the Privacy risk construct was subsequently dropped, then the revised model was again assessed and achieved reliability, homogeneity, and unidimensionality.

Convergent validity evaluation for the first pre-testing.

The model was then tested for convergent validity. Convergent validity indicates the amount of variance the indicators have in common. High factor loading and Average Variance Extracted (AVE) above 0.5 are indicators of convergent validity. From the model assessment results, it was seen that the loadings for each of the constructs were all above 0.7 except for PU, PR, FC, CC and PC. In particular, the factor loading for Item PU6 under perceived usefulness was 0.67, the factor loading for item PR3 under privacy risk was 0.35, the factor loadings for items FC2 and FC4 under the facilitating conditions construct were 0.63 and 0.66 respectively, the factor loading item CC6 under the community consciousness construct was 0.62 and the factor loading for item PC6 under the personal consciousness construct was 0.66. All the items with factor loadings below 0.7 were subsequently dropped from the measurement model. The measurement model was reassessed, and the results showed AVE ranges from 0.65 to 0.81 and factor loading of 0.72 to 0.96 indicating convergent validity (AVE above 0.5 and factor loading above 0.7). Therefore, the construct validity was shown to be acceptable.

Discriminant validity test for the first pre-testing.

The last validity test applied to the measurement model was to assess discriminant validity. Discriminant validity shows how distinct a given construct is from the other constructs. It can be checked by the loyalty of the indicators to their respective latent variables which is reflected in the cross-loadings of the observed variables. The loading of the indicators associated with a given construct should be greater than their loading with any other construct. The results showed that there were no traitor indicators in the model. The loyalty of the indicators supported discriminant validity as it had a high factor loading against itself.

Since PLS-SEM was used in the assessment of the measurement model, the statistician ran a pre-test on the structural model. The hypothesis testing results showed that only perceived usefulness and perceived value were significant with a p-value of 0.00 and 0.000 respectively. Although Trust in technology was not significant at p-value < 0.00, it was the only construct, of all, that had least significance at the 0.05 level.

The comments provided by the participants of the second pre-test were studied. Some participants raised concerns about the wording of the items as they felt that the questions were targeting only smart meter users and were not accommodating non-smart meter users. In response, the items were re-worded in the future tense to incorporate those who did not have smart meter technology. The questionnaire was branched to accommodate those who were currently using smart meters. Therefore, a general question was added to determine if a participant was using a smart meter or not, with the response options: Yes/No.

5.6.2 Second phase of pre-testing of the measurement instrument.

The statistician performed a simple structural model fit and the results showed that the model could predict 63.3% of the behavioral intention to use smart meters. The equivalent PLS-SEM goodness of fit achieved was 0.63 which was not a bad fit considering the small sample size (73 participants) but the low construct significance levels for the hypothesis was a concern. Consequently, the original TAM was revisited, and two additional constructs, Attitude and Social norms were incorporated into the study model and Trust in service provider, Trust in the legal system, Personal consciousness and Community consciousness were dropped since they were not hypothetically significant based on the CFA.

New items were created for Attitude and Social norms (Appendix 2 - Construct Items) The third measurement instrument was later modified and compiled to have the following constructs: Trust in Technology (TT), Perceived Usefulness (PU), Perceived ease of use (EU), Facilitating Conditions (FC), Attitude (A), Monetary Cost (MC), Privacy risk (PR), Perceived Value (PV), Social Norms (SN) and Behavioral Intention (BI). The same 7-point Likert Scale was retained as for the first pilot model. The reworked questionnaire was sent to the 55 participants who took part in the second pre-testing survey. As before, the measurement model and structural model were tested using PLS-SEM.

The results of the second pre-test showed that MC1= 0.55, C2 = 0.65, PR2= 0.55, PU2 = 0.56, PU4= 0.68, PU5= 0.56 and PU6 = 0.48, that is, all factor loadings were a 0.7 cut off. Though Facilitating conditions and Privacy risk constructs each had one item below a cut-off of 0.7, they each had 3 recommended measuring items per construct remaining in comparison with Perceived usefulness which ended up having only 2 measuring items on the construct PU1 = 0.93 and PU3=0.86. The statistician advised rewording PU2 = 0.56 and PU4 = 0.68 since they were the ones closer to the

0.7 cut off. The changes made to the questionnaire after pre-test phase two are shown in Appendix 2 – Construct Items**.**

After all the items below a cutoff of 0.7 had been removed, the model was reassessed for reliability, homogeneity, convergent validity, discriminant validity and factor loading. Finally, all the test results achieved acceptance metrics. Factor loadings were all above 0.7, AVE above 0.5 and as for discriminant validity, all constructs were loading high on themselves other than with other constructs. The hypothesis testing on the structural model showed significant at p-value <0.001 and p-value <0.05. The final measurement instrument was used to collect the final data for this research study. Measurement model fit, construct validity and structural model fit are discussed in Chapters 6 and 7 respectively.

5.7 Data collection procedure and response rate

The main research method used to collect the smart meter related quantitative data was a self-administered questionnaire, deemed to be the most appropriate method for data collection for this study. The rationale for using this research method was its strength to keep participants anonymous, confidential and allowing them the freedom to agree or disagree about participating in the study. One of the major advantages of this research method is its ability to collect data quickly and economically from dispersed participants within the shortest time period. Though many advantages of this this method of data collection can be noted, it suffers from a poor response rate, especially when the questionnaire survey is long (leading to participants becoming fatigued) and it asks sensitive questions. In this study, the final questionnaire was evaluated again before it was sent out to participants.

A final questionnaire consultation with the Tshwane University of Technology Statistician was done in order to check if all the measuring scale types and the number of items per construct were within the acceptance ranges for future measurement and model evaluation. The appropriate permission letters were acquired and sent to various companies and public organizations within the City of Tshwane. Two research assistants were employed to carry out data collection and, based on the two data collection processes used in this study, close to 800 participants responded to the survey, although, only 768 questionnaires were completed fully. The total response rate from both the electronic and hard copy versions was approximately 60% and 80% respectively. The evaluation of missing data and the method of handling missing data is discussed in Chapter 6, Section 6.2.1.

5.8 Quantitative data analysis

The quantitative data collected from smart meter consumers were statistically processed by a statistician from the Research and Innovation Department of the Tshwane University of Technology. Chapters 6, 7 and 8 cover analysis of the results to test for measurement model and structural validity respectively. All the relevant descriptive statistics of the smart meter data are reported in Chapter 6, Section 6.5. Results of the application of SEM techniques used to test for construct validity and reliability and measurement model fit validity are presented in Section 6..1. Results of the assessment of the structural model and structural relationship testing are reported in Chapter 7, Sections 7.3 to 7.5.

5.9 Conclusion

This chapter covered Stages 1 to 3 of Hair's approach to application of SEM (Hair et al. 2010). Based on the literature review and theoretical underpinning chapters (Chapter 2 and Chapter 3 respectively), several constructs were identified (Section 5.1). These constructs provided a basis for the development of the measurement model used in this research study. Drawing on information from various behavioral and technology acceptance modelling studies, 11 constructs were identified as relevant for planning consideration of smart meter implementation in South Africa. In order to model the constructs to achieve the intended objective, a minimum of four and maximum of six construct items identified from the literature were adapted and reworded to fit this research context. This approach was consistent with that adopted in other research studies about technology acceptance. In addition, a SEM statistical rule of thumb is that a minimum of three or four construct items are deemed necessary for SEM-based research (Hair et al.2010). All eleven (11) of the constructs were tested and used in the design and compilation of the measurement instrument for this research study. The measurement instrument went through rigorous content validity and participants testing. It was tested for expert judgement and subjected to two pilot testing events to insure that the construct items were sound from the expert judgment perspective. Thereafter, two pilot testing events were conducted through the survey of people with the profile of potential participants in the research study. The pilot testing was conducted to make sure that the latent variable that is intended to be measured from the participant responses is understood clearly by all participants. Finally, the resultant output of 10 constructs were found to be relevant for use in a final questionnaire which supported data collection for the research study (Section 5.5.3). Chapter 6 discusses analysis and measurement model validity of the data collected using this final questionnaire.

CHAPTER 6:
DATA ANALYSISAND MEASUREMENT MODEL VALIDITY

6.1 Introduction

Individual constructs used in developing the measurement model for this study were identified, defined and discussed in detail in previous chapters. In particular, Chapter 5 covered step one of the two-step structural equation modeling process that deals with defining the individual constructs, specification of the measurement model and design of the measurement instrument. Chapter 6 aims to cover –step two of the two-step structural equation modelling process that tests the construct validity and measurement model fit. Consequently, there will be a focus on stages 3 and 4 of the six stage structural equation modelling process in this chapter. Firstly, quantitative data analysis procedures will be considered. These were performed to identify any problems that could affect the empirical results during the testing of the measurement model such as sample size, data entry errors, the approach to dealing with missing values and model specifications. The study's underlying measurement theory was tested, applying all relevant SEM standard rules and procedures, and an outline of the critical decisions taken to produce the empirical confirmatory results based on the study measurement theory was developed. Secondly, Chapter 6 presents the descriptive statistics and empirical results of relationships among variables and constructs mirrored in the measurement theory. Most commonly used Goodness-of-Fit (GoF) indices and construct validity measures were presented in order to check how well the measurement theory fitted the sample data that were statistically analysed.

6.2 Analysis of the quantitative data

The quantitative data used in this research study were gathered through a self-administered questionnaire that was categorized into two sections, one with demographic questions and one with construct measurement questions. The questionnaire was designed after conducting an extensive literature review and synthesis of information from similar studies (Davis, 1989, Smith et al.2010). The questionnaire consisted of six demographic questions and ten constructs with a minimum of four to six items each, amounting to 64 closed-ended questions and only one open-ended question. Most of the constructs in the questionnaire had a minimum of four measurement items each, except for trust, social norms and behavioral intentions which had six measurement items each. The questionnaire underwent content and face validity tests. After adopting constructs from a range of behavioral studies (; Abdulkadir et al. 2013; Davis, 1989; Sun, 2013; Venkatesh et al. 2012; Xiong,

2013) the questionnaire was sent to various experts, seasoned researchers and prospective participants of the sample populace for comment in order to refine and remove ambiguity. The demographic section was designed to provide data about gender, age, income and current smart meter user status, whereas the purpose of the construct measurement section was to provide data that could be statistically analysed in relation to the significance of the investigation about smart meter acceptance in South Africa (Alazzam, Bakar & Hamzah, 2012).

All the quantitative data captured from the QuestionPro version 16.1 online questionnaire and from the hard copy questionnaires were processed and converted in STATA version 13 for statistical analysis. The statistically analysed quantitative data were presented in percentages and frequencies to summarize and enable quick and easy interpretation and understanding of the results. Sections 6.2 and 6.3 describe the data capture and input process. Careful data entry and appropriate handling of missing data was vital for the level of precision required in the quantitative data analyses.

6.3 Overview of the data entry process

The quantitative data for this study was captured from two data sources, electronically using QuestionPro v16.1 and manually from the hard copy questionnaires which were collected from users and captured and verified individually on QuestionPro version 16.1 downloaded as an SPSS data file using AMOS software. This was done so that the manual entries could easily be identified during the double check verification process against the questionnaire hard copies. In order to provide good quality data for statistical analysis and to assist understanding of the results, it was necessary to report on missing data and how it was handled in the research study (Hair, Matthews, Matthews, & Sarstedt, 2017; Schlomer, Bauman & Card, 2010). Section 6.3 describes how missing data were handled in this study.

6.4 Missing data

According to Schlomer et al. (2010), missing data problems become a major challenge in behavioral sciences research. Therefore, these authors suggest that researchers must report on the proportion of missing data and how the missing data were handled because missing data is as important as any other statistical data analysis result. Peng et al. (2006) report that most researchers still omit missing data reports in their studies, because, despite the importance of doing so, they do not understand why they should include it. Dong & Peng (2013) and Schlomer et al. (2010) further suggest that reporting missing data helps readers to understand the quality of the empirical results of a study and also with interpretation of the results. In support, Schlomer et al. (2010) indicates that failure to report missing data might mean that empirical results and their interpretation may be biased. Therefore, a researcher must report missing data and outline the approach used to deal with it in order to provide unquestionable empirical results, because biased results do not add value to the body of knowledge (Schlomer et al. 2010).

Hair et al. (2010) suggest that, before a researcher can remedy (handle) and report missing data, two critical questions must be answered:

a. *Is the missing data sufficient and nonrandom so as to cause problems in estimation or interpretation?*
b. *If missing data must be remedied, what would be the best handling approach?*

6.4.1 Missing data sources.

For researchers to answer the two questions posed above, they need to understand the two common sources of missing data. Schlomer et al. (2010) point out that missing data can be as a result of item non-responsiveness by participants during the completion of the questionnaire. This may be caused by several situations depending on the participants, such as limited options on the questionnaire, sensitive questions or impractical questions. Participants may, therefore, skip or not complete some items on the questionnaire resulting in missing data.

The other source of missing data links to the problem of participant attrition (Schlomer et al.2010). Participant attrition usually occurs when data collection is done on or in two or more occasions or sessions because a participant may be available for one session and not the other leading to missing data. In other situations, participant attrition may be a result of boredom or fatigue when a participant ends up not fully completing a survey with a questionnaire-based cross-sections design (Schlomer et al.2010).

In this study, both situations relating to missing data might have occurred. Item non-responsive could have been linked to the limited options given for the gender questions and for behavioral intention, since some participants thought the questions were the same. Missing data owing to participant attrition could have occurred due to the pilot survey conducted when refining the measurement instrument.

There were four data collection events in this study, a three pilot surveys and the final data collection activity. The first pilot survey involved fifteen (15) experts and researchers who were tasked with validating the terminology and assessing the relevance of the questions in the measurement instrument. The second pilot survey involved 73 participants, including both researchers and intended participants, and was conducted to refine the questionnaire language levels and understandability, and hone the question clarity and remove ambiguities, if necessary. Participant attrition could have occurred because some of the participants involved in the two surveys could have become part of the final survey and hence skipped the questions. Apart from identifying the possible sources of missing data, as described above, there is also a need to understand the pattern of missing data because of its probable biasing effect on the data (Hair et al. 2017; Schlomer et al.2010). Section 6.3.1 considers matters associated with pattern of missing data.

6.4.2 Patterns of missing data.

Hair et al. (2010), emphasize that missing data must be addressed in cases where the missing data is non-random or more than 10% of the data item is missing. Most quantitative data researchers (Hair et al. 2010; Schlomer et al. 2010) concur that patterns of missing data have a probable biasing effect on the data. Three patterns of missing data have been described: (1) missing completely at random (MCAR), (2) missing at random (MAR) and (3) not missing at random (NMAR).

Hair et al. (2010) describe MCAR as data that show no patterns of missing data or missing values that are associated with the variables under study. In comparison, MAR is considered when the pattern of missing data for a given variable is associated with the other variables, but not related to its own values. Cautiously, Schlomer et al. (2010), outline that if the data reflects the MAR pattern, the researcher must be trying to include the variable to be observed in the analysis to avoid potential biasing. Schlomer et al. (2010) suggest that NMAR is mainly an inference pattern of missing data since the pattern of missing data is such that the likelihood of missingness is associated with the score of the same variable that a participant responded to. Hence, NMAR tends to become systematic missing data to the variable under study. For example, the participant might score high or low for a variable related to trust and then skip answering another variable associated with the same variable. Section 6.4.3 provides a brief description of the various methods used to handle missing data.

6.4.3 Methods for dealing with missing data.

In literature reviews about quantitative statistical analysis, there are a variety of methods postulated for dealing with missing data. Hair et al. (2010) propose four basic methods, namely, (1) Listwise deletion, (2) pairwise deletion, (3) imputation (mean substitution), a model-based approach that consist of maximum likelihood (ML) method and expectation-maximum (EM) and (4) full information maximum likelihood (FIML).

In agreement, Schlomer et al. (2010), classified the methods for dealing with missing data into three categories, as follows: *deletion method* that includes the listwise and pairwise methods, *non-stochastic imputation* methods that include mean imputation, regression substitution and pattern-matching imputation and the *stochastic imputation method* that includes stochastic regression, expectation maximum, multiple imputation (MI), and full information maximum likelihood. Schlomer et al. (2010) further clarify that the imputation and model-based approaches outlined by Hair et al.(2010) do not fall under imputation methods but rather are classified into two main categories, namely, non-stochastic and stochastic imputation methods. The deletion method and the stochastic and non-stochastic imputations were considered in relation to this study.

Deletion method.

The *listwise deletion method* is conventionally the simplest method used to handle missing data (Hair et al.2010; Schlomer et al.2010). This method is also referred to as the complete case wise or complete case approach where cases or responses with any missing data occurrence on the measured variable are completely eliminated from the data analysis (Hair et al.2010). This method, therefore, uses only complete cases for analysis and, as much as it is the easiest and simplest way to handle missing data, it has its disadvantages when it comes to statistical power (Table 6.1). Schlomer et al. (2010) warn against using the listwise method as it can reduce a large dataset to a small sample that might not be representative of the population as it will have lost statistical power and represents a waste of the resources used to collect the data. Apart from the loss of statistical power, the listwise deletion has a likelihood of non-convergence, meaning SEM might not come up with a conclusive solution to the study (Table 6.1).

The *Pairwise deletion method* is notably the most accommodative method for dealing with missing data. It uses the maximum data available in a dataset and is also referred to as all-available cases analysis (Hair et al.2010). Applying this method, only cases that have missing data on the required construct (variable) are removed as opposed to the listwise deletion method. The major advantage of the pairwise deletion method is its ability to maintain statistical power while having few challenges with regard to convergence. Since it uses different cases for each variable, it would not be advisable to calculate the correlation coefficient between variables (Schlomer et al.2010). A detailed discussion of model-based imputation and FIML is not considered in this section but the advantages and disadvantages of these approaches are included in Table 6.1 below.

Non stochastic imputation methods.

As mentioned above, the non-stochastic imputation methods consist of various methods, including mean imputation, regression imputation and multiple imputations. For the purposes of this research study, only mean imputation was considered. Schlomer et al. (2010) describe *mean imputation* as a method that uses the average value of the variable responses to replace the missing values in the dataset. Mean imputation assumes that the data to be used reflect the MCAR pattern and also that the values of the non-missing data are true, otherwise the results generated may be biased.

Stochastic imputation methods.

In stochastic imputation methods, *full information maximum likelihood* is one of the model-based methods that estimates parameters in the presence of both the missing data and complete data available (Hair et al.2010; Schlomer et al.2010). During the parameter estimation, FIML does not create any new datasets, unlike the mean imputation method. According to Schlomer et al. (2010) FIML produces more accurate standard errors by not reducing the sample size but rather maintaining the original sample size (Table 6.1).

Table 6.1: Methods of handling missing data- Advantages and disadvantages

Method	Advantages	Disadvantages
Complete case (Listwise)	• $\chi 2$ shows little bias under most conditions. • The effective sample size is known. • It is easy to implement using any program.	• Increases the likelihood of non-convergence (SEM program cannot find a solution) unless factor loadings are high (> 0.6) and sample sizes are large (> 250). • Increases the likelihood of factor loading bias. • Increased likelihood of bias in estimates of relationships among factors.
Pairwise (all available)	• There are fewer problems with convergence. • Factor loading estimates are free of bias. • It is easy to implement using any statistical software.	• X^2 is biased upwards when the amount of missing data exceeds 10%, factor loadings are high, and the sample size is high. • Increases the likelihood of factor loading bias. • The effective sample size is uncertain. • This method is not as well-known as the others.
Model-based (MI/EM)	• There are fewer problems with convergence. • X^2 shows little bias under most conditions. • Least bias under conditions of random missing data.	• Not available on older SEM programs. • The effective sample size is uncertain for EM.
Full information maximum likelihood	• The remedy is directly in the estimation process.	• The researcher has no control over missing data.

Method	Advantages	Disadvantages
(FIML)	• In most situations this method has less bias than other methods.	• There is no knowledge of how missing data impacts estimates. • Typically, only as a subset of fit indices.

In this study, there was missing data for all the demographic questions mainly owing to item nonresponsiveness (Section 6.3.1), whereas for some of the construct measurement item questions, for example, about trust and behavioral intention, some participants answered only one question on the construct instead of all questions. The participants thought that the questions were the same and ended up not answering all the questions for some construct items.

All the questions in the questionnaire were examined for completeness, and it became evident that some questions, especially in the construct measurement sections, were not completed fully. Missing data for the demographic questions were handled using pairwise deletion. This choice was based on the fact that descriptive statistics provide only an overview of the sample data, not necessarily statistical significance for a unit of analysis. Therefore, the descriptive statistics reported on all the data available.

About 63 of the 768 questionnaires were not answered fully. According to Hair et al. (2010), if the missing data is more than 10% of the data items then a missing data handling approach can be used to address the missing data problem. Schlomer et al. (2010) put forward various expert suggestions about the missing data percentage that can become problematic. Some researchers agree with Hair et al. (2010), while others restrict the percentage to 5%. Still others suggest that a 20% or more missing data value should be considered a problem. Contrary to these suggested cut-off percentages, Schlomer et al. (2010), emphasise that missing data can only be considered problematic based on two circumstances, namely, if the amount of the missing data affects the statistical power of the resultant sample data and the pattern of missing data.

Overall, the number of questionnaires collected that had missing data was 63 or 8.2% of the total number. The missing data percentage for this study was, therefore, more than the 5% recommended by Hair et al. (2017) and Schaffer (1999)) but less than the 10% recommended by Hair et al. (2010). Hair et al. (2017) explicitly put forward that, if the missing data is below 5%, non-treatment of missing data will not have any significant impact on the results. In such cases, using either listwise or pairwise deletion is recommended, whereas if the missing data is more than 10%, the expectation-maximum imputation method can be used (Kang 2013).

Cautiously, in this study, the recommendation by Schlomer et al. (2010) was adopted, that treatment of missing data should not be attached to a cut-off percentage but should rather be considered in terms of the pattern of data and statistical power of the resultant data. Since the pattern of missing data in this study was skewed most towards MCAR and considering the large sample dataset and factor loadings above 0.6 in this study, the listwise deletion method was used to handle the missing data issue (Hair et al.2010). Dong & Peng (2013) suggest that adoption of the listwise deletion method to handle missing data can yield unbiased analysis of the dataset. Consequently, the 63 incomplete cases were completely eliminated from the sample of 768 cases and only 705 complete valid cases were considered for statistical analysis. The elimination of the 63 questionnaires in the sample did not have any relevant impact on the sample size since a sample of 705 valid cases was still above the recommended sample size of 500 participants for a population of 52 million (Hair et al.2010; Krejcie & Morgan, 1970). The next section provides an overview of the sample selection and size.

6.5 Sample selection and size

The sample population of this study was restricted to people within the borders of South Africa. Most of the participants in the study were smart meter users and non-smart users from major metropolitan areas such as the City of Johannesburg and the City of Tshwane, but participants in other areas were also included. Though the self-administered questionnaire has inherent low response and error rates, it was considered a suitable data collection method owing to time limitations of the study and the data collection cost budget. In order to reduce researcher bias in the study, two independent research assistants were employed during the data collection process. Owing to the technical nature of the research, some additional information communicated with the aid of pictures of smart meter technology and flow of information was provided to the participants, but how the questionnaires were completed remained the participant’s responsibility.

6.6 Participants sample profile

In order to have a general understanding of the sample population, widely used demographic variable details such as gender, place of residence, educational level, age, income, smart meter user provider and smart meter user current status were collected (Lee et al.2010). These demographic variables can be very important in the future in terms of implementation, planning, awareness campaigns, workshops and other operational plans.

Though the demographic information collected had no bearing on the level of analysis in this study, it provided a global generalized view of the areas where smart meter technologies are being implemented. It also indicated the number of males and females that actively participated in a technical research study and provided income and age data that could be used for education and awareness programmes in future, in case of misunderstanding of the impact of smart meter technology in managing electricity supply and demand. The next section presents and discusses the descriptive statistics in this study.

6.7 Descriptive statistics

The measurement instrument was divided into three sections: Section A, which consisted of the invitation letter requesting consent from participants to engage in the research survey, Section B, which aimed to collect demographic information and Section C, which contained questions about the construct measurement items. For the purposes of descriptive statistics, Section B of the questionnaire was used.

6.7.1 Gender.

The first question in Section B of the questionnaire was about gender. Of a total of 705 responses, 661 valid participants indicated their gender. Table 6.2 shows that 54.16% of males were involved in this research as compared to 45.84% females. About 6.24% of participants did not complete this gender based question. In the pilot study, some participants indicated that they found this question sensitive and did not want to participate as they felt that the research questionnaire did not accommodate their sexuality. Others requested that the research instrument include more options such as transgender, gay or lesbian. Though participants requested these options in the pilot phase, the measurement instrument was not changed and the general demographic variables of male and female, based on the usual and most common demographic variables provided by Statistics South African (Statistics South Africa, 2019) were retained as the only gender options. Though some participants abstained from answering some of the demographic questions which they termed sensitive, they completed the construct measurement questions which were more important in this research study.

Table 6.2: Gender descriptive statistics

Gender	Frequency	Percentage
Male	358	54.16
Female	303	45.84
Missing data	44	6.24

6.7.2 The highest level of education.

As reported in Table 6.3, 656 participants indicated their level of education. Education level for most participants ranged from at least some form of schooling to postgraduate qualifications, including

Masters and Doctoral degrees. Only 5 (0.76%) participants had no form of schooling at all. The sample data showed that 5(0.76%) of participants had no schooling, 21 (3.20%) had some schooling, 84 (12.80%) had matriculated, 76 (11.76%) had a certificate of some form, 164 (25%) had graduated with a diploma, 203 (30.95%) had an undergraduate qualification, including an Honors degree and 103 (15.7%) had graduated with either a Masters or a Doctorate (Table 6.3). The results also showed that 49 (6.95%) participants did not indicate their level of education.

Table 6.3: Highest level of Education

Qualification	Frequency	Percentage
No schooling	5	0.76
Has some schooling	21	3.2
Matriculated	84	12.80
Certificate	76	11.76
Diploma	164	25
Undergraduate (with Honors	203	30.95
Masters and Doctorates	103	15.7
Missing data	49	6.95

Feedback from participants during the pilot study indicated that some felt the question about level of education placed a judgement on their failure to pursue further education beyond the qualification they held, hence some did not answer this question. The statistical data indicated that, in general, the participants were well educated. The results showed that most of the participants had at least matriculated with a large proportion having diplomas, degrees and post-graduate degrees. In respect of this study, level of education can assist smart meter users to understand the information they will receive from the utility company via their smart meter in order for them to make a decision about changing their electricity use behavior. Therefore, education is a potentially critical aspect in impacting change of behavior towards smart meter adoption.

6.7.3 Age descriptive statistics.

As shown in Table 6.4, only 655 participants indicated their age. The permitted minimum age of participants was 18 and there was no maximum age specified. The sample data showed 100 (15.27%) of the participants were aged between 18 and 25. The 26 to 35 age group had the highest number of participants. (195 (29.77%)) followed by the 36 to 45 age group with 191 (27.63) participants. There were 96 (14.66%) participants between the ages of 46 and 50 years, and 83 (12.67%) were older than 50. There was missing age data in 50 (7%) questionnaires. Based on feedback from the pilot study, most people, especially the woman, found it difficult to disclose their actual age so age ranges were in included in the final questionnaire. The age results indicated that it was mostly people who were within the age range of 18 to 45 years who were interested in participating in the study possibly owing to their technological inclinations and how they perceived smart meter technology to be beneficial in comparison with the older generation. The greatest number of participants were within the age range of 26 to 35 years (29%) and 35 to 45 years (27%). It was also noted from the survey that the older generation preferred the traditional monthly electricity payment system in comparison with smart meter technology.

Table 6.4: Age descriptive statistics

Age	Frequency	Percentage
18-25	100	15.27
26-35	195	29.77
36-45	181	27.63
46-50	96	14.66
> 50	83	12.67
Missing data	50	7

6.7.4 Average annual income.

As presented in Table 6.5, only 633 participants indicted their average annual salary. The majority of participants (263 (41.55%)) earned an average of less than R150 000 per year with the lowest number of participants (21 (3.32%)) earning an average of R750 000 to R899 999 per year. The sample data also show that 143 (22.59%) of participants earned between R150 000 and R299 999 per year, 92 (14.33%) earned between R300 000 and R449 999 per year, 57 (9%) earned between R450 000 and R599 999 per year, 34 (5.37%) earned between R600 000 and R749 999 per year and only 23 (3.63%) earned above R900 000. The missing data percentage was 10.21%. The table 6.5 shows the detailed statistics for incomes of the participants.

Generally, research questions about income levels are regarded as sensitive hence the high percentage of missing data reported for this demographic factor. The results indicated that, in general, the participants in this study were young adults who are in their early years of employment, hence, the need to understand the impact that smart meter technology can have in helping them save on their low incomes.

Table 6.5: Average annual Income

Qualification	Frequency	Percentage
Less than R150 000	263	41.55
R150 000 and R299 000	143	22.59
R300 00 and R449 000	92	14.33
R450 000 and R599 000	57	9
R600 000 and 749 000	34	5.73
Above 900 000	23	3.63
Missing data	103	10.21

6.7.5 Smart meter usage status.

As reported in Table 6.6, only 645 of the participants indicated their current smart meter usage status. The results indicated that the majority of the participants (358 (55.50%)) were non-smart meter users and 287 (44.50%) were using smart meter technology to manage their electricity at the time of this study. The missing data value for smart meter usage status was 60 (8.50%).

The results about smart meter usage concur with the experience of the research assistants during the survey as they. at times, needed to explain what smart meters were to provide perspective and understanding to the participants. These results suggest that smart metering is still in its infancy stages in the geographical areas surveyed, most likely because there are still challenges in the provision of electricity as a basic need (Department of Economic Development and Tourism (2014); Ndaba, 2013; Sustainable Energy Africa, 2015). Hence, this research can help in the investigation of rationale-based factors that need to be considered in relation to smart meter implementation planning within the South African context.

Table 6.6: Smart meter usage status

Smart users descriptive	Frequency	Percentage
Current users	287	44.50
Non-users	358	55.50
Missing data	60	8.50

6.7.6 Smart meter provider.

As reported in Table 6.7 only 655 of the participants indicated their smart meter service provider. The results showed that 363 (55.42%) smart meter services were provided by the City of Tshwane municipality, 89 (13.59%) by Eskom, 49 (9.31%) by the Johannesburg Metropolitan municipality, 41 (6.26%) by private companies, 26 (3.97%) by the Ekurhuleni Metropolitan municipality, 10 (1.53%)

by Non Metropolitan providers and 7 (1.07%) by the, eThekwini Metropolitan municipality. There was a report of 7.09% of missing data for the service provider question. The results concur with the Smart Metering Overview report by the SEA in 2015 which indicated that the major service providers, who are in smart meter pilot and implementation stages are City Power, the City of Tshwane, Eskom and Nelson Mandela Bay.

Table 6.7: Smart meter provider descriptive

Smart meter service provider descriptive	Frequency	Percentage
Tshwane Metropolitan	363	55.42
Eskom	89	13.59
Others	61	9.31
Johannesburg Metropolitan	49	7.48
Private Companies	41	6.26
Ekurhuleni Metropolitan	26	3.97
Non Metropolitan	10	1.53
Cape Town Metropolitan	9	1.37
eThekwini Metropolitan	7	1.07
Missing data	50	7.09

6.7.7 Residential location.

As reported in Table 6.8, only 659 participants indicated where they were residing at the time of the survey. Most of the participants (478 (72.53%)) were resident in the City of Pretoria region and 60 (9.10%) lived in the City of Johannesburg confines. The “Other” option was selected by 54 (8.16%) participants but there was no provision on the questionnaire for indicating a residential location not included as a survey option. The Ekurhuleni Metropolitan Municipality was home to 25 (3.79%) participants, 10 (1.52%) lived in the City of eThekwini, 9 (1.37%) in the Nelson Mandela Bay area, 9 (1.37%) in the Mangaung Municipality and 4 (0.61%) in Buffalo City. There was a report of 6.50% of missing data for this question. Most of the participants who participated in the study were residing in the City of Tshwane and the City of Johannesburg, the two cities that are ahead in terms of smart meter deployment in the country. (Department of Economic Development and Tourism, 2014; Sustainable Energy Africa, 2015). The results suggest that most people who are using or have an interest in smart meter deployment in their places of residence are in cities and towns where the projects have been initiated.

The descriptive statistics presented above provide a general overview of the demographic characteristics of the survey participants. The next section assesses how well the data collected fits the underlying measurement theory.

6.8 Assessment of measurement model validity

According to Hair et al. (2017), a valid measurement theory must exhibit and confirm characteristics of good research. Assessment of the measurement model helps the researcher to examine and confirm if the proposed underlying measurement theory matches the reality. Hair et al. (2010) suggest that a two-phase model assessment of both the overall model fit and construct validity must be conducted. Earlier research showed that only qualitative analyses of the face and content validity (refer to Chapter 5) were used to validate the measurement model (Hair et al.2017). However, owing to the development of SEM statistical analysis approaches, measurement models can now be assessed quantitatively using confirmatory factor analysis (CFA) model fit indices as well as construct validity estimates. In support, Ahmad et al. (2016) suggest that there are various CFA models fit indices in SEM that are used to assess how well a model fits the sample data, namely, Root mean squared error of approximation (RMSEA), Chi-Square (X^2, Degree of Freedom (*df*), Comparison Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-fit Index (GFI), Normed Fit Index (NFI), Adjusted Goodness-of-Fit Index (AGFI) and Chi-squared/f.

The CFA model fit indices are classified into three categories (Table 6.10). As mentioned above, several model fits can be reported to assess the measurement model validity, using the rule of thumb suggested by Hair et al. (2010) that at least one model index must be presented, including the degree of freedom and chi-squared. In addition, Hair et al.(2010) put forward that the output of some model fit indices is at times different depending on the SEM statistical software used to conduct the analysis. Despite the different sets of model fit outputs, (Hair et al.2010) emphasise that key model fit values such as the X^2 statistic, CFI and RMSEA must be basic to any output. The overall model fit indices used in this study are considered in Section 6.9

6.9 Fundamental model fit indices

Table 6.9 below presents the selected absolute model fit indices used in this study. The overall measurement model shows that $X^{2\,=}$ 2658.67, with a degree of freedom of 944 (p < 0.001). The *p*-value is significant using the type 1 error rate of 0.001. As suggested by Hair et al. (2010), for the measurement model to be considered a good fit, it must have at least one absolute fit and incremental fit index within the acceptable level, in addition to X^2 output.

Table 6.8: Goodness of fit indices for the measurement model

Name of category	Index	Index name	Acceptable level
Chi Square (X^2)	X^2	Discrepancy chi square	n/a
Degrees of freedom	*Df*	Degrees of Freedom	n/a
	RMSEA	Root mean squared error of approximation	<0.06 or 0.07
	GFI	Goodness-of-Fit	> 0.9
Absolute Fit	90% CI of RMSEA	90% confidence interval of Root mean squared error of approximation	0.03 - >0.08
	RMR	Root mean residual	< 0.05
	SRMR	Standardised root mean residual	< 0.05
	Normed X^2	Normed chi square	<2.0 - <5.0
	NFI	Normed Fit Index	> 0.90
Incremental Fit	NNFI	Non-Normed Fit Index	> 0.90
	CFI	Comparative Fit Index	> 0.90
	TLI	Tucker-Lewis Index	> 0.95
Parsimony Fit	PNFI	Adjusted Goodness of Fit Index	> 0.9
Indices	AGFI	Parsimony Normed Fit Index	> 0.9

Source: Hair et al. (2010), Hair et al. (2017) and Schlomer et al. (2010)

6.9.1 Absolute fit indices.

Hooper et al. (2008) suggest that absolute fit indices be used to determine how well the proposed model maps on to the sample data while validating how the proposed model has the better model fit. Hair et al. (2010) refer to absolute fit indices as a direct measure of how well the specified model represents the sample data. In this study, the absolute fit indices measured were the RMSEA, 90% confidence interval for RMSEA, and the SRMR and the Normed X^2(Table 6.9).

Root squared error of approximation.

Root mean squared error of approximation is one of the most commonly used measures that attempts to correct for the tendency of the chi-squared goodness of fit test statistics to reject models with a large sample or large RMSEA (Hair et al. 2017). Over the past years, the accepted RMSEA index cut-off value has been 0.05 or 0.08 for indicating a good measurement model fit, but with continued research advances, most researchers now recommend a cut-off value of 0.06 or 0.07 (Hooper et al. 2008; Hu and Bentler, 1999). The RMSEA index value for this study was 0.05, which is below the cut-off value of 0.06, thereby indicating that the measurement model used has a good model fit.

Hair et al. (2017) found that RMSEA has an advantage in that a confidence interval can be constructed providing a range of RMSEA values for a given level of confidence. Hair et al. (2010)

suggest the 95% confidence interval RMSEA values of 0.03 - 0.08. Hooper et al. (2008) further emphasise that a well-fitting model has a lower limit RMSEA value close to zero and an upper limit of 0.08. Considering that in this study a 90% confidence level was used for RMSEA, the results show that the true value of RMSEA was between 0.04 and 0.05, which is lower that the upper limit cut-off value of 0.08 at a 95% confidence interval.

Squared root means residual.

The squared root means residual (SRMR) was another absolute fit index examined. Hooper et al. (2008) refer to SRMR as a square root of the difference between the residual of the sample covariance matrix and the theorized covariance model. The SRMR is one of the best indices to examine in cases where there are different scales for a variable. The SRMR results show a value of 0.023 which is far below the recommended cut-off value of 0.05 (Hair et al.2017, 2010; Hooper et al.2008), thus suggesting that the SRMR indicates a good fit.

Normed $X.^2$

The final absolute fit statistic examined in this section is the normed X^2. Hair et al. (2017) express the normed chi-squared as the chi-squared value divided by the degrees of freedom (X^2/df). Hair et al. (2010) outlined that the normed chi-squared measure is commonly reported but some SEM software may not provide a statistic, hence it can easily be calculated using the model fit results. According to Hair et al. (2010), a normed chi-squared less than 2.0 is considered a very good fit while values ranging from 2.0 - 5.0 are acceptable. Thus, the normed X^2 value of 2.8 for this study indicates an acceptable measurement model fit. The next section considers the incremental fit indices examined in this study.

6.9.2 Incremental fit indices.

Hair et al. (2010) note that incremental fit indices assess how well the estimated specified model fits relative to the null model, assuming that all the variables are uncorrelated. These indices are also referred to as comparative fit indices (CFIs) or relative fit indices (Hooper et al.2008). Not all SEM programs provide all the standard output results for multiple incremental fit indices; however, the CFI and TLI are the most commonly used indices. In this study, the CFI and TLI indices were examined for model fit.

Comparative fit index.

The comparative fit index is one of the most reported incremental fit indices. Like other model fit indices, values for the index range from 0.0 – 1.0, with values close to 1.0 indicating good fit (Hooper et al.2008). Initially, a cut-off value of 0.9 (Hair et al.2010) was considered a good fit but the literature review suggests a greater CFI value of 0.95 is considered a good fit. In this study, the CFI value was 0.97, which is greater than the recommended 0.95 (Ahmad et al. 2016), thus indicating a close to perfect model fit.

Tucker-Lewis index.

The Tucker-Lewis index is also a recommended incremental fit index that needs to be reported (Hair et al.2010). Like the CFI, the TLI is similar to the NFI and only differs in that it is actually a comparison of the normed chi-square value for the null and specified model. Since the TLI is not normed, its value can be below 0 and above 1. When the TLI values are closer to 1, the model is considered a good fit while values greater than 1 indicate a better fit. In the results, the TLI measure was 0.96, which suggests a good fit.

Overall, the model fit results in Table 6.10 show that all the absolute fit indices and the incremental fit indices calculated in this study were within the rule of thumb recommended cut-off values for good model fit. Therefore, model fit results for this study indicate that the proposed smart meter measurement model provides a perfect model fit.

Table 6.9: Goodness-of-Fit for the proposed smart meter measurement model validity

Name of category	**Index**	**Recommended level**	**Measurement model values**	**Comments**
Chi Square (X^2)	X^2	n/a	2658.66	
Degree of freedom	*Df*	n/a	944	
	RMSEA	<0.06 or 0.07	<0.05	Achieved level
Absolute fit	90% confidence interval RMSEA	0.03 - 0.08	0.04 - 0.05	Achieved level
	SRMR	> 0.05	0.02	Achieved level
	Normed X^2	<2.0 and <5.0	2.8	Achieved level
	CFI	> 0.90	> 0.97	Achieved level
Incremental fit	TLI	> 0.95	> 0.96	Achieved level

The model fit assessment results (Table 6.10), indicate that the measurement model used in this study is valid. Section 6.9.3 examines and presents measurement model construct validation.

6.9.3 Construct validity.

Validating a measurement model entails determining that the measurement instrument developed is measuring what it is supposed to measure in relation to one or more of the construct or latent variables (Attuquayefio, Samuel, & Addo, 2014; Ahmad, et al. 2016; Hair et al.2010). As such, construct validity can be defined as the extent to which the measured items are accurately measuring the phenomena under consideration (Hair et al.2010). Construct validity simply confirms the accuracy of the measurement, since it provides evidence that item measures from the sample reflect the true scores from the existing population. Therefore, in order to reduce the measurement error and verify the construct validity of the measurement instrument (Hair et al.2010), model fit (i.e. goodness-of-fit validation), convergent, discriminant validity and construct reliability need to be examined. In this study, convergent validity and reliability were considered and are discussed in Section 6.9.4.

6.9.4 Convergent validity

According to Hair et al. (2010), convergent validity reflects the extent to which all the items of the same construct converge or correlate. In this study, the convergent validity was assessed based on factor loading, construct reliability and the average variance extracted (AVE). Ahmad et al. (2016) point out that convergent validity is achieved when factor loading, AVE and reliability of the measurement model are within acceptable recommended statistical parameters.

6.9.5 Factor loading

Hair et al. (2010) emphasise that construct factor loading is one of the vital statistics in evaluating convergent validity. High factor loading on the construct items suggests that the items on the latent variable have a convergence. Factor loading is considered statistically significant if a factor loading of 0.5 or higher is achieved, ideally, a recommended a lower cut off value of 0.7.

In the initial SEM measurement model evaluation, the factor loading results showed that FC2, PR2, PU2, PU2, PU4, PU5, and PU6 were all below the recommended 0.7 cut-off factor loadings. Therefore, the respective construct items were reconstructed based on information from the literature review and comments from participants in the pilot survey. Though Facilitating conditions and Privacy risk each had one item dropped that was below 0.7, each still had at least 3 construct items as recommended by Hair et al. (2010). The Perceived usefulness construct item was rigorously reworked to remove ambiguity because there were only two items left, which was below the recommended number of items per construct (Hair et al. 2010).

After the final measurement instrument was compiled, it was sent out for data collection and then SEM analysis was conducted to produce factor loading results. As indicated in Table 6.11, the standardised factor loadings for this study ranged between 0.84 and 0.96, which is above the recommended 0.7 cut-off value. These results suggest that all the items measured in the study converge at some common point in the construct and that the factor loadings are statistically significant.

Table 6.10: Standardized factor loadings

Indicator	Final item wording	Standardized factor loadings
Perceived ease of use		
EU1	I will find it easy to use a smart meter.	0.904
EU2	I will find it easy to learn how to operate the smart meter.	0.944
EU3	I will find it easy to get the smart meter to do what I want it to do.	0.904
EU4	It will not require any mental effort to use the smart meter.	0.848
Facilitating Conditions		
FC1	Facilitating conditions gaining access to information about the use of smart meters will be easy.	0.936
FC2	Facilitating conditions obtaining instructions for smart meter use will be easy.	0.962
FC3	Facilitating conditions obtaining guidelines on how to use smart meters will be easy.	0.947
FC4	I can easily get support when I experience difficulties using smart meters.	0.871
Perceived Usefulness		
PU1	Perceived usefulness make it easier for me to monitor and adjust my electricity usage.	0.944
PU2	Perceived usefulness make it easier to manage electricity usage.	0.968
PU3	Perceived usefulness make it easier for me to get timely billing information.	0.937
PU4	Perceived usefulness make it easier for me to use electricity efficiently.	0.937
Monetary Cost		
MC1	Smart meter technology will make me pay more money unnecessarily.	0.891
MC2	Smart meter technology will make me pay more than the old manual system.	0.932
MC3	Smart meter technology will cause me to incur a higher cost than the old manual system.	0.936
MC4	Smart meter technology will be expensive to a consumer like me.	0.863
Privacy Risk		
PR1	I think smart meter technology will allow easy access to my personal data without my knowledge.	0.908

Indicator	Final item wording	Standardized factor loadings
PR2	I think smart meter technology will make it easy for my personal data to be misused for market research and advertising without my knowledge.	0.949
PR3	I think smart meter technology will make me vulnerable to criminals.	0.866
PR4	I think smart meter technology will put my privacy at risk.	0.904
Perceived Value		
PV1	Smart meter technology has high value.	0.781
PV2	Smart meter technology is worth considering.	0.916
PV3	Smart meter technology will provide me with more benefits than disadvantages.	0.953
PV4	I appreciate what smart meter technology will do for me.	0.948
Trust in Technology		
TT1	I think smart meter technology is trustworthy.	0.942
TT2	I think smart meter technology is dependable.	0.920
TT3	I think smart meter technology is credible when managing electricity demand and supply.	0.925
TT4	I think smart meter technology has a good reputation in the electricity industry.	0.934
TT5	I think smart meter technology improves the reliability of my electricity supply.	0.938
TT6	I think smart meter technology records electricity billing information accurately.	0.924
Social Norms		
SN1	I will support smart meter technology use because my family supports it.	0.906
SN2	I will support smart meter technology use because my friends support it.	0.937
SN3	I will support smart meter technology use because my colleagues support it.	0.936
SN4	I will support smart meter technology use because people important to me say it helps save the environment.	0.931
SN5	I will support smart meter technology use because people important to me think it is the right thing to do.	0.940
SN6	I will support smart meter technology use if my community thinks it saves electricity.	0.877
Attitude		
AT1	I think using smart meters is a good idea.	0.959

Indicator	Final item wording	Standardized factor loadings
AT2	I think using smart meters is a wise idea.	0.954
AT3	I think using smart meters would be a pleasant experience.	0.949
AT4	Generally, I like the idea of using smart meters.	0.960
Behavioral Intention		
BI1	I will be happy to have a smart meter installed in my home.	0.964
BI2	I intend to have a smart meter installed in my home.	0.919
BI3	I will volunteer to have a smart meter installed in my home.	0.949
BI4	I am comfortable with having a smart meter installed in my home.	0.963
BI5	I am positive about a city-wide roll-out of smart meters.	0.937
BI6	I support the installation of smart meters in the city.	0.953

Apart from the assessment of factor loading in evaluating the convergent validity of the measurement model, construct reliability was assessed based on a two-phase approach. Firstly, construct reliability was assessed based on model fit indices and it indicated that the measurement model achieved a good fit (Table 6.10). Secondly, the construct reliability was assessed based on the Cronbach alpha and the AVE (Ahmad et al.2016).

6.9.6 Average variance extracted

Hair et al. (2010) note that AVE is calculated as the mean variance extracted for the items loading on the variable of interest. The resultant of the computed standardised loadings provides a summary of the construct item convergence. In cases where the SEM software does not provide the AVE statistic, the value can be calculated using the following formula:

$$AVE = \frac{\sum_{l=1}^{n} Li^2}{n}$$

Where L^i represents the standardised factor loadings,

i is the number of items

n times

The AVE is computed as the total of all the squared standardised factor loadings divided by the number of items within a latent construct under consideration. Hair et al. (2010) point out that if an AVE of 0.05 or higher is achieved then the rule of thumb suggests adequate convergence. Refer to Table 6.13 for more details.

6.9.7 Discriminant validity

Another construct validity measure that was examined in this study is discriminant validity. Hair et al. (2010, 2017) posit that discriminant validity is the extent to which the construct in the measurement model is unique from other constructs both in terms of how much it correlates with other constructs and how distinctly the measured variable represents the single construct under consideration. Therefore, discriminant validity is achieved when the AVE value of the latent variable is higher than its Squared Correlation (SC) with another latent variable in the model, showing that each latent variable shares more variance with its associated indicators than with any other variable expressed by different sets of indicators in the model. In this study, the comparison of the AVE for any two constructs with the squared correlation estimate of those two constructs shows that the AVE estimate was greater than the squared correlation estimate.

Table 6.11: Construct correlation matrix

Construct	EU	FC	PU	MC	PR	PV	TT	SN	AT	BI
EU	1.000									
FC	0.731	1.000								
PU	0.675	0.660	1.000							
MC	0.025	0.028	0.043	1.000						
PR	0.141	0.143	0.184	0.200	1.000					
PV	0.505	0.466	0.549	0.015	0.208	1.000				
TT	0.550	0.563	0.575	0.017	0.179	0.746	1.000			
SN	0.387	0.390	0.433	0.017	0.190	0.501	0.620	1.000		
AT	0.530	0.509	0.588	0.013	0.160	0.683	0.769	0.620	1.000	
BI	0.556	0.524	0.598	0.007	0.136	0.705	0.778	0.615	0.901	1.000

EU: Perceived ease of use (EU), FC: Facilitating Conditions, PU: Perceived Usefulness, PR: Privacy Risk, PV: Perceived Value, TT: Trust in Technology, SN: Social Norms, AT: Attitude, BI: Behavioral Intention.

Significance Level: *= 0.05, **0.01, ***=0.0001. Discriminant Validity: AVE values > Squared correlations : **NOTE**: Values below the diagonal are correlation estimates among constructs, the diagonal element is constructed variance, and values above the diagonal are squared correlations

Thus, the results in Table 6.12 provide evidence that the constructs were unique to other constructs and achieved discriminant validity. Table 6.12 summarises the correlations of constructs in the measurement model.

6.9.8 Construct reliability

Another convergent validity measure that was considered in this study was construct reliability. Construct reliability refers to how consistent the measurement model is in measuring the latent variable repeatedly (Ahmad et al.2016). In most research studies, the coefficient alpha remains the most commonly used and applied statistical estimate, though it may understate reliability. According to Hair et al. (2017), reliability for the construct is assessed using the Cronbach alpha and AVE statistics. In this study, the Cronbach alpha, internal consistency values and AVE were used as the statistics to assess construct variability. The results are presented in Table 6.13 and Table 6.14 respectively.

Table 6.12: Summary of the Standardized factor loadings, Reliability and Average extracted variance

Construct	Factor loading	Cronbach alpha (Construct reliability)	Average variance extracted
	0.904		
Perceived ease of use	0.944	0.944	0.811
	0.904		
	0.848		
	0.904		
Facilitating Conditions	0.944	0.961	0.864
	0.904		
	0.848		
	0.904		
Perceived Usefulness	0.944	0.972	0.896
	0.904		
	0.848		
	0.904		
Monetary Cost	0.944	0.947	0.540
	0.904		
	0.848		
	0.904		

Construct	Factor loading	Cronbach alpha (Construct reliability)	Average variance extracted
Privacy Risk	0.944	0.949	0.549
	0.904		
	0.848		
	0.904		
Perceived Value	0.944	0.945	0.543
	0.904		
	0.848		
	0.904		
Trust in Technology	0.944	0.975	0.865
	0.904		
	0.848		
	0.904		
Social Norms	0.944	0.971	0.849
	0.904		
	0.848		
	0.904		
Attitude	0.944	0.977	0.608
	0.904		
	0.848		
	0.904		
Behavioural Intentions	0.944	0.981	0.6.00
	0.904		
	0.848		

NOTE: If the Factor Loading >= 0.7, AVE cut off values > 0.5 and Cronbach alpha > =0.7 **then the constructs show Convergent validity.**

Ahmad et al. (2016), Hair et al. (2010) and Hair et al. (2017) indicate that, to achieve an acceptable construct reliability, the value of Cronbach alpha for all the constructs in the measurement model should be at the cut-off level of 0.6 or higher. Ideally, 0.7 should be the minimum recommended acceptable value, while an AVE cut-off value above 0.5 is also recommended. The construct reliability estimates are indicated in Table 6.14 below.

Table 6.13: Construct reliability: Internal consistency and Average extracted variance

Construct	Average item-test correlation	Cronbach alpha	Average extracted variance (AVE)
Perceived ease of use (EU)	0.926	0.944	0.811
Facilitating Conditions (FC)	0.945	0.961	0.864
Perceived Usefulness (PU)	0.962	0.972	0.896

Construct	Average item-test correlation	Cronbach alpha	Average extracted variance (AVE)
Monetary Cost (MC)	0.930	0.947	0.54
Privacy Risk (PR)	0.931	0.949	0.549
Perceived Value (PV)	0.926	0.945	0.543
Trust in Technology (TT)	0.943	0.975	0.865
Social Norms (SN)	0.934	0.971	0.849
Attitude (AT)	0.967	0.977	0.608
Behavioral Intentions (BI)	0.956	0.981	0.600

Significance Level**: *= 0.05, **0.01, ***=0.001.**
If the AVE cut=off values > 0.5 and Cronbach alpha > =0.7 **the construct has achieved construct reliability.**

Both the results for convergent and discriminant validity for this study indicated that the measurement model constructs were valid and significant. Also, the AVE, average inter-item correlation, and Cronbach alpha values suggested that all measurement items were both significant and consistent.

6.10 Conclusion

Chapter 6 covered Stages 3 and 4 of the six-stage structural equation modelling process (Hair et al.2010). The quantitative data used in this study were collected from the major cities of South Africa using both electronic and hard copy questionnaires. The electronic questionnaire was distributed by email and via social media, while the hard copy questionnaire was printed and administered manually by two research assistant to avoid direct principal researcher involvement. Including both formats, 768 questionnaires were gathered of which 705 were assessed to have valid responses. The 63 incomplete questionnaires were eliminated using the listwise deletion method to address the missing data. The responses contained in the 705 complete questionnaires were statistically processed using STATA version 13. The complete case wise sample of 705 valid questionnaires was above the recommended sample size representative of the overall population under consideration (Hair et al.2010; Krejcie & Morgan, 1970).

Descriptive statistics provided an overview of the demographics of the participants in terms of their gender, level of education, age, income, their residential location, their smart meter user status and their smart meter provider. Missing data for the descriptive statistics were handled using the pairwise deletion method. The reason for using a pairwise approach was mainly to be able to report on an overview of the sample data as compared to the listwise approach that was used for the construct measurement questions. The construct measurement questions could not have missing data because of the risk of introducing bias into the research statistics.

The sample data showed that more males (54.1%) than females (45.9%) participated in the study. The demographic data indicated that most of the participants were adults between the ages of 18 and 45 years. Generally, the participants were well educated with post school qualifications that ranged from certificates to doctorates. This might suggest that participants are sufficiently well educated to want to understand how smart meter technology can impact their lives. The descriptive data showed that most of the participants resided in the City of Tshwane (72%) while the least number of participants were from Bloemfontein (0.61%).

The 705 valid responses were statistically assessed for goodness-of-fit, construct validity and reliability. The results in Tables 6.10 showed that the sample data represented the proposed model and also that all the constructs were valid. The model data indicated a chi-square of 2568 and degrees of freedom of 944 ($p < 0.000$) and absolute fit indices as follows: RMSEA of 0.05, SRMR of 0.02 (which are both below the recommended cut-off of 0.06 and 0.05 respectively) and a Normed chai-square of 2.8 (which was below the cut-off of less than 5. The model data also indicated incremental fit indices, as follows: CFI of 0.97 and TLI greater than 0.96 (which are both above the recommended cut-off value of 0.95).

It was also found that the measurement model achieved the recommended levels of construct validity and reliability (Tables 6.13 and 6.14). The convergent validity was assessed through standardised factor loadings (Table 6.11) which were higher than the recommended 0.7 cut-off value, an AVE value of 0.5 and an internal reliability value of above 0.7. Having determined the validity of the measurement model, the next step was to evaluate it for structural theory and structural model validity. These analyses represent the last two stages of the six-stage structural equation modelling process and are discussed in Chapter 7.

CHAPTER 7:
STRUCTURAL MODEL EVALUATION

7.1 Introduction

Chapter 6 dealt with evaluation of the sample data and measurement model validity through assessment of the construct validity and reliability. This chapter deals with the final two stages of the six stage structural equation modelling process, namely, Stage 5, which involves specifying the structural theory, and Stage 6, which requires assessment of the structural model validity. Firstly, the structural theory was assessed by defining the structural relationships between constructs of the proposed model. The various constructs that were used in the structural model and their relationships were motivated and established. This led to the creation of a visual path analysis diagram to establish a proposed smart meter structural model. Secondly, the proposed structural model was evaluated using goodness-of-fit indices to verify if the structural relationships were consistent with the structural theory. Finally, the structural relationships were tested for statistical significance.

7.2 Specifying the structural model

According to Hair et al. (2010), the process of specifying and validating the structural model is a vital stage in SEM and should follow on from assessment of the measurement model (as covered in Chapter 6). According to Hair et al. (2010), a structural model is specified by establishing dependence relationship types to represent the structural hypothesis of the proposed research model. Therefore, in this study, the structural relationships between constructs were established and translated into a structural theory underlying the analysis and the visual path diagrams that were used to estimate the relationships between constructs in the proposed research model. Hair et al. (2010) further emphasizes that all structural relationships between each construct are represented by establishing a specific hypothesis and then evaluating its significance.

In order to provide general understanding of the two important terms, “structural theory” and “structural model”, Hair et al. (2010) define a structural theory as a conceptual representation of the structural relationships between constructs, whereas a structural model is described as a representation of the underlying theory of a study using various sets of equations and usually depicted in terms of path diagrams. Hair et al. (2010) further suggest that the structural relationships between the constructs be expressed using parameter estimates or path estimates.

Section 7.3 considers the structural theory basis for this study about implementation of smart meter technology.

7.3 Structural theory of the study

The proposed structural theory of this study was based on information from the behavioral studies literature about technology acceptance and use from a consumer perspective. Theory extracted from the literature was used to formulate a framework that could enable prediction of the behavioral intention to accept the implementation of smart meter technology within the South African context. There are limitations to consideration of all the possible constructs that can influence behavioral intention to accept smart meter technology. Consequently, based on extensive review of the literature and synthesis of behavioral studies theory, 10 constructs were identified and researched in this study (Chapter 5). The 10 constructs identified from related studies included four fundamental TAM variables (perceived usefulness, perceived ease of use, attitude and behavioral intentions) and an additional six variables (monetary value, privacy risk, social norms, facilitating conditions, perceived value and trust in technology). These constructs were included in the structural theory of the study.

In the proposed research model, the exogenous constructs: monetary cost, privacy risk and perceived usefulness were expected to relate to perceived value. Facilitating conditions were expected to relate to perceived ease of use, and perceived ease of use, monetary cost and trust in technology to relate to perceived usefulness. Perceived usefulness and perceived ease of use were expected to relate to attitude. Finally, social norms, trust in technology, facilitating conditions, attitude, perceived usefulness and perceived value were expected to relate to behavioral intention to accept smart meters in the context of implementation planning within the South African context.

Section 7.3 discusses the structural theory of the research model and the additional constructs that were adapted and added to the TAM are presented in Section 7.5.

7.4 The Technology Acceptance Model (TAM)

Through extensive review of the literature (Chapter 3), the TAM was identified as the research model for modelling behavioral intention to accept and use smart meters. In applying the TAM to this study, behavioral intention was defined as a consumer's indication of his/her readiness to accept and use smart meter technology (Davis et al.1989). The TAM suggests that the intention towards a behavior can be predicted from perceived ease of use and perceived usefulness that is governed by a consumer's attitude towards using a technology, such as a smart meter, as is the case in this study.

7.4.1 Attitude.

Attitude is expected to have a direct positive relationship with behavioral intentions to accept smart meter technology. According to Fishbein and Ajzen (1975), attitude is defined as the degree to which the performance of the behavior is positively or negatively valued by an individual. In support, Davis et al. (1989), suggest that the attitude towards performing a behavior is jointly influenced by perceived usefulness and perceived ease of use. This joint relationship confirmed by Davis et al. (1989) is widely accepted and verified by several past studies. As hypothesized by the TAM (Davis et al. (1989), if a consumer has a positive attitude towards using smart meter technology, he or she is more likely to have an intention to use a smart meter. Therefore, the following relationship was tested:

H1: Consumers with a positive attitude towards smart meter technology will have a positive behavioral intention to use smart meter technology.

Though the TAM provided the base on which the structural theory of the proposed research model for this study was established, it has certain weaknesses in overlooking other individual constructs that could influence the choice to accept or reject a technology (Chen et al.2011). Consequently, other individual factors were included to provide the interrogative view needed to explain or predict technology acceptance as it relates to this study about smart meter technology implementation.

7.4.2 Perceived usefulness.

Perceived usefulness is expected to positively influence both attitude and behavioral intention to accept and use smart meter technology. Perceived usefulness is defined as the prospective user's subjective probability that using a specific application will increase his or her job performance within an organizational context (Davis et al, 1989). In the context of this study, the intention to accept smart meter technology is expected to be linked to benefits that can be derived from using it. Based on previous studies, perceived usefulness has been found to be a strong determining factor in predicting behavioral intention (Davis et al.1989; Tan et al.2012, Venkatesh et al.2013,). Similar to the TAM hypothesis, perceived usefulness is most likely to encourage a consumer to derive more benefits in managing electricity using a smart meter. Therefore, the following hypothesis was tested:

H2: Consumers with higher perceived usefulness will have a positive behavioral intention to use smart meter technology.

Apart from perceived usefulness influencing behavioral intentions, Davis et al. (1989) note that there is empirical evidence that shows perceived usefulness to have an influence on attitude towards using a technology. Taking the findings of Davis et al. (1989) into consideration, this study posits that benefits derived from using a smart meter will impact positively on how a consumer perception of how favorable smart meter technologies are. Therefore, the following hypothesis was tested:

H3: Consumers with higher perceived usefulness will have a positive attitude towards the use smart meter technology.

7.4.3 Perceived ease of use.

In this study, perceived ease of use is expected to have a positive influence on both perceived usefulness and attitude. Perceived ease of use is defined as the degree to which a user perceives the effort required to use a particular technology will be minimal (Davis et al.1989; ten Kate et al.2010 ;). The structural model of this study predicted that the perceived ease of use construct has a direct relationship with both perceived ease of use and attitude. This notion is based on prior studies (Davis et al.1989; Venkatesh et al.2012). For the purposes of this study, it is postulated that if a consumer believes that using a smart meter is effortless, they are likely to exhaust all the benefits that can be derived from using it, and, when realising the maximum benefits will have a positive attitude towards using the system. Considering the finding of prior studies, if a consumer finds it easy and effortless to use a smart meter, he or she is likely to use it and have a positive attitude towards smart meter technology. Therefore, the following hypothesis is tested:

H4: Consumers with higher perceived ease of use will have a significantly positive relationship with perceived usefulness towards the use smart meter technology.

H5: Consumers with higher monetary cost will be significantly positive towards the attitude to use smart meter technology.

7.5 Technology acceptance model integrated constructs related to smart meter technology

Although the TAM was found to inadequately to provide all the relevant factors that might influence customer behavior (Chapter 3), supplementary factors that might have relevance in predicting the behavioral intention to use smart meters were added to the model developed for this study. Sections 7.5.1. to 7.4.4. consider these supplementary factors and the proposed hypothesis that were investigated in relation to these

7.5.1 Perceived Value.

Perceived value is expected to have a positive and direct influence on behavioral intention to accept smart meter technology. Perceived value can be defined as a consumer's overall subjective evaluation of the utility of a product or service mainly based on the trade-off between perceived benefits (utility) and perceived sacrifices or cost (Hazen et al.2015; Zeithaml, 1988). As found in other studies, individuals are likely to adopt a new technology if the perceived benefits outweigh the cost of acquiring or using the system (Rogers et al.2006; Sun, 2013; Xiong, 2013). Perceived value can be expressed as an equation:

Perceived Value = Benefits (functional benefits + emotional benefits) / Costs (monetary costs + time costs + energy costs + privacy risks)

In agreement, Xiong, (2013) suggests that consumers tend to value mobile banking more if the benefits of using it are greater than the monetary cost and privacy risk to be incurred. Therefore, if consumers believe that using smart meter technology is valuable, they are likely, in turn, have positive intentions towards accepting and using it. The following hypothesis related to perceived value were tested:

H6: Monetary cost negatively affects the perceived value of using smart meter technology.

H7: Consumers with higher privacy/perceived risk will have a negative influence on perceived value of smart meter technology.

H8: Consumers with higher perceived value will have a positive behavioral intention to use smart meter technology.

H9: Monetary cost positively affects the perceived usefulness of using smart meter technology.

H10: Perceived usefulness will have a positive effect on perceived value of using smart meter technology.

7.5.2 Facilitating conditions.

Facilitating conditions are expected to have a positive influence on both perceived ease of use and behavioral intentions to accept and use smart meters. According to Ghalandari (2012) and Venkatesh et al. (2012), facilitating conditions can be defined as the extent to which consumers perceives that the resources and support required to perform a behavior is available. In the context to this study, resources and support could be in the form of awareness campaigns, educational workshops and demonstration sessions on how to use the smart meters in order to enhance effortless use of the system. As suggested in some studies, facilitating conditions can influence intention to accept a technology both directly and indirectly through attitude (Fathema et al.2015; Ghalandari, 2012; Sanchez-Prieto et al. 2016; Venkatesh et al.2012). In contrast, other studies suggest that facilitating conditions are found to influence perceived ease of use as compared to their influence on attitude (Fathema et al.2015; Venkatesh et al.2012). Hence, if a consumer believes that facilitating conditions make it easy to operate a smart meter without much effort, he or she is likely to have the intention to accept smart meter technology. Therefore, the following two hypotheses were tested:

H11: Consumers with high levels of facilitating conditions will have significant relationship with perceived ease of use.

H12: Consumers with high levels of facilitating conditions would have a positive behavioral intention to use smart meter technology.

7.5.3 Trust in Technology.

Trust in technology is another of the additional independent constructs incorporated into the model used in this study. Trust in technology is expected to have a positive influence on both attitude and behavioral intention to accept and use smart meter technology. Prior research has shown that trust has been a critical factor in predicting the intention to accept and use technology (Dinev et al.2006; Gefen et al.2003; Joubert & van Belle, 2013; Zhou, 2011). In general, Mayer et al.1995:712) defines trust as the willingness of a user to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party. Based on the findings of other studies, trust becomes a key driver for intention and use of online systems owing to its relevance to deal with uncertainty and risk vulnerability transactions (Doney & Connon, 1997; Gefen et al.2003; Thatcher et al.2009). McKnight et al. (2002) further suggest that institutional-based trust (referred to as trust in technology) also has an impact on attitude toward accepting and using a particular technology. Hence, if a consumer perceives that the smart meter environment, including supporting structures and regulations, makes the environment feel safe, he or she is likely to have positive attitude towards the system, which in turn will lead to an intention to accept and use smart meter technology and a belief and trust in the technology. Therefore, the following three hypotheses were tested:

H13: Consumers with higher trust in technology will have a positive perceived usefulness towards the use smart meter technology.

H14: Consumers with higher trust in technology will have a positive attitude toward the use smart meter technology.

H15: Consumers with higher trust in smart meter technology will have a significant positive relationship with behavioral intention to use smart meter technology.

7.5.4 Social norms.

Social norms are another independent construct added to the modified TAM, which is expected to relate positively to behavioral intention to accept smart meter technology. Social norms construct is described as social pressure placed on the consumer to perform or not to perform a behavior (Ajzen, 1985; Fishbein and Ajzen, 1975). While most studies concur, that social norms have an influence on behavioral intentions, some TPB studies emphasise that the assertion holds when technology acceptance is mandatory. In this study, the influence from friends, family, colleagues, and other social groups have a positive impact on the consumer's intention to accept smart meter technology. Hence, the following hypothesis was tested:

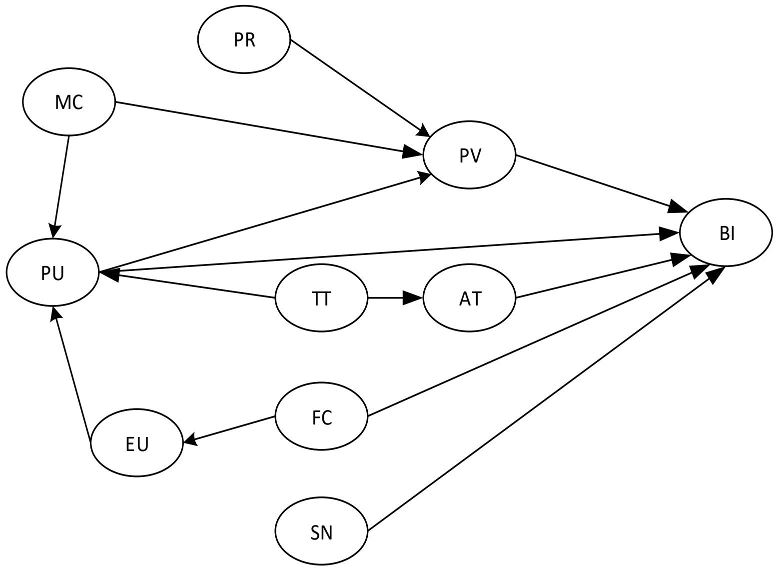
H16: Consumers with higher social norms will have a positive behavioral intention to use smart meter technology.

After the specification of the research model structural theory, all the constructs used were classified in into two groups, namely, exogenous constructs and endogenous constructs. This was done as part of the process of developing the structural model.

7.6 Structural model

In this study, a path diagram of the structural model was developed to represent the structural theory. Facilitating conditions, social norms, monetary cost and privacy risk were classified as exogenous constructs. As suggested by Hair et al. (2010) exogenous constructs are independent constructs that are used to predict other constructs in the structural model, hence they are not hypotheses that can be tested on them. Therefore, as per the path diagram, they are single-arrows that are supposed to enter then but rather, the arrows that came from them enter endogenous constructs.

Hair et al. (2010) refer to endogenous constructs as the constructs in the structural model that are determined by other constructs (exogenous constructs). They further emphasize that endogenous constructs are usually the resultant of the hypotheses to be tested and verified. Therefore, in order to test the proposed structural relationships in the structural model, structural equation modelling was used to test all 16 hypotheses. Considering the proposed research model in Figure 3.12 and Figure 7.2, only 13 hypothesis were accepted and presented in the Figure 7.1.in the structural model.



***BI**: Behavioral intention, **AT**: Attitude, **PV**: Perceived value, **PR**: Privacy risk, **MC**: Monetary Cost, **PU**: Perceived usefulness, **EU**: Perceived ease of use, **TT**: Trust in technology, **FC**: Facilitating conditions, **SN**: Social norms*

Figure 7.1: Proposed research structural model

After establishing the structural model for this study, the next step was to evaluate the structural model validity in terms of goodness-of-fit indices. These analyses are discussed in Section 7.7.

7.7 Assessment of Goodness-of-fit for structural model validity

According to Hair et al. (2010), assessment of structural model validity is the final stage of the six SEM stages. To complete this stage, the structural model depicted in Figure 7.1 (the proposed model) was examined and assessed to establish if the structural model fit was valid and if the structural relationships were consistent with the structural theory specified above (Stage 5 hypotheses and model). In this stage, the structural model fit, and the measurement model fit were comparably assessed to identify the degree to which the structural relationship had decreased the model fit.

The structural model fit in this study was examined using the same goodness-of-fit statistical indices applied to the measurement model fit (SEM Stage 4). To assess goodness-of-fit of the structural model, the same rule of thumb (as suggested by Hair et al. (2010) for the measurement model) was applied. For the structural model to be considered a good fit, it must have at least one absolute fit and one incremental fit index at an acceptable level, in addition to the ΔX^2 output. Table 6.10 provides details of the recommended goodness-of-fit indices cut-off values that were applied to both the measurement model fit and the structural model fit with a significant level cut-off value of 0.05 (Hair et al.2017, 2010; Hu & Bentler, 1999; Kline, 2011).

Table 7.1: Goodness-of-fit measure for the structural model

Name of category	Index	Proposed structural model
Chi Square (ΔX^2)	ΔX^2	3199.66
Degree of freedom	*Df*	963
Probability	*P*	0.05
	RMSEA	0.057
Absolute Fit	90% confidence interval RMSEA	0.055 – 0.06
	SRMR	0.06
	Normed X^2	3.32
	CFI	0.955
Incremental Fit	TLI	0.952

Significance Level**: *P < 0.05*, P < 0.01**, P < 0.000*** P > 0.1*** *Not Supported*

Table 7.1 shows the overall structural model fit indices for this study. The ΔX^2 was 3199.66 with a degree of freedom of 963 ($p < 0.05$). Details about the absolute and incremental fit examination and assessment are provided in Sections 7.6.1. and 7.6.2.

7.7.1 Absolute fit indices

As for the measurement model, the structural model was measured and examined using the RMSEA index which is one of the most commonly used measures that attempts to correct for the tendency of the chi-squared goodness-of-fit test statistic to reject models with a large sample or large RMSEA (Hair et al.2017, 2010). Results presented in Table 7.1 show that the RMSEA index value for this study was 0.057 which is below the cut-off value of 0.06 (Hooper et al.2008; Hu & Bentler, 1999), thereby indicating that the structural model had a good model fit. The results also showed a 90% confidence level for RMSEA of 0.055 – 0.06, which is lower that the upper limit cut-off value of 0.08 at the 95% confidence interval (Hair et al.2010; Hair et al.2017).

The SRMR was another absolute fit index examined. The SRMR result (Table 7.1) showed a value of 0.06 which was far below the recommended cut-off value of 0.08 (Hair et al.2010, 2017; Hooper et al.2008; Hyun & Park, 2010), thus, suggesting that the SRMR indicated a good fit.

The third absolute fit statistic applied to the structural model was the normed X^2. Hair et al. (2017) expressed the normed chi-squared as the chi-squared value divided by the degrees of freedom (X^2/df). Hair et al. (2010) points out that a normed chi-squared less than 2.0 is considered a very good fit while values ranging from 2.0 - 5.0 are acceptable. Thus, the normed ΔX^2 value of 3.3 for this study indicated an acceptable structural model fit. The next section presents the incremental fit indices examined in the study.

7.7.2 Incremental fit indices

Hair et al. (2010) suggest that incremental fit indices assess how well the estimated specified model fits relative to the null model, assuming that all the variables are uncorrelated. Incremental fit indices are also referred to as comparative fit indices or relative fit indices (Hooper et al.2008). As with the measurement model, TLI and CFI values were determined for the structural model.

The comparative fit index is one of the most reported incremental fit indexes. Like other model fit indices, values for the index range from 0.0 – 1.0, with values close to 1.0 indicating good fit (Hooper et al.2008). Hair et al. (2010, 2017) put forward that a CFI value > = 0.95 is considered a good fit. In this study, the CFI had a value of 0.955, which was greater than the recommended 0.95, thus indicating a good structural model fit (Table 7.1).

Finally, the Tucker-Lewis index (as recommended by Hair et al. (2010)) was used to examine structural model fit. The TLI values closer to 1 are considered a good fit while values greater than 1 are considered a better fit. In this study, the results showed a TLI measure 0.952, thus indicating a good model fit (Table 7.1).

Overall, the structural model fit results (Table 7.1) showed similar goodness-of-fit indices in comparison to the measurement model fit indices (Table 6.10). All the absolute fit indices and the incremental fit indices presented in this study are within the rule of thumb recommended cut-off values for good fit (Table 6.9 and Table 6.10). Therefore, the model fit results for this study indicated that the proposed smart meter structural model provided a good model fit.

7.8 Comparison of the measurement model and structural model goodness-of-fit

This section provides a comparison between the measurement model fit and the structural model to assess if the structural model fit was valid and consistent with the structural theory specified in Stage 5. Based on the structural model fit results in Table 7.1, all model fit values were within the recommended cut-off values that prove a valid and satisfactory model fit., The indices indicate, therefore, that the structural model exhibited an overall good fit. As seen from the results in Table

7.2, some of the structural model fits were slightly different with the only noticeable changes associated with the ΔX^2, *df* and the normed ΔX^2. The chi squared and the degrees of freedom were the only two statistics that showed a substantial difference between the two models, with chi-squared increasing from 2658.66 to 3199.66 and a difference of 20 degrees of freedom Table 7.2). There was not much difference in the other model fit indices between the two models.

From Table 7.2 it can be seen that the absolute fit index RMSEA was slightly higher for the structural model. The same applied to the SRMR value (a difference of 0.04) and the normed ΔX^2 value (a difference of 0.5. In contrast, the incremental fit indices for CFI and TLI decreased by 0.002 and 0.008 respectively. As much as there were some differences between the index values for the two models, the structural model for the study was found to be within the recommended cut-off values for a good model fit.

Table 7.2: Comparison of Goodness-of-fit measures for measurement model and structural model validity

Name of category	**Index**	**Proposed measurement model**	**Proposed structural model**
Chi Square (X^2)	ΔX^2	2658.66	3199.66
Degree of freedom	*Df*	944	963
Probability	*P*		0.05
	RMSEA	0.051	0.057
Absolute Fit	90% confidence interval RMSEA	0.04 - 0.05	0.055 – 0.06
	SRMR	0.02	0.06
	Normed ΔX^2	2.8	3.32
	CFI	0.97	0.955
Incremental Fit	TLI	0.96	0.952
Significance Level***: P < 0.05*, P < 0.01**, P < 0.000*** P > 0.1***			

From the model fit assessment results it is evident that the structural model for this study is valid. The next section examines and presents the construct validity of the measurement model.

7.9 Hypothesis testing of the structural model

The assessment of the structural model validity was not enough to confirm the structural relationships between constructs; therefore, individual parameter estimates of the proposed model were measured to establish whether the parameter estimates were significant or not. The SEM results in Table 7.3 **(**Standardised parameter estimates) were assessed based on the coefficient β value and the p-value. According to Hair et al. (2010), a significant parameter estimates entails that the t-value must be greater than 1.96 and the p-value <= 0.05. Hair et al. (2010) also emphasise that a significant parameter estimate value must be > 0 for positive relationships and < 0 for negative relationships whereas the p-value must be < 0.01 in both instances. Though other researchers accept a p-value < 0.1 when the t-value > 1.28 as a marginal level of significance (Kwon & Suh, 2004), in this study a marginal level of significance for a hypothesis to be accepted or rejected was set at p-value is < 0.01 and t-value > 1.96 and p-value < 0.05 when t-value > 1.64 (Tenja et al.2014).

The sections below will discuss in detail how the proposed hypotheses were either accepted or rejected. For ease of presentation of the results, the discussion is organised into categories of hypotheses with similar exogenous constructs.

7.9.1 Facilitating conditions → Perceived ease of use

The structural relationship between facilitating conditions and perceived ease of use of smart meters was examined. The results indicate that there was a positive significant relationship between facilitating conditions and perceived ease of use (β = 0.867, *t* =78, *p* < 0.001). Thus, *H11* was confirmed and accepted. This means that participants agree and confirm that facilitating conditions play an important role in assisting consumers to be able to use smart meters easily. These results concur with previous research (Venkatesh et al.2013) in that, as individuals are provided with information about how to use smart meter technology, it further enhances their cognitive level. This means that when facilitating conditions increase, the perceived ease of use also increases.

7.9.2 Perceived usefulness, Privacy risk and Monetary cost → Perceived value

The structural relationship between perceived usefulness and perceived value of smart meters was also examined. The results indicated that perceived value was positively and significantly related to perceived usefulness (β = 0.688, *t* = 30.02, p < 0.001), thus confirming hypothesis *H10.* Benefits that come from the use of smart meter technology can make people value the use of smart meters. The relationship between privacy risk and perceived value of smart meters was also examined and it was found that privacy risk was significantly associated with perceived value (β = 0.0.223, *t* = 7.07 p < 0.001). Though these results confirmed hypothesis *H7*, the strength of the relationship was weak (β = 0.223). These results may suggest that, if there are many perceived risks towards the use of smart meters, this will tend to impact negatively on the use of smart meter technology. Furthermore, the relationship between monetary cost and perceived value of smart meters was also examined and found to be significant (β = -0.127, *t* = - 4.26, p <0.001). Hypothesis *H6* was confirmed, even though the relationship between the two constructs was negative and weak with a coefficient (β= -0.127).

The results indicate that if there is high monetary cost towards the use of smart meters, people tend to become negative towards the use of smart meter technology. In summary, the results showed that perceived usefulness (($\beta = 0.688$) was the best predictor for perceived values in comparison to privacy risk ($\beta = 0.223$) and monetary cost ($\beta = -0.127$) respectively.

7.9.3 Perceived ease of use, monetary cost and trust in technology → Perceived usefulness.

The structural relationship between perceived ease of use and perceived usefulness of smart meters was found to be significant ($\beta = 0.567$, $t = 18.83$, $p < 0.0001$), thus verifying hypothesis *H4*. The structural relationship between monetary cost and perceived usefulness of smart meters was found to be positive and significant ($\beta = 0.080$, $t = 3.75$, $p < 0.0001$), thus, verifying hypothesis *H9*. The results indicated that participants believed that they derived more benefits from the use of smart meters if the cost towards the use of smart meters was less. Furthermore, trust in technology and perceived usefulness were also examined and it was found that trust in technology and perceived usefulness of smart meters was positive and significant ($\beta = 0.362$, $t = 11.57$, $p < 0.0001$), thus verifying hypothesis *H13*. Participants believe that if technology is trustworthy, dependable and reliable it will, in turn, improve the perceived benefit of using smart meters.

In summary, the results showed that perceived ease of use ($\beta = 0.567$) was the best predictor of perceived usefulness in comparison with trust in technology ($\beta = 0.362$) and monetary cost ($\beta = 0.080$). The participants think that the perceived ease of use of smart meters does have an influence on their perceived usefulness of smart meters. The results also concur with the findings of previous studies (Davis et al.1989; Tan et al.2012).

7.9.4 Perceived usefulness and trust in technology and perceived ease of use → Attitude.

The relationship between perceived usefulness and attitude towards smart meters was found to be positive and significant ($\beta = 0.202$, $t = 18.83$, $p < 0.0001$). Consequently, the hypothesis *H3* was verified and confirmed. These results suggest that, as more benefits are derived from smart meter perceived usefulness, people will end up changing their attitude towards smart meters in managing electricity usage. The relationship between trust in technology and attitude was also examined and was found to be significant ($\beta = 0.690$, $t = 24.30$, $p < 0.0001$), thus hypothesis *H14* was verified and accepted. The structural relationship between perceived ease of use and attitude towards smart meters was examined and found not to be significant ($\beta = 0.055$, $t = 1.47$, $p > 0.142$), thus hypothesis *H5* was verified and rejected. This might suggest that participants think that perceived ease of use of smart meters does not have much influence on their attitude toward using smart meters.

In summary, of the three constructs that influence attitude towards smart meters, only trust in technology and perceived usefulness were found to be significant, with trust in technology being the best construct to predict the consumer's attitude towards the use of smart meters. Perceived ease of use was rejected as a construct that influenced attitude.

7.9.5 Perceived value, attitude, facilitating conditions, social norms, trust in technology and perceived usefulness → Behavioral intention.

The relationship between attitude and behavioral intention to accept smart meters was significant ($\beta = 0.70$, $t = 22.38$, $p < 0.001$), thus hypothesis *H1* was verified and accepted. The results suggest that positive attitude towards smart meter technology can be influenced by trust in technology and perceived usefulness, which in turn have a significant influence on the behavioral intention to use and accept smart meter technology. The relationship between perceived usefulness and behavioral intentions to accept smart meter technology was found not to be significant ($\beta = 0.038$, $t = 1.34$, $p > 0.01$), thus hypothesis *H2* was verified and rejected. The relationship between perceived value and behavioral intentions toward use and acceptance of smart meters was found to be significant ($\beta = 0.11$, $t = 4.07$, $p < 0.001$), thus hypothesis *H8* was verified and accepted. The more people see value in the use of smart meter technology, the more consumers will tend to accept and use smart meter technology.

The relationship between facilitating conditions and behavioral intentions was found to be not significant ($\beta = 0.020$, $t = 0.80$, $p > 0.1$), thus hypothesis *H12* was verified and rejected. The relationship between trust in technology and behavioral intention towards accepting smart meter technology was found to be positive and significant ($\beta = 0.103$, $t = 2.76$, $p < 0.05$), thus hypothesis *H15* was verified and accepted. These results suggest that consumers are willing to accept smart meter technology when it is trustworthy, dependable and reliable. The relationship between social norms and behavioral intentions to accept smart meters was found to be significant ($\beta = 0.058$, $t = 2.49$, $p < 0.01$), thus hypothesis *H15* was verified and accepted.

In summary, of all six constructs that influence behavioral intention to accept smart meters, attitude is the most relevant factor that can be used to predict a consumer's behavioral intention to accept smart meters. Though other factors, such as perceived value ($\beta = 0.11$), trust in technology ($\beta = 0.103$) and social norms ($\beta = 0.058$) were significant, they had very weak relationships with behavioral intention. Facilitating conditions and perceived usefulness were rejected as they were found not to influence consumers to accept smart meter technology, though the two constructs were found to be positively influencing perceived ease of use and attitude respectively.

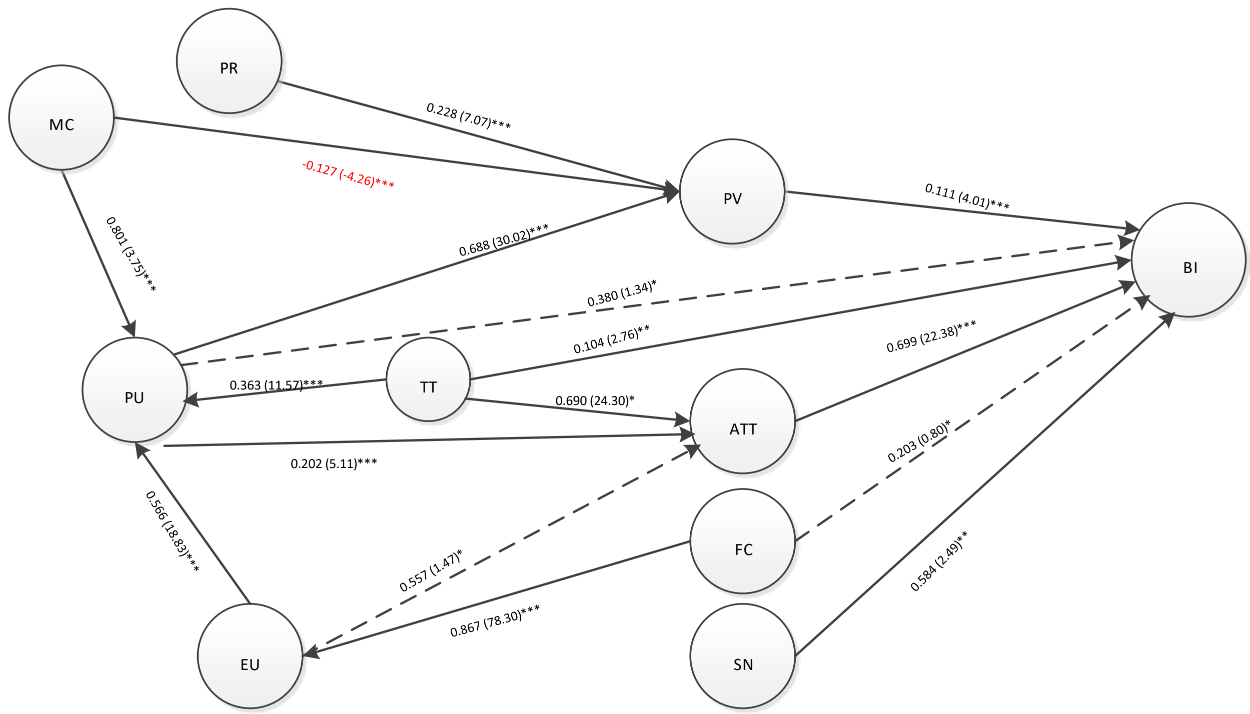


Figure 7.2: Standardized path estimates for the final smart meter structural model

Numbers in brackets are t-values. The numbers outside the brackets are standardized path coefficients. Dotted arrow lines indicate that the hypothesis is not significant (p > 0.1) *. The solid arrow lines indicate that the hypothesis is significant (p < 0.05) *, (p < 0.01) ** and (p < 0.001) ***

The structural model shows that 13 out of 16 hypotheses were found to achieve the recommended levels of significance and construct validity and reliability (Table 7.3).

Table 7.3: Structural Parameter Estimates for the Smart Meter Model

Hypothesis	**Paths**	**Std. Err**	**Coefficient (β)**	**t-value**	**Hypothesis**
H1 Facilitating conditions→Perceived ease of use	FC → EU	0.110	0.867	78.30	Supported***
H2 Perceived ease of use →Perceived Usefulness	EU → PU	0.030	0.566	18.83	Supported***
H3 Monetary Cost→Perceived Usefulness	MC→ PU	0.021	0.080	3.75	Supported***
H4 Trust in Technology→Perceived Usefulness	TT → PU	0.031	0.362	11.57	Supported***

Hypothesis	Paths	Std. Err	Coefficient (β)	t-value	Hypothesis
H5 Perceived Usefulness→Perceived Value	PU →PV	0.022	0.687	30.02	Supported***
H6 Monetary Cost→Perceived Value	MC→ PV	0.029	-0.126	-4.26	Supported***
H7 Privacy Risk→ Perceived Value	PR → PV	0.032	0.2276	7.07	Supported***
H8 Perceived ease of use →Attitude	EU → AT	0.379	0.055	1.47	Rejected
H9 Perceived Usefulness→Attitude	PU → AT	0.039	0.202	5.11	Supported***
H10 Trust in technology→Attitude	TT → AT	0.028	0.689	24.30	Supported***
H11 Perceived Usefulness →Behavioral Intention	PU → BI	0.028	0.0380	1.34	Rejected
H12 Perceived Value→Behavioral Intention	PV → BI	0.027	0.111	4.01	Supported***
H13 Attitude→ Behavioral Intentions	AT → BI	0.031	0.699	22.38	Supported***
H14 Facilitating conditions→Behavioral Intention	FC →BI	0.025	0.020	0.80	Rejected
H15 Trust in technology→ Behavioral Intention	TT → BI	0.037	0.103	2.76	Supported**
H16 Social Norm→ Behavioral Intention	SN → BI	0.023	0.058	2.49	Supported
Significance Level: **p < 0.05*, p < 0.01** , p < 0.000***, p > 0.1 Rejected**					

7.10 Conclusion

Chapter 7 focused on a consideration of the last two stages of SEM, Stages 5 and 6. The measurement model resultant was used to evaluate if the measurement instrument or measurement model was consistent and also to see if the structural specifications and relationships measured were valid. Goodness-of-fit analysis of the structural model was done, and it was found that the data collected represented a true reflection of the population behaviour.

The results in Table 7.1 indicate that the structural model shows that the constructs were valid. The structural model data had a chi-square of 23199.66 and degrees of freedom of 963 ($p < 0.000$) and absolute fit indices: RMSEA of 0.057, SRMR of 0.06 (which are both below the recommended cut-off of 0.06 and 0.05 respectively), and the Normed chai-square of 3.2 (below a cut-off <5). The incremental fit indices, CFI of 0.955 and TLI > 0.952 were both above the recommended cut-off values of 0.95 respectively.

Finally, in Table 7.3, it can be seen that 13 out of 16 hypotheses were found to achieve the recommended levels of significance and construct validity and reliability. The justification for the structural model output will be discussed in detail in Chapter 8.

CHAPTER 8:
PLANNING CONSIDERATION

"The greatest discovery of my generation is that human beings can alter their lives by altering their attitudes of mind. "William James (1842-1910)

8.1 Introduction

This chapter brings Chapter 3 (Theoretical underpinning), Chapter 6 (Measurement model evaluation) and Chapter 7 (Structural model evaluation) together into a coherent discussion of various factors that were found to be critical in the planning considerations of smart meter implementation in South Africa. Though the technology acceptance model was the chosen research model for this study, it was found not adequate to cover all the factors relevant to consumer acceptance of a pervasive technology such as smart meters. Various theories and models were reviewed to assist with the identification of the factors that are potentially critical in planning consideration of smart meters in general (Chapter 3). Thereafter, a quantitative equation modelling approach, using SEM, was implemented to evaluate the selected factors in relation to their relevance to the main aim of this research (Chapters 6 and 7). The resultant significant factors formed the basis for the development of a strategic management tool that can be used by smart meter providers in relation to planning considerations for smart meter implementation in South Africa. Development of a planning considerations tool is discussed in this chapter.

Section 8.2 provides a brief summary of the structural model and of the key relationships between the factors that potentially influence smart meter acceptance and use. Thereafter an overview of the Business Model Canvas is provided, including a discussion of the nine components (Sections 8.3 to 8.5). Section 8.6 explains how the planning guidelines were developed, based on the accepted hypotheses, and concludes with mapping the planning guidelines to the Business Model Canvas to produce a strategic management tool. The discussion, recommendations and mapping of the planning considerations help smart meter providers with better insight on smart meter planning consideration within the South African context and contribute an African perspective to research and discussion about smart meters, a topic currently dominated by research and experiences in developed countries such as Europe and the USA. Apart from providing an African perspective on the planning consideration factors, this study can provide a platform for further research into other smart meter related areas of interest in South Africa. Chapter 8 begins with a brief summary of the structural model showing the final resultant research model.

8.2 Structural model summary

Based on statistical analysis of both the measurement and structural models, documented in Chapters 6 and 7 respectively, these section summaries the structural model relationships that were evaluated as significant for this research study. The significant factors and the relationships between these are illustrated in Figure 8.1.

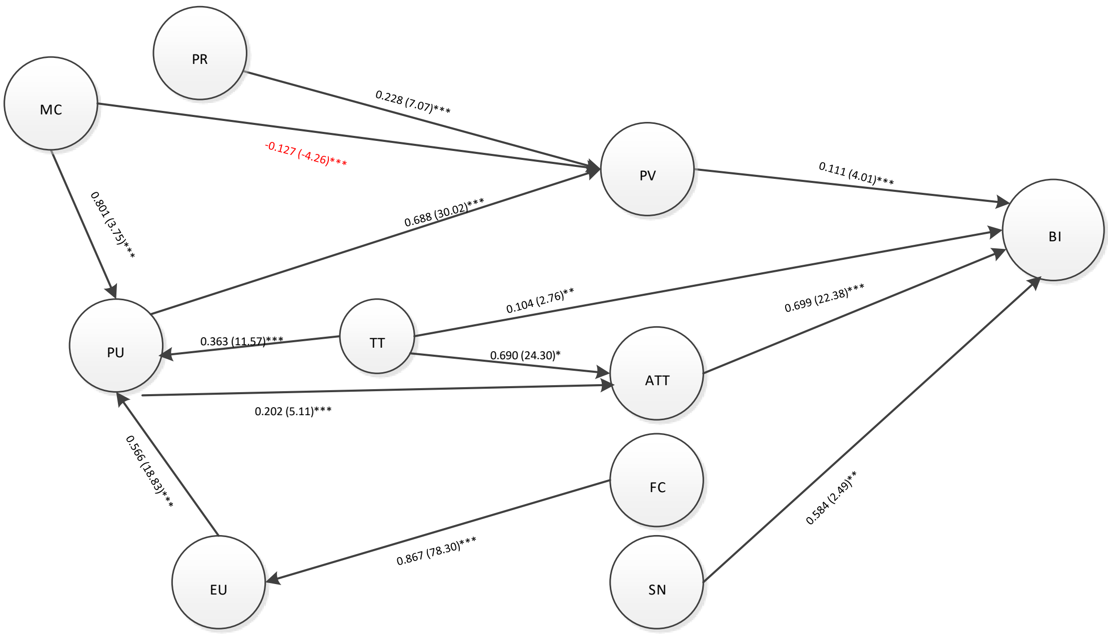


Figure 8.1: Final research model - Proposed structural relationships

Note: Numbers in brackets are t-values. The numbers outside the brackets are standardized path coefficients. Dotted arrow lines indicates that the hypothesis is not significant paths ($p > 0.1$) *. The solid arrow lines indicate that the hypothesis is significant ($p < 0.05$) *, ($p < 0.01$) ** and ($p < 0.001$) ***

As discussed in Chapter 7, 16 proposed structural relationships were identified as potentially relevant for planning considerations of smart meter implementation in South Africa. However, evaluation of the structural model confirmed that only 13 of the 16 structural relationships were significant (at *p-value < 0.05 and p-value < 0.001*) and, therefore, relevant for planning considerations for smart meter implementation.

As depicted in Figure 8.1, facilitating conditions (FC) was found to be significant when considering perceived ease of use (EU), while perceived ease of use appeared to be important for perceived usefulness (PU) from the smart meter electricity consumer's perspective. However, facilitating conditions did not seem to have any direct influence on attitude (AT) towards the use and acceptance of smart meter technology.

Trust in technology (TT), monetary cost (MC) and perceived ease of use (EU) were found to be significant when considering the perceived usefulness (PU) of smart meter technology (Figure 8.1). In the same light, perceived usefulness (PU) and trust in technology (TT) were found to be relevant in enhancing the potential smart meter consumer's attitude towards acceptance and use of smart meter technology.

While perceived usefulness (PU), and trust in technology (TT) had a significant relationship with attitude towards acceptance and use of smart meter technology, perceived ease of use (EU) was found to be insignificant in this regard (Figure 8.1). Monetary cost (MC) and privacy risk (PR) were found to have a significant relationship with perceived value (PV) indicating that these factors have a potential impact on how people view the value that smart meter technology can offer as compared with the traditional manual system in the management of electricity consumption.

Finally, it was found that perceived value (PV), attitude (AT) and trust in technology (TT) are the most critical factors that must be incorporated into planning considerations for the implementation of smart meters as they impact significantly on the potential smart meter consumer's behavioral intention (BI) to accept and use smart meter technology (Figure 8.1). It is, therefore, important to understand how these factors (as discussed above) may assist in planning and implementation of smart meters if the value proposition is to yield consideration from the potential consumer's perspective. Consequently, the findings of this study, as illustrated in Figure 8.1, should be used to facilitate the creation of guidelines for smart meter service providers. The Business Canvas Model (BMC) was used to accomplish this.

Sections 8.3, 8.4 and 8.4 discuss the BMC in relation to its purpose, its components and its potential for incorporating the results of this research study into planning consideration guidelines for smart meter implementation.

8.3 Business Model Canvas

According to Osterwalder and Pigneur (2010), the Business Model Canvas (BMC) is a shared language for describing, visualizing, assessing and changing business models. The BMC describes the rationale of how businesses create, deliver and capture value in the economic, social and cultural contexts that form part of the business. In short, the BMC is a method of representing the key aspects of a complex business environment. These key aspects or components are shown in Figure 8.2.

Application of the BMC provides insights about what customers wants and how these needs can be met through a mixture of activities and services (Teece, 2010). For the purposes of this study, and in order to understand the value propositions, activities, and resources that are critical to the successful implementation of smart meter technology, the accepted hypotheses were mapped to the nine components of the BMC. The outcome of this exercise was a strategic management tool for planning considerations in the implementation of smart meter technology within the South African context.

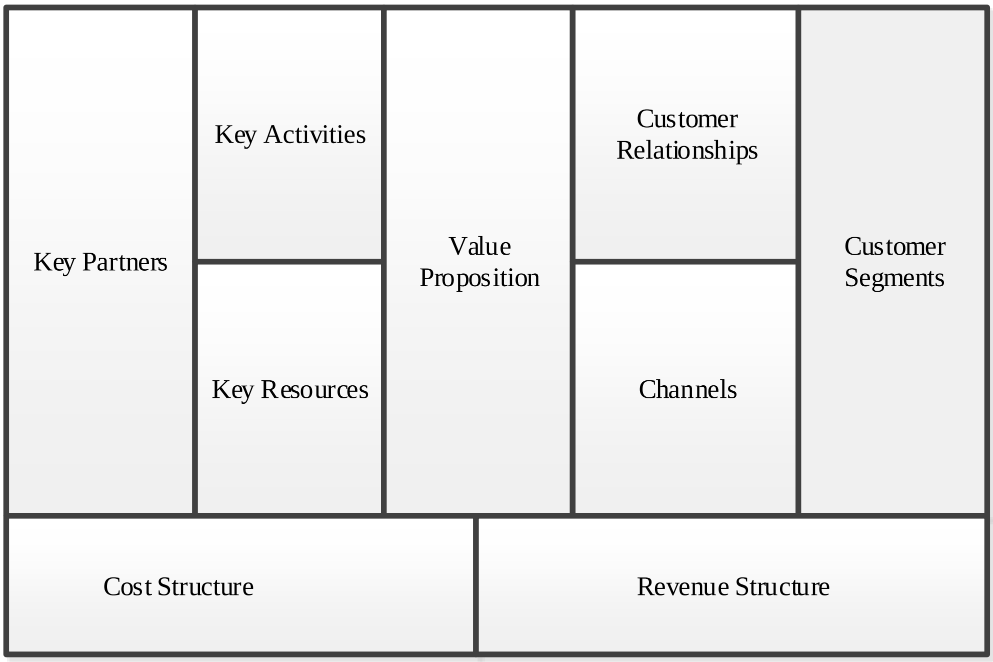


Figure 8.2: Components of the Business Model Canvas Framework (Adapted from Osterwalder and Pigneur (2010))

8.4 Overview of the Business Model Canvas

According to Osterwalder and Pigneur (2010), the nine components of the BMC (Figure 8.2) can be grouped into four main business focus areas, namely, (1) customers, (2) offers (value proposition), (3) infrastructure and (4) financial viability. Business models like the BMC can, therefore, provide a roadmap for implementation of successful value proposition through business structures, processes and systems (Osterwalder & Pigneur, 2010).

8.5 Business Model Canvas components in relation to

Section 8.5 discusses each of the nine components of the BMC to provide an understanding of the model in relation to its use in this study.

a. Customer segments

The customer segments component of the BMC represents different types of customers, classified into categories based on their needs, common characteristics and behaviors. Consideration of customer segments is critical to the successful acceptance of new innovations and sustainable revenue generation for any business. Although customer segments were not explicitly identified in this research study, inferences made from the demographic data collected indicate that there are various stakeholder groups that should be considered in smart meter acceptance and implementation. Inferred potential customer segments, in relation to smart meter adoption, include residential and business customers, computer illiterate and computer literate customers, low, middle and high income earning customers and customers with varying degrees of environmental consciousness. Considering the main objective of this research, ascertaining the various customer segments relevant in planning consideration for successful acceptance of smart meter technology is a critical exercise. Therefore, in order to effectively present a value proposition that different stakeholder groups can accept and buy into with minimal resistance, smart meter providers must thoroughly investigate and identify customer segments that are relevant to the smart meter industry. More information about mapping of customer segments into the BMC is provided in Section 8.6.

b. Value Proposition

Value proposition in the BMC relates to a business creating values for its customers by offering a variety of products and services that can solve the customer's problems or satisfy their day-to-day or long term needs (Osterwalder and Pigneur, 2010). Since smart meters are a new technology for managing electricity supply to various customer segments, utility companies need to provide a value proposition that will be perceived to be more beneficial and useful in comparison with what they are currently using. The value propositions that a utility company could put forward in relation to smart meter acceptance and use range from perceived ease of use , facilitating conditions and reduced cost to control and management of electricity consumption and efficient customer feedback. It is important that the value propositions offered by smart meter providers seek to solve customer problems and satisfy their needs (Osterwalder and Pigneur, 2010), otherwise the result is fruitless expenditure. In general, higher value propositions lead to better acceptance.

c. Channels

According to Osterwalder and Pigneur (2010), channels in the BMC represent the modes or mediums through which the business value propositions are communicated to the target customers. The context of the smart meter industry, channels are, therefore, the means through which smart meter providers can achieve the following:

1. Make the customer segments aware of the smart meter provider's value propositions.
2. Help the customers to evaluate the smart meter provider's products and service on offer.
3. Allow customers to purchase specific products or services offered by the smart meter provider.
4. Enhance the smart meter provider's capacity to deliver its value proposition to its customers (for example, through distribution).
5. Provide smart meter post-implementation support to the smart meter customers.

In general, there are a variety of channels that can be used to make customers aware of, evaluate, deliver and support the value propositions of a business. In the context of this research study, various channels that a smart meter service provider could use to reach different customer segments include radio and TV advertisements, print mass media, USSD and SMS campaigns, web portals, social media, billboards and demonstration videos. Some of these channels are referred to as direct channels (for example: mass media advertisements) while indirect channels include advertisement and sales through a partner distribution store. Although there may be many channels that could be utilized to convey value propositions associated with smart meter technology, it is critical to understand the different channels that would be relevant for specific customer segments. Practically, smart meter providers need to consider a suitable mix of direct and indirect channels to achieve the five actions listed above.

d. Customer relationships

Customer relationships, in the context of the BMC, are described as the types of relationships that a business establishes and maintains with each of its customer segments. According to Osterwalder and Pigneur (2010), these customer relationships can be established and maintained through personal contact, virtual (online) engagement, automated communication or a mixture of these. Considering that some of the relationships with customer segments in smart meter implementations are remotely controlled with some virtual interactions, it is very important that smart meter users are constantly informed, and their problems solved as quickly as possible. Also, since the level of computer literacy may vary within and between customer segments, businesses need to develop various types of relationships with their customer segments in order to attract new customers and retain existing ones thereby encouraging re-use of smart meter products and services.

e. Revenue streams

Revenue streams is an important component of the BMC because it represents viability in terms of profitability of a business. For sustained viability, smart meter providers need to understand the streams through which revenue will be generated such as sale of electricity and services, commission from partners or suppliers, fees for coordinating the suppliers and buyers and fees for renting or leasing equipment. Therefore, an understanding of the various revenue streams by smart meter providers is the basis for profitability and viability. As much as the revenue streams component is important, the cost structure becomes equally important for business profitability projections.

f. Cost structure

Cost structure is considered to be the most important component for determining whether or not a business will be a going concern. The operating costs of a business relate to creating and delivering the value proposition and maintaining customer relationships while generating enough revenue to sustain the business. In the smart meter industry, if the costs of operating smart meter technology infrastructure and services are higher than the revenue generated, then service providers will run at a loss and could potentially liquidate. In simple terms, if the smart meter value proposition does not attract enough customers to acceptance and ongoing use of smart meter technology, then service providers will go out of business.

g. Key resources

Key resources is also an important component of the BMC associated with creating and delivering the value propositions. Key resources include the following: reaching markets, maintaining relationships with customer segments and generating revenue depending on the nature of the business. Key resources can be classifed as physical, intellectual, human capital or even financial resources. Key resources facilitate the activities of a business that enable it to achieve its intended objective.

h. Key activities

The key activities have a direct relationship with the key resources discussed above. Key activities refer to the most important planned activities that a business needs to action in order to create and offer the value propositions to their customer segments. If these activites are not actioned, the footprint of the business, customer relationship creation and maintainance and revenue generation will remain only a strategic objective.

i. Key partners

It may be difficult for a business to acquire all the resources that it needs and perform all the key activities it requires to create and deliver the value propositions to its intended and exisitng customer segments. Therefore, creation of key partnerships with other businesses can assist in optimising the allocation of key and general resources and in actioning key activities. Reduction of risk and uncertianities and acquisition of specific resources and activities can be accomplished through business partnerships.

Section 8.6 details how the planning consideration guidelines were derived, based on the accepted hypotheses from the investigations and mapping of the planning consideration on the BMC as a strategic planning implememtation tool to the smart meter providers.

8.6 Development of planning guidelines using the Business Model Canvas

This section discusses each of the 13 hypotheses that were accepted in this study in relation to planning considerations for smart meter acceptance in the South African context. The discussion covers how the Business Model Canvas was used as a framework to derive guidelines for consideration by South African smart meter providers when planning for smart meter implementation. Each of the guidelines was mapped onto the BMC to provide a simple graphic tool to assist with strategic planning for smart meter implementations.

8.6.1 Facilitating conditions and perceived ease of use.

A positive relationship between facilitating conditions and perceived ease of use was identified and confirmed (Section 7.9.1). This finding was consistent with the findings of other studies in relation to these two variables.

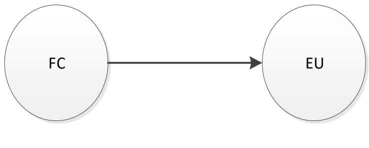


Figure 8.3: Positive relationship between facilitating conditions (FC) and perceived ease of use (EU) Source: own

Consumers with higher levels of facilitating conditions will lead to higher perceived ease of use.

The findings suggest that smart meter consumers with higher levels of facilitating conditions will find it easier to operate smart meters as compared to those with limited or low levels of facilitating conditions. Facilitating conditions reflect the extent to which consumers perceive that the resources and support required to perform a behavior are available (Venkatesh et al. 2012). The relationship between facilitating conditions and perceived ease of use suggests that perceived ease of use of smart meters can be enhanced if the smart meter consumers are provided with relevant resources and support required operating them.

Relevant resources and support can be provided to smart meter consumers through various channels. The demographic data collected showed that smart meter consumers are quite diverse (Section 6.5). Though smart meter users were not explicitly classified using these data, it was observed that there was variation in level of education, income, smart meter user status, age and area of residence suggesting various customer segments. Channels may be considered in the context of various smart meter consumer segments. Guideline 1 (G1) relates to consumer segments and channels for the provision of facilitating conditions.

G1 (Customer segmentation): Identify applicable smart meter customer segments and consider the applicability of various channels for sharing relevant resources and support with each segment.

Various channels may be considered to target smart meter users, for example, awareness campaigns, training, adverts, educational workshops, demonstration sessions or videos, instructional manuals and web portals (Ghalandari, 2012; Venkatesh et al. 2012).

Seeing that there are diverse customer segments, relevant channels have to be deployed to specific smart meter users in order to communicate the intended value proposition. For example, smart meter users with lower levels of computer literacy might benefit more through the use of dedicated help-desk support, demonstration videos, TV adverts and educational training workshops as compared to smart meter users with better computer literacy. Use of these particular channels suggests that the smart meter users with poor computer literacy need more personal attention in comparison with the computer literate users who are more technology savvy. The smart meter users with better computer literacy might need only instructional manuals, leaflets and self-help web portal instructions to learn about, adopt and use smart meter technology.

The non-smart meter users with lower levels of education and who are older might need a more personal approach in communicating the value proposition. Hence, the use of TV advertisements and educational awareness campaigns might be of assistance in showing and demonstrating how they can easily operate smart meter Technology.

Since there are various smart meter user segments, various customer relationship management strategies need to be considered. For example, smart meter users with low computer literacy might need more personal or face-to-face contact whereas smart meter users that are computer literate might cope just with an automated online self-help or web portal dashboard with real-time feeds.

Creation and delivery of value propositions to the intended and existing customer segments may need to be considered as this cannot be achieved solely by the smart meter provider. Evidence of various smart meter customer segments suggests that different facilitating conditions need to be developed for targeted smart meter users. Therefore, the need to create partnerships with relevant businesses and companies to create and deliver the perceived ease of use value proposition to smart meter customer segments becomes vital. Guideline 2 (G2) relates to facilitating conditions and business partnerships, as follows:

G2 (Partnership): Facilitating conditions must be created by partnering with experts in the applicable field.

There are many key partners that may be considered to help in the development of instructional content for advertisements, demonstration videos, training workshops, dedicated helpdesks, web portal dashboards and educational awareness campaigns. For example, the smart meter provider might need to partner with IT content/application providers to assist in the creation of interactive websites to provide demonstration videos and web portals with near real-time dashboards to target smart meter customer segments. Partnerships with mobile cellphone companies, through the use of the Unstructured Supplementary Service Data (USSD), to provide instructions to computer literate smart meter users may become vital. Partnering with a broadcasting service provider like MultiChoice or the SABC can be vital and invaluable as both providers have television and radio platforms that broadcast to the South African population at large. Since the smart meter provider cannot provide all relevant facilitating conditions to its customer segments, business partnerships are necessary, and the smart meter providers might incur some costs in the provision of facilitating conditions via its key partners (Figure 8.4).

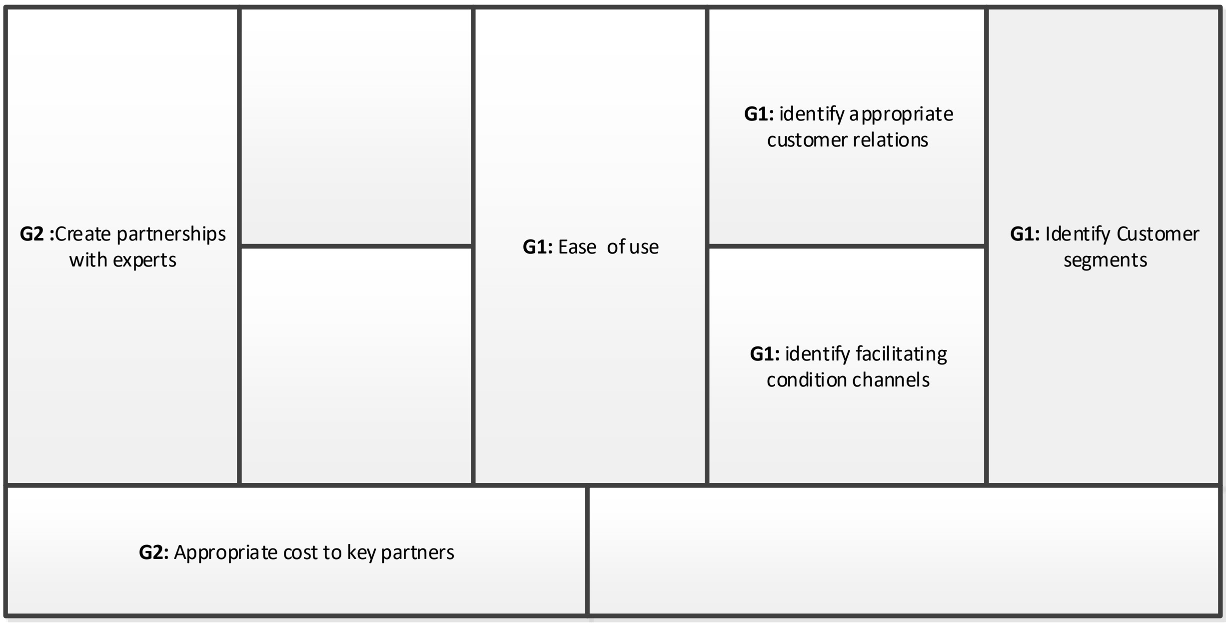


Figure 8.4: Perceived ease of use value proposition mapped onto the BMC: Source: Own

8.6.2 Perceived ease of use, trust in technology and monetary cost related to perceived usefulness.

The quantitative empirical data results showed that perceived ease of use, trust in technology and monetary cost had positive relationships with perceived usefulness (Section 7.9.3). These three proposed structural relationships explore the impacts of perceived ease of use, trust in technology and monetary cost on perceived usefulness in order to provide insight and appropriate guidelines for planning considerations for smart meter implementation in South Africa. The section below discusses the impact of these three factors on perceived usefulness, starting with perceived ease of use.

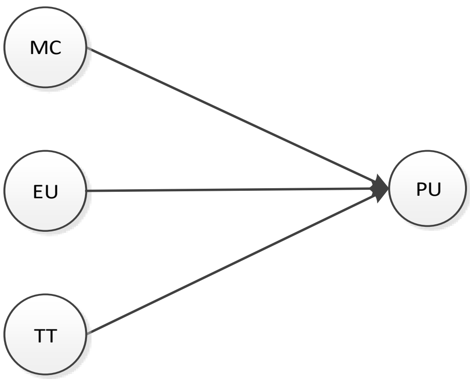


Figure 8.5: Factors that influence that influence perceived perceive usefulness. Source: Own

Perceived ease of use and perceived usefulness.

The results (Section 7.9.3) validated and confirmed the theoretical arguments that there was a positive relationship between perceived ease of use and perceived usefulness. The data significantly showed that, of the three factors, perceived ease of use was the best predictor of perceived usefulness (Section 8.4.2). This finding is consistent with research about the research TAM framework and other behavioral studies results.

Consumers with higher perceived ease of use will have a significantly positive relationship with perceived usefulness towards the use smart meter technology.

Therefore, these findings suggest that smart meter customers with higher perceived ease of use may tend to use smart meters more in comparison with those who find it difficult to operate them. Perceived ease of use is defined as the measure of the extent to which a smart meter user believes that operating smart meters requires little or no cognitive effort (Davis et al.1987 & Venkatesh et al.2012).

This means that smart meter customers who perceive that using smart meters is effortless and easy tend to believe that using smart meters is beneficial and enhances management and effective use of electricity. Results in Section 7.9.1 confirm that if a consumer believes using a smart meter is effortless, they are likely to exhaust all the benefits that can be derived from using it, consequently realizing the maximum benefits which in turn generate positive attitudes towards accepting and using the system. In contrast, if a consumer finds a smart meter difficult to use, they will end up feeling frustrated thereby leading to negative attitudes towards use and acceptance of smart meters. The relationship between perceived ease of use and perceived usefulness of smart meters was found to be significant.

As suggested in **G1**, the different smart meter customer segments identified may be evaluated based on the perceived ease of use. Applicable channels might have to be developed to demonstrate perceived ease of use functionality of the smart meters to the various identified smart meter customer segments. Guideline 3 (G3) relates to perceived ease of use and perceived usefulness.

G3 (Benefits Communication): Improve perceived usefulness by demonstrate the functionality and ease of smart meter operations to various smart meter customer segments.

The various channels identified in Section 8.4.1 may need to be considered in order to reach appropriate customer segments when demonstrating the perceived ease of use and functionality of smart meters. For example, smart meter customers who are not technologically savvy might benefit from the use of demonstration instructional videos about how to operate smart meters whereas, smart meter customers who finds it easy to operate smart meters might need only a self-help website or a social media platform with instructions on how to operate a smart meter. The use of leaflets/brochures and instructional guideline manuals might be cheaper and more effective, especially for awareness campaigns and workshops. In the same light, short television adverts during prime time, between 18:00hrs – 20:00hrs, could also be a cheaper and easier way to show and demonstrate how easy and beneficial it is to operate smart meters. While demonstrating or giving instructions might enhance ease of operation, smart meter customers must, in the end, be able to explore the most important functions and features that enable them to derive the benefits of using smart meter technology as compared to the traditional monthly metering payment system.

The partnership considerations suggested in **G2**, may also become invaluable and critical in assisting smart meter service providers to design and develop appropriate channels to demonstrate the functionality and perceived ease of use of smart meters to various smart meter customer segments. Partners with expertise in TV adverts, YouTube, mobile applications and educational materials development could assist in designing appropriate demonstration videos or instructional media that may be suitable for smart meter customers identified in Section 8.4.1. For example, TV adverts, YouTube and mobile applications can be designed for smart meter customers with limited technological knowledge whereas the instructional guideline flyer and online infographics may be relevant to those with better computer/technological knowledge. Guideline 3 was mapped onto the BMC as shown in Figure 8.4.

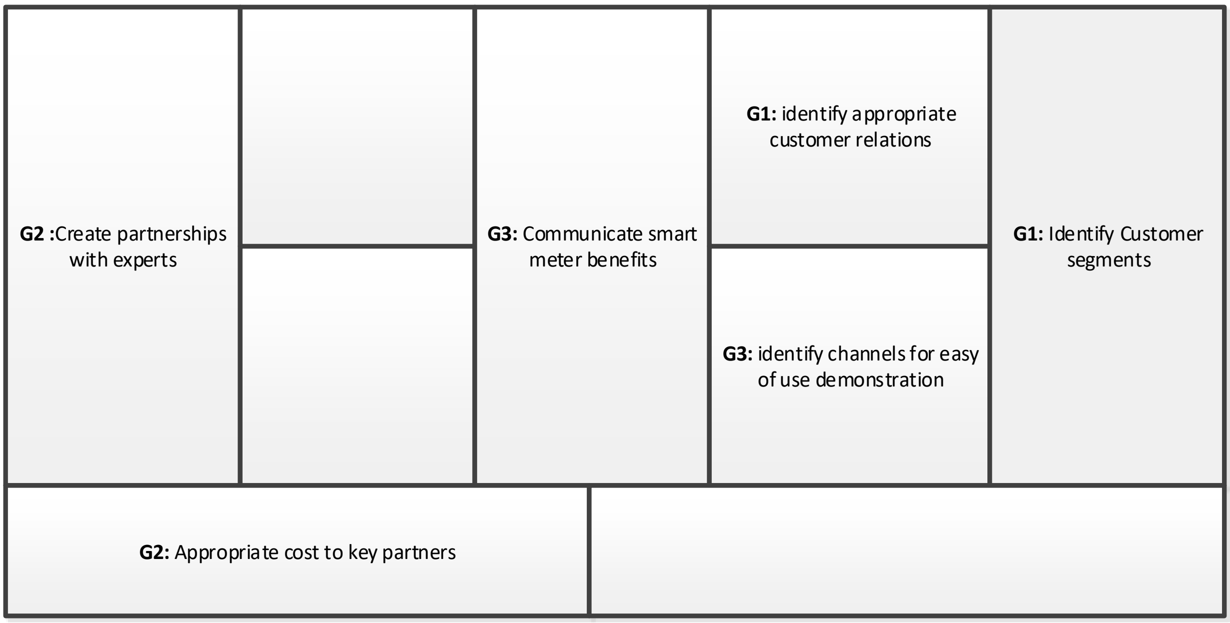


Figure 8.6: Smart meter benefits mapped on BMC, Source ; own

The next section discusses the impact of trust in technology on perceived usefulness.

Trust in technology and perceived usefulness.

Though the relationship between trust in technology and perceived usefulness might have been overlooked in technology adoption and acceptance studies, validation and confirmation of the relationship was evident in the findings of this study (Section 7.9.3.). The relationship between trust and perceived usefulness is not widely evident in many behavioral studies as most researchers tend to test the structural relationship between trust and attitude and behavioral intension (McKnight et al. 2002). The relationship between trust in technology and perceived usefulness was consistent with comments from participants during data collection activities as compared to what is suggested in the literature.

Consumers with higher trust in technology will have a positive perceived usefulness towards the use smart meter technology.

Smart meter customers with higher levels of trust in smart meter technology tend to be confident and feel safe and secure thereby deriving more benefits from using it in comparison with smart meter users who feel that smart meter technology makes them vulnerable. Trust is defined as a psychological state in which an individual is willing to become vulnerable to another party with the belief that he or she will act favorably with no opportunistic attitudes (Thatcher et al. 2009). This means that smart meter customers who feel vulnerable when the smart meters collect and track their behavioral patterns and store and process their personal information without their knowledge and control might stop using them. Hence, an increase in trust in smart meter technology may directly increase smart meter customer's perceived usefulness.

It was evident from the data collected in this study that most South African smart meter customers had issues with trusting the smart meter providers, especially the municipalities and private electricity providers, in regard to billing methods and operational transparency. During the data collection phase, customers outlined the challenges they were experiencing, such as inaccurate billing statements, selling of private personal data, third party access to private information and poor customer services. In this regard, a low trust relationship became evident, which in turn impacted on the trust relationships between the two parties. Therefore, anything that may come from these service providers may not generally be trusted. However, smart meter providers may need to build trust from the public before proposing the new metering system. Considering that smart meter technology collects, processes and disseminates information virtually between a smart meter and the service provider, there is a need for smart meter customers to trust the non-physical electronic data collection, and transparent billing becomes critical in the trust building process. Guideline 3a (G3a) considers trust and transparency in relation to perceived usefulness. Figure 8.5 shows Guideline 3a mapped onto the BMC.

G3a (Benefits Communication): Improve perceived usefulness by building trust relationships and transparent service for the applicable smart meter customer segments.

Considering the various smart meter customer segments identified in Section 8.4.1, developing appropriate trust relationships using appropriate channels becomes critical. For example, across the board (all customer segments) bi-annual or annual customer satisfaction surveys that focus on service level excellence and perceptions about smart meter technology may assist smart meter service providers with relevant insights on the services that need improvements and also on services that are performing well. In the case of users with limited or no technical knowledge of smart meters, workshops that are conducted in vernacular languages (such as Sotho, Zulu and Afrikaans) or under interpretation may be relevant to reduce miscommunication of information presented in English. The need to consider instruction in different languages became evident during the data collection phase, where some participants could not understand English, and needed interpretation to be able to understand some of the questions asked. For technology savvy customers, the use of web sites or social media platforms might be an easy and appropriate channel for providing constant online communication at regular intervals. During the February – March 2019 loading shedding, effective Facebook and Twitter electricity load shedding schedules, communicated by Eskom, City Power and the City of Tshwane proved that constant online communication is invaluable to electricity users (Twitter and Facebook account for the respective service providers, 2019). This enables the electricity user to adjust daily electricity usage activities and manage it effectively.

As trust is critical in promoting the benefits of using smart meters, transparent communication of time-based billing tariff options, which smart meters offer via a time-of-use functionality (peak, off peak, high peak prices), if implemented effectively, may enhance trust relationships and operational transparency thereby increasing perceived usefulness. Though the variable trust in smart meter providers was dropped (second pre-test phase), comments during the data collection phase suggest that the behavior of smart meter providers indirectly affects customer trust in the technology. This study did not explicitly test this assertion, and the suggestion is to investigate the relationship in future research as it might yield some insights that could be helpful in planning considerations for smart meter implementation.

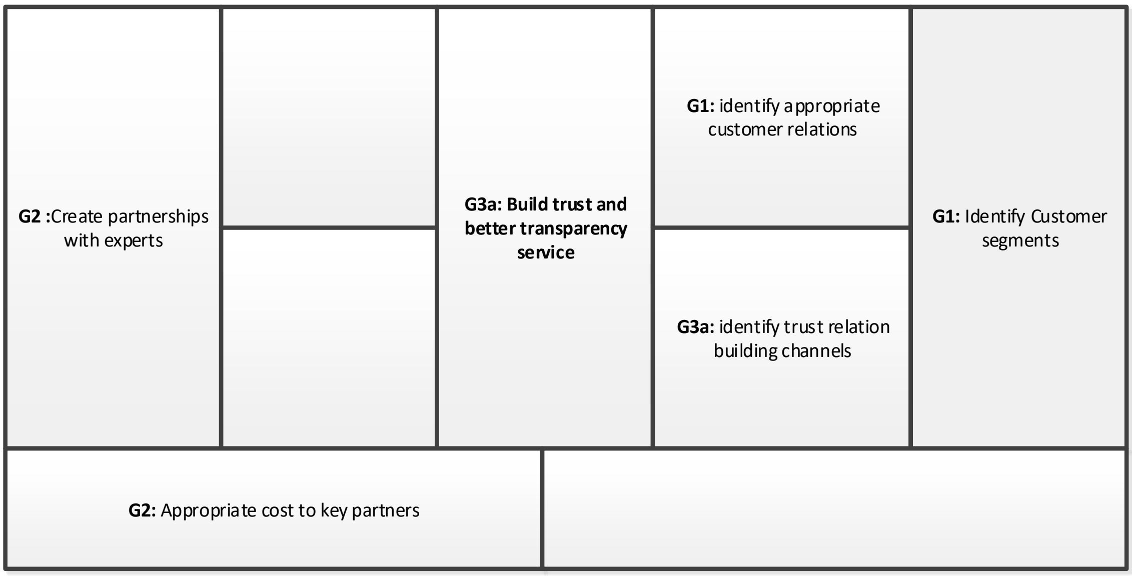


Figure 8.7: Trust building and more transparent services mapped onto the BMC

The next section discusses the impact of monetary cost on perceived usefulness.

Monetary cost to perceived usefulness

The relationship between monetary cost and perceived usefulness was identified and confirmed (Section 7.9.3). The need to statistically evaluate the relationship was not initially proposed in this study but was initiated based on comments during the data collection phase. The comments related to concerns about high electricity costs in South Africa. This finding was consistent with the participants' perceptions but not evident in the findings of other studies.

Consumers with lower monetary cost will lead to higher perceived usefulness.

The findings suggest that smart meter consumers with lower monetary cost impact might have perceived smart meters to be useful. This could lead to more prepaid and postpaid electricity users wanting to migrate from the manual prepaid and postpaid billing system to smart meter technology. Monetary cost is referred to as an economic exchange for a product or service (Venkatesh et al.2012). Therefore, the perceived usefulness of smart meters could be increased if the cost of installing, using and managing electricity is cheaper than the post-paid and prepaid system.

Since perceived usefulness can be increased by lowering the monetary cost of using smart meters, smart meter providers have to cost their electricity usage through the day. With the different smart meter segments and channels identified earlier in Guidelines 1 and 2 respectively, the use of various tariffs during the course of the day might be appropriate. Therefore, considering various price tariff models and rebate methods in the context of the smart meter customer segments may be necessary. Guideline 3b (G3b) considers perceived usefulness in relation to cost.

G3b (Benefits Communication): Improve perceived usefulness by communicating various price tariff structures to benefit different smart meter customer segments.

Various channels were identified in association with Guideline 2 to communicate the efficient use of electricity value propositions. Various electricity pricing models may be considered that include a time of use (ToU) price structure, time-independent pricing/fixed rate tariffs, dynamic rate tariff and electricity charge per appliance (Alam & Shahriar, 2012). For example, smart meter customers who leave home early in the morning and return home at night might benefit from using the ToU pricing structure as it charges electricity usage based on the time of the day, having high charges during peak times and lower rate charges during off peak times. In cases where smart meter customers are using more than 1000 kWh, the Department of Energy made a regulation to use smart meter systems and a ToU to ensure better usage of electricity in the country (Department of Energy Regulation 773). As for smart meter customers who need to use electricity during off peak times, the time-independent pricing might be suitable as they are only charged on electricity used on an aggregated basis over a period of a month (Alam & Shahriar, 2012). In cases where smart meter customers are disadvantaged by flat rate and ToU, an electricity charge per appliance might address these perceived unfair charges as the smart meter customer may have better control of electricity usage. The tariff pricing per appliance usage might also motivate and enhance the perceived usefulness of smart meters thereby improving electricity usage behavior and effectiveness of electricity usage. In cases where smart meter customers effectively control their electricity usage, service providers might use slab based tariff rate. Where a slap-based tariff rate is calculated, the charge per unit is less if electricity consumption is less and more if the consumed units are more.

As outlined above, the communication of the value propositions cannot solely be achieved by a service provider owing to the cost implications, therefore, considering various partnerships may assist in addressing the cost and effective use of electricity. For example, government may provide subsidies to the low income household bracket during installations and price per KWh. Figure 8.6 shows Guideline 3b mapped onto the BMC.

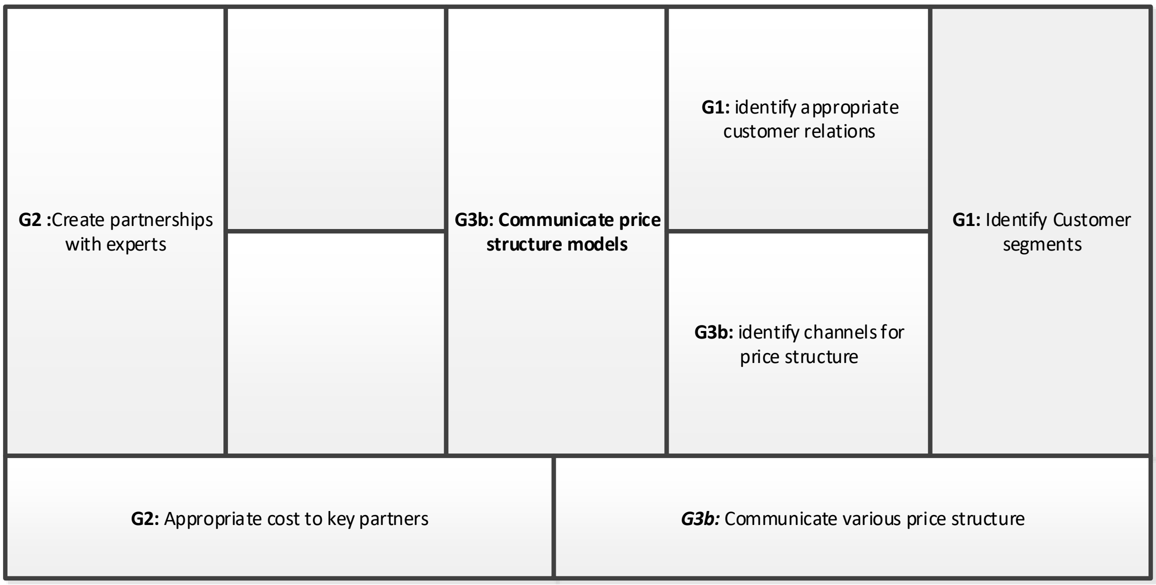
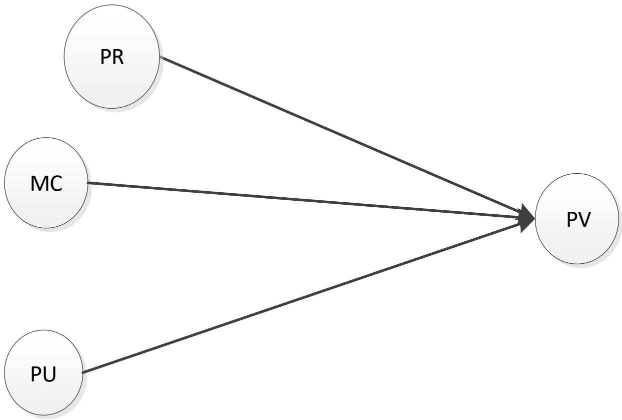


Figure 8.8: Communicate price structure models mapped on BMC.Source: own

The next section discusses the three factors that have an impact on perceived value.

8.6.3 Perceived usefulness, privacy risk and monetary cost on perceived value.

The data showed that perceived usefulness, monetary cost and perceived risk have a positive relationship with perceived value (Section 7.9.2). The significant impact and the meaning of these three factors is discussed individually in the sections below.



Perceived value (PV), Perceived usefulness (PU), Monetary cost (MC), Privacy Risk (PR)

Figure 8.9: Factors that influence perceived value. Source: own

Perceived Usefulness and Perceived Value.

A positive relationship between perceived usefulness and perceived value was identified and confirmed (Section 7.9.2). This finding was consistent with both the data collected and the results of other studies.

Consumers with higher perceived usefulness will lead to a positive perceived value towards smart meters.

The findings suggest that smart meter consumers who derive more benefits from the use of smart meters in managing electricity tend to value them as compared to those who might think otherwise. Appreciating that perceived value is defined as a consumer's overall subjective evaluation of the utility of a product or service mainly based on the trade-off between perceived benefits (utility) and perceived sacrifices or cost (Hazen et al.2015; Zeithaml, 1988). This means that electricity consumers are more likely to value smart meters if they derive more benefits as compared to their currently manual system.

Since the perceived benefits are critical to how smart meter consumers value smart meters, therefore, smart meter providers need to provide various ways to communicate this value proposition (**G2**). Taking into consideration the various smart meter customer segments already discussed in Section 8.4.1, the need to identify benefits applicable to various customer segments might be invaluable to various customers. Guideline 4a (G4a) considers perceived value in relation to customer segment.

G4a (Value Identification/Management): Communicating perceived value identifying smart meter benefits applicable to smart meter customer segments.

The various channels that have been identified earlier are used to communicate the value propositions for perceived values through the lens of perceived usefulness. From the data collected, the participants provided insight on the aspects smart meter providers may need to consider important in terms of perceived usefulness (Section 8.4.2). Although monetary cost, trust and perceived ease of use were identified to be significant factors, perceived ease of use was found to be the best predictor for perceived usefulness. These aspects may need to be factored in when evaluating a smart meter customer's perception on the value of smart meters. Smart meter customers may consider smart meters to be valuable if they can derive more benefits than risks or harm from using them (Chi et al.1991). Hence, the perceived benefits that smart meter customers may derive need to be greater than the risks they may suffer. This needs to be communicated to the target customer segment explicitly otherwise, if they find it to be different, it may affect the trust relationship (Section 8.4.2.). The benefits smart meters offer range from quick electricity data communication feedback in terms of usages (ranging from 15 minutes to an hour) to variable billing options (**G3b**), quick detection and restoration of electricity faults, monitoring and effective use of electricity, perceived ease of use and better control of appliances usage.

For example, smart meter customers who are computer literate may benefit from the use of near real-time dashboard web portals, social media, mobile application and even SMS to communicate electricity feedback in terms of usage. Mostly, working smart meter customers might need a mobile application to remotely monitor their electricity usage, which in turn offers them a better appliance usage control and the possibility of saving electricity. For those who may not be well versed with technology, the use of the smart meter display unit may become a viable proposition. In cases where smart meter users are not computer literate, the use of TV adverts demonstrating the benefits of smart meters may be more relevant and applicable.

Since detection and restoration of electricity faults is a challenge in the manual electricity system, smart meter technology allows the smart meters to report tampering, faults and allow the smart meter providers to restore electricity easier and quicker.

Various partnerships (G2) becomes necessary in order to reduce the cost involved in delivering these various benefits to applicable customer segments. Figure 8.7 shows Guideline 4a mapped onto the BMC.

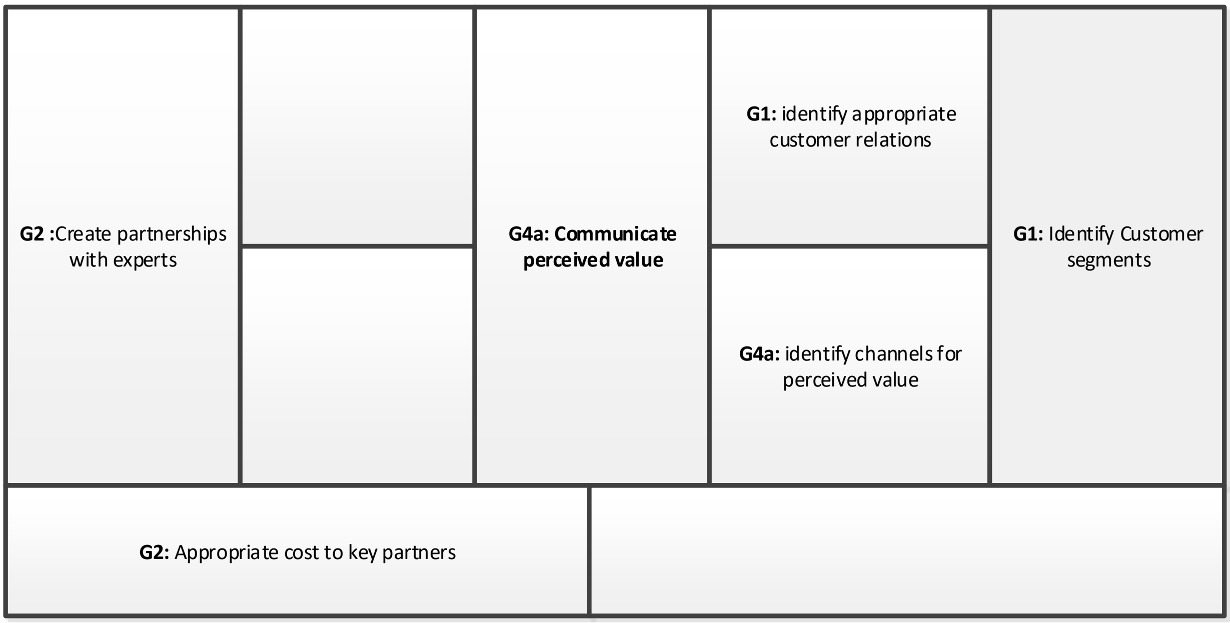


Figure 8.10: Communicate perceived value models mapped on BMC. Source : own

The next section discusses the impact of privacy risk on perceived value.

Privacy Risk and perceived value.

A positive relationship between perceived privacy risk and perceived value was identified and confirmed (Section 7.9.2). This finding was both consistent with the data collected and the findings of other studies.

Consumers with higher privacy risk will have a negative influence on perceived value of smart meter technology

The data findings suggest that smart meter customers with higher privacy concerns are more likely to refrain from using smart meters as compared to the ones who have low or no concerns about their privacy appetite. Privacy risk is the potential loss of control over personal information when an organisation fails to provide proper security and privacy safeguards to personal information, even when the customer has given consent (Taneja et al.2014). This means that, smart meter customers may value smart meters if personal information collected, processed, stored and disseminated is protected from smart meter provider opportunistic behaviors (G4) and unauthorized access that might cause personal damage. Trust building becomes a vital component in reducing high perceived privacy risk. Guideline 4b (G4b) considers perceived value in relation to the safety of personal information.

G4b (Value Identification/Management): Communicating perceived value by guaranteeing safeguarding and confidentiality of personal information to the identified applicable smart meter customer segments.

Privacy risk in smart meter technology implementation is too technical for the general electricity customer to evaluate whether their personal information is protected and used as per their consent. The smart meter provider must be able to publish or provide policies and implement best practices in order to reduce the risk of misuse and handling of customer personal information in their custody. For example, the smart meter provider must at least have policies and best practices that follow the Organisation for Economic Cooperation and Development (OECD) Privacy principles that include: (1) notice and purpose of data collection, (2) choices and consent available to users and consent to collect, handle, process and disseminate personal information, (3) individual access to personal information in order to correct inaccuracies, (4) security and safeguard personal information and (5) educate smart meter customers about smart meter privacy risks and mitigation solutions.

The various channels that have been considered in G1 may need to be considered in order to communicate the safeguard and confidentiality value proposition to applicable smart meter customer segments (NIST 7628 report, 2010). The use of TV adverts, educational workshops and awareness campaigns and websites with Frequently Asked Questions (FAQ) may be appropriate for most of the smart meter customer segments identified in G1.

Key partners with relevant expertise in policy development, best practices implementation (privacy impact risk assessment) and educating smart meter privacy mitigation practices are critical in order for smart meter providers to capture all the important considerations to cater for all the smart meter customer privacy issues. For example, legal expertise and external policy development consultants may assist in this regard. The privacy risk considerations are mapped on to the BMC below. Guideline 4b was mapped onto the MBC (Figure 8.8).

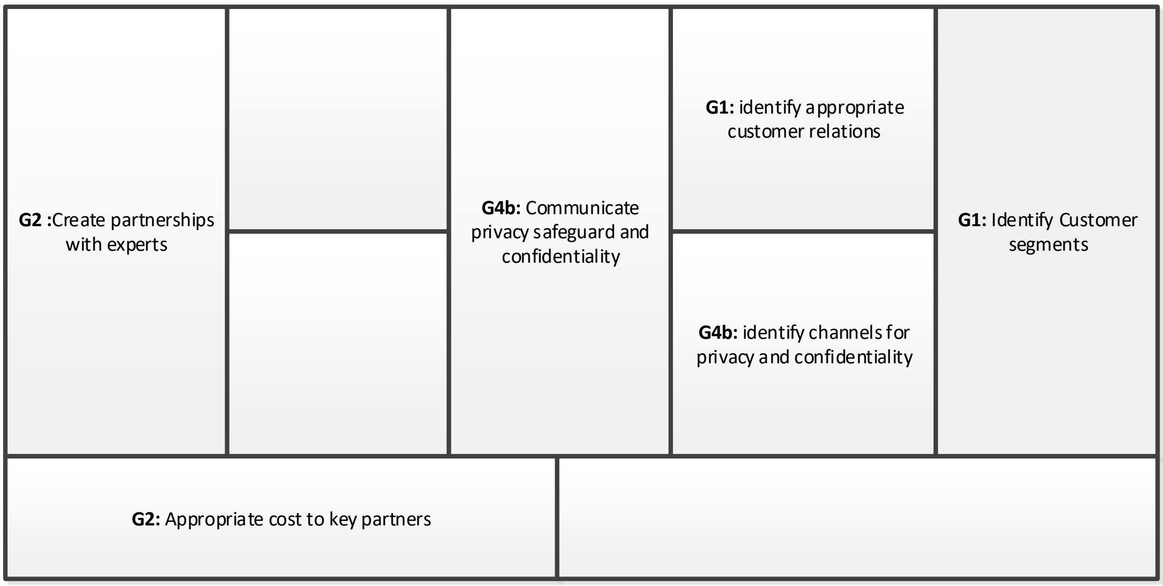


Figure 8.11: Communicate privacy safeguard and confidentiality mapped on BMC. Source : own

The next section discusses the impact of monetary cost on perceived value.

Monetary cost and perceived value.

A positive relationship between monetary cost and perceived value was identified and confirmed (Section 7.9.2). This finding was consistent with previous studies with regard to the relationship between these two factors.

Monetary cost negatively affects the perceived value of using smart meter technology.

Consistent with previous research, the results of this study suggest that perceived monetary cost affects smart meter customers' evaluation of more than the benefits they derive. Therefore, the improvement in smart meter customers' perception of cost would become a critical factor to consider in smart meter technology adoption. As previously discussed, reduction of installation cost, tariff charges per KWh and other related costs may enhance the perceived value from the customer perspective. Guideline 4c (G4c) considers value identification and management.

G4c (Value Identification/Management): Communication of perceived value by evaluating the value for money on the services applicable to the identified smart meter customer segments.

Taking into consideration the various channels and smart meter customer segments identified in G1, potential smart meter customer segments that are sensitive to cost involved in the implementation of smart meter technology may evaluate the perceived value mainly on cost without taking into account the benefits to be derived. In some cases, where the customer weighs the other non-monetary benefits that they can derive by adopting smart meters, acceptance levels will be high.

Apart from evaluating the value of the services being offered to the monetary cost, smart meter customers continual creation of customer relationships through social media platforms and community awareness campaigns might need to be considered in order to collect information to improve value for services being offered.

The communication of the value proposition to the intended smart meter customer segments also needs appropriate channels and coordinated partnerships with experts. The Value Identification/Management was mapped onto the BMC (Figure 8.9).

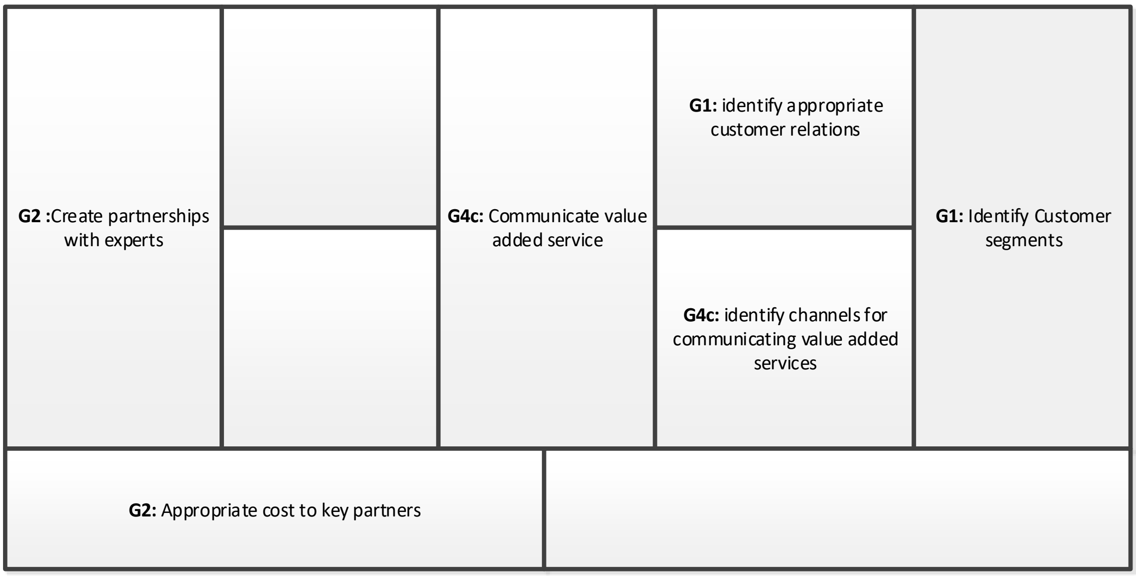
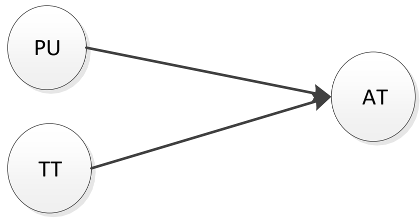


Figure 8 12:Communicate value added service mapped onto the BMC

8.6.4 Perceived usefulness and trust in technology to attitude.

The quantitative data shows that perceived usefulness and trust in technology have a positive relationship with smart meter customer's attitude toward the use of smart meters (Section 7.9.4). The significant effects of the two factors is discussed individually in the sections below.



Attitude (AT), Perceived usefulness and Trust in technology (TT)

Figure 8.13: Factors that influence attitude. Source: own

Perceived usefulness and attitude.

A positive relationship between perceived usefulness and attitude toward smart meters was identified and confirmed (Section 7.9.4). Drawing from the TAM, this finding was consistent with previous studies with regard to the relationship between the two factors.

Consumers with higher perceived usefulness will have a positive attitude toward the use of smart meter technology.

The findings suggest that the usefulness of smart meters in electricity supply to residential homes in various provinces of South Africa greatly influences the attitudes toward smart meter technology. Meaningful use of smart meters in managing electricity billing information, fault detection and reporting, diverse billing options and easy monitoring of electricity usage may be a key means of persuading different customer segments to utilize smart meters in electricity management.

Most smart meter users focused more on the bad publicity owing to the corrupt activities that happened around the tendering system in relation to awarding a contract to the service providers, especially in government. Once the benefits that smart meters offer for the management of electricity, attitudes changes. Most of the smart meter users become interested in smart meter implementation. Guideline 5a (G5a) considers attitude in relation to communicating the benefits of smart meter use. Figure 8.10 shows Guideline 5a mapped onto the BMC.

G5a (Customer Attitude): Improve attitude by communicating the perceived usefulness of smart meters in effective management of electricity to the identified smart meter customer segments.

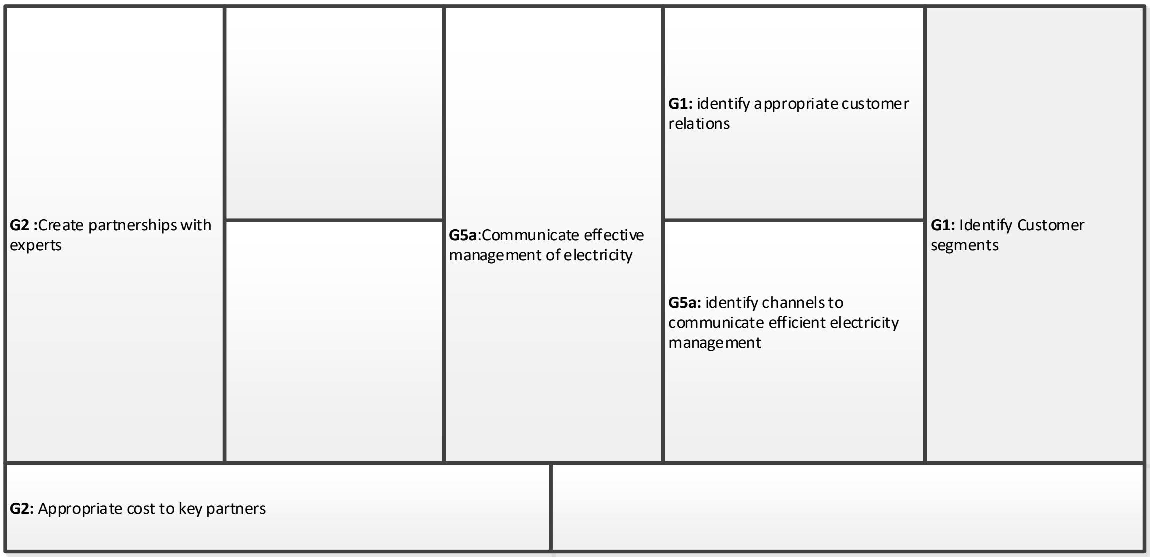


Figure 8.14: Communicate effective management of electricity mapped onto the BMC. Source: own

Trust in technology and attitude.

A positive relationship between trust in technology and attitude was identified and confirmed (Section 7.9.4). This finding was consistent with both the data collected and studies reported in the literature.

Consumers with higher trust in technology will have a positive influence on attitude towards smart meter technology.

The findings suggest that smart meter customers with higher levels of trust in technology are more likely to have a better attitude towards using smart meters as compared to the ones who do not trust technology. The smart meter customers who feel strongly about privacy and security of their personal information might need to be guaranteed that their personal information is secure in order to have a better attitude towards using smart meters. Trust in technology can also be associated indirectly with perceived usefulness in its impact on attitude towards smart meters This means that proper security and privacy of smart meters may enhance the smart meter customer's attitude towards using smart meters (Taneja et al.2014). Guideline 5b (G5b) considers attitude in relation to guaranteed security of personal information.

G5b (Customer Attitude*): Improve attitude by guaranteeing security and privacy of personal information of the identified smart meter customer segments.*

The various channels that have been identified in Section 8.4.1 may be useful in communicating the security and privacy of personal information for the customer segment outlined earlier. For example, smart meter customer segments who are conscious of their privacy might need the smart meter provider to guarantee that their personal information is kept confidential and used only for the purposes communicated to them. Personal electricity data containing personal information may be sold to third parties who might use that information for various opportunistic behaviors such as marketing and campaigns targeting particular customer segments. Furthermore, the service provider might need to assure customers that information collected, stored and communicated will not be given to a third-party without customer consent. In case smart meter customers are not aware or concerned about their privacy and security aspects, educating them about their privacy rights might be important for improving the customer's judgement thereby enhancing attitude towards smart meter acceptance and use.

Partnerships are also critical in designing appropriate channels to reach the identified customer segments. Partners with expertise in TV advertisements, mobile applications, demonstration videos, content development and community trust building may be invaluable in enhancing the customer attitudes towards smart meters. Customer Attitude Management (5b) is mapped on the BMC in Figure 8.11.

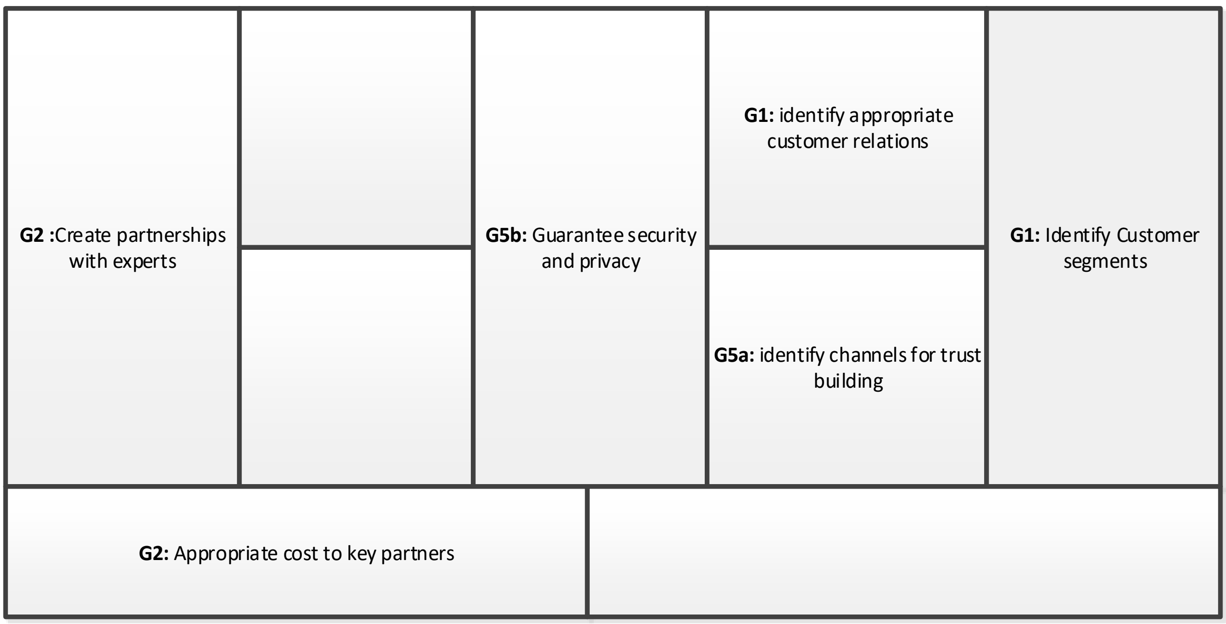
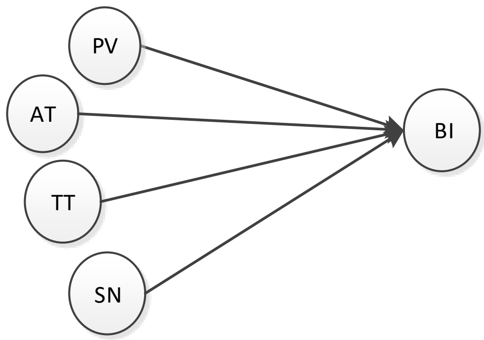


Figure 8.15: Guarantee security and privacy mapped onto BMC. Source: own

8.6.5 Behavioral intention towards smart meters.

The study utilized structural equation modeling to ascertain the extent to which various factors such as perceived usefulness, perceived ease of use, trust in technology, perceived value, privacy risk, monetary cost, attitude, social norms and facilitating conditions could assist in the planning considerations for implementing smart meters in South Africa.

Perceived value, attitude, social norms and trust in technology were found to be the most critical factors that may influence the behavioral intention to use smart meters.



Behavioral intention (BI), Perceived value (PV), Attitude (AT), Trust in technology (TT) and Social norms (SN)

Figure 8.16: Factors that influence behavioral intention. Source: own

These endogenous factors were found to be important in determining the behavioral intention to use smart meters. The data suggested that privacy risk, monetary cost and perceived usefulness need to be considered as they were found to have significance in determining perceived value. The results might mean that smart meter users who feel that their personal information will not be communicated and is stored securely and confidentially at an affordable tariff with more benefits to them might value smart meters more as compared as those who view smart meter technology otherwise.

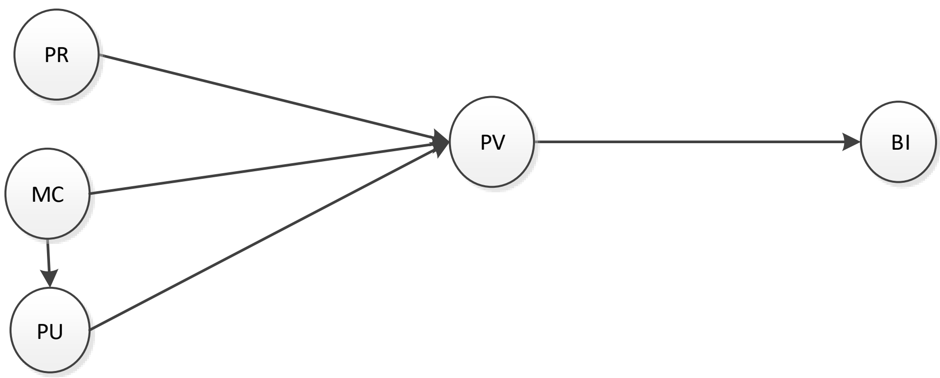


Figure 8.17: Impact of perceived value on behavioral intention

Considering that attitude and trust are personal psychological assessments of smart meters, trust in technology and perceived usefulness were found to be two important factors that might need to be considered in attitude assessment of smart meter users in the planning considerations towards smart meter implementation in South Africa. As indicated in Figure 8.18, attitude is influenced by many factors. Facilitating conditions have an influence on perceived ease of use, which in turn positively impacts on perceived usefulness which affects attitude. In the same light, trust in technology was found to influence attitude both directly and indirectly. As smart meter customers feel that smart meters are safe and secure in protecting their information, they tend to use this technology, while in the process improving their attitude toward using it. On the other hand, the moment smart meter consumers have trust in smart meters for electricity supply management, the more smart meter customers will tend to use them.

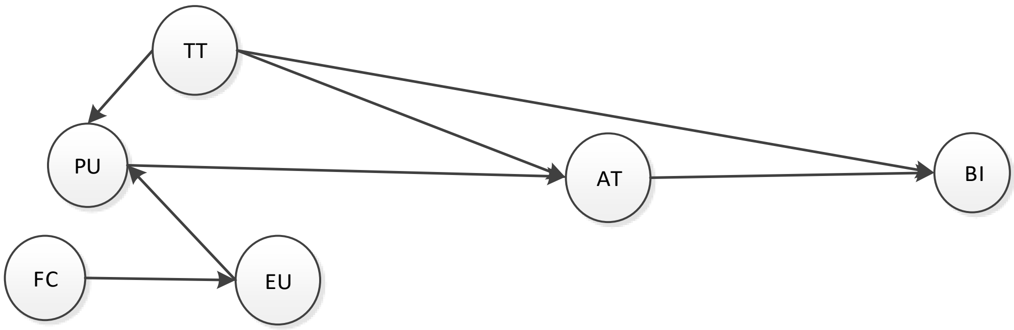


Figure 8.18: Impact of attitude and trust in technology on behavioral intention

Social norms have also been found to be important in the assessment of smart meter acceptance. This is consistent with other behavioral studies, meaning that the influence of friends, family and political affiliations play a part when it comes to consumer decisions to use smart meters. Since South Africa believes in the communal view when deciding on important matters, the influencing effect of high profile people like politicians might assist in the motivation of smart meter consumers to achieve a higher acceptance.

Figure 8.19. Impact of social norms on behavioral intention. Source: own

Based on the discussion above, the overall findings of the analysis have broader implications for South African electricity providers when planning to introduce a smart way to collect electricity billing information, more efficient fault management and effective and efficient electricity demand and supply management. Therefore, perceived value, attitude, social norms and trust in technology should be incorporated into the planning consideration for successful smart meter implementation in South Africa. Figure 8.12 shows all the guidelines mapped onto the BMC.

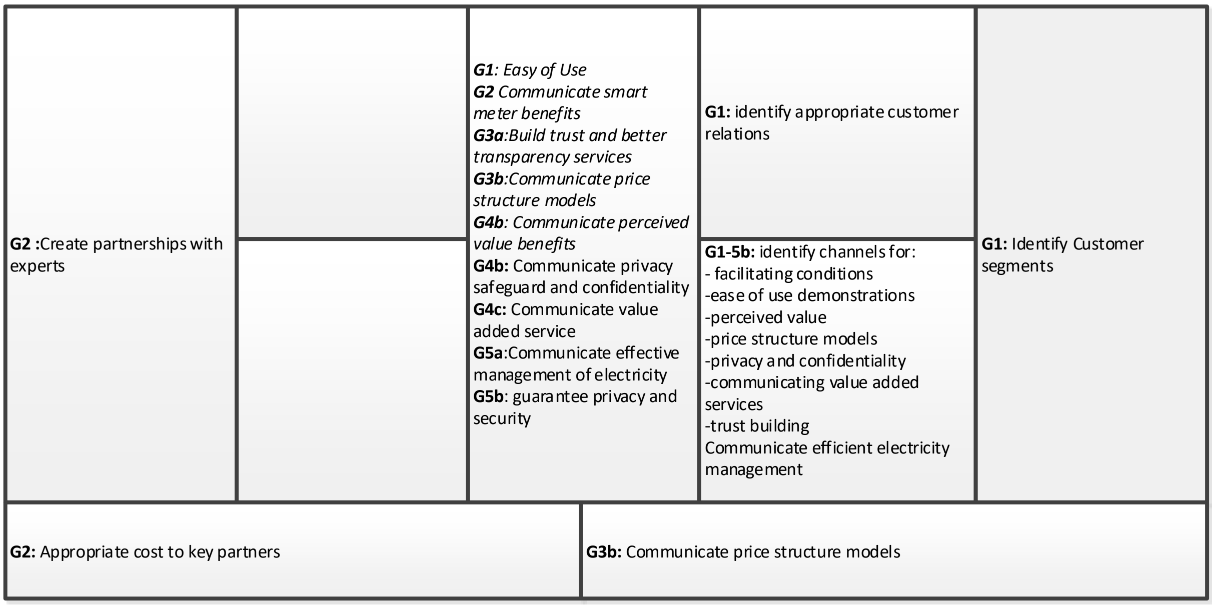


Figure 8.20: Planning guidelines mapped onto the BMC

8.7 Conclusion

This chapter discussed the development of the planning guidelines that were derived from the 13 significant hypotheses in this research. These findings were mapped to BMC models as part of the guideline development process. A final BMC model containing all the guidelines was created (Figure 8.12). The findings suggested that perceived value, trust in technology and attitude are critical factors that need to be incorporated in the planning considerations for implementation of smart meters in South Africa.

CHAPTER 9:
CONCLUSION AND RECOMMENDATIONS

To get the bad customs of a country changed and new ones, though better, introduced, it is necessary first to remove the prejudices of the people, enlighten their ignorance, and convince them that their interests will be promoted by the proposed changes; and this is not the work of a day.

Benjamin Franklin (1781)

9.1 Introduction

This thesis is the result of an empirical investigation on the customer-centric factors for planning considerations in smart meter implementation in South Africa. The investigation encapsulated theoretical reasoning from various behavioral theories and models together with extensive literature syntheses and analysis about smart meter technology in general. As discussed in Chapter 4, a quantitative research approach using a structural equation modelling statistical analysis was employed to identify and model the relationships among various consumer-centric factors identified in Chapter 2 and 3 respectively. As outlined in Chapter 5, a sample of 705 smart and non-smart electricity customers within the boundaries of South Africa were involved in this study. Through extensive synthesis of literature and quantitative structural equation modeling, this study aimed to explore the central question that underpins this research: ***How can the consumer-centric factors be incorporated in the planning consideration of smart meter technology implementation in the context of South Africa?*** En route to answering the main research question (RQ), specific sub-questions were addressed:

- **RQ1**: What are the consumer-centric factors that influence the attitude and intention to accept and use technology?
- **RQ2**: How can these consumer-centric factors be incorporated into a smart meter technology acceptance and adoption model?
- **RQ3**: Which are the most significant consumer-centric factors that are pivotal in the acceptance and use of smart meter technology within the South African context?

In order to address RQ1, a generalized reasoning approach to factors that may influence technology acceptance and use was applied to an extensive review of the literature as covered in Chapter 2, while specific factors that have been identified through widely applied acceptance theories and models were also considered (Chapter 3). After considerable analysis of various factors that may influence technology acceptance and use in general, the structural equation modelling approach was used to streamline and identify factors relevant for the South African context. The evaluation of the validity of both the measurement and structural models based on the data collected and analysed formed part of a process to assist with answering RQ2 (Chapter 5, 6 and 7). Based on the acceptance hypotheses derived from RQ2, RQ3 was addressed by developing generalized recommendations for planning considerations through the use of the Business Canvas Model as a strategic management tool for use by smart meter service providers to increase smart meter technology acceptance and implementation within the South African populace (Chapter 8).

Chapter 9 concludes this thesis by presenting the overall thesis summary in Section 9.2. Section 9.3 contains summaries of the empirical research findings, outlining how the research questions were answered and the objectives achieved. Section 9.4 discusses the recommendations of the planning guidelines and implications of the main findings for policy makers, technology innovators, smart meter providers and academia. The chapter concludes with discussion about the contribution of the study and limitation of the research in Section 9.5 and Section 9.6 respectively. Thereafter, Section 9.7 presents possible future research studies and the chapter conclusion. The next section provides a chapter summary of the key findings of this thesis.

9.2 Overall summary of the thesis

As discussed in Chapter 2, there are several factors that make the South African context different from other countries where smart meter technology has been deployed. South Africa is a developing country with dynamics ranging from low digital literacy in relation to smart meter use of both citizens and policy makers, misunderstanding of how smart meters can help in reliable, cost effective and efficient electricity demand and supply distribution, to political propaganda, general citizen poverty, professional technical skills shortages, and little or no focused legal framework to guide proper implementation of smart meter technology. Chapter 2 presented relevant literature that was used to assist in identifying customer-centric factors that influence smart technology acceptance in the South African context.

Chapter 3 documented the literature review process that lead to selection of the Technology Acceptance Model (TAM) as the fundamental research framework for investigating the critical consumer-centric factors in smart meter technology acceptance within the South African context. As discussed in the literature, the TAM is a well-known model that has proven to be a suitable theoretical construct for helping to explain consumer behavior towards technology acceptance. Though the TAM provides valuable insights that focus mainly on determinants of intention, it does not predict how perceptions are formed and how they can be motivated to enhance user acceptance and increased technology usage. Hence, for the purposes of this study, additional relevant consumer-centric factors from other technology acceptance models such as trust in technology (Geffen et al.2003; Wu & Chen, 2005), privacy risk (Keith et al.2014; Zhou, 2011), facilitating conditions (Venkatesh et al.2012, 2016), monetary cost and perceived value were introduced to the study model to further understand South African smart meter consumer behavior. These additional factors cannot be explained or explicitly dealt with individually in the TAM or other acceptance models.

Chapter 4 outlined and discussed the research process used in the investigation of a predictive model and considerations for implementation planning of smart meter technologies within the South African context. Owing to the nature of this research study and the intended artifact, the theoretical underpinning was within the positivism research philosophy, since the research aimed to produce an artifact in the form of a predictive model for planning considerations. Therefore, a quantitative research approach was deemed relevant, with a Business Canvas Model used as a strategic planning tool for understanding the value propositions for policy makers, technology innovators and utility companies in general. The numeric data that was collected using a self-administered digital questionnaire on QuestionPro and a hardcopy questionnaire (handed out to respondents) was statistically examined and tested through CB-SEM using the STATA statistical software package. Pre-testing and final data collection approaches were employed in order to validate the measurement instrument and model. Various measurement and structural model fit tests, under SEM, were applied to verify if the model constructs were measuring what they were intended to measure.

Chapter 5 was based on the fundamental theoretical grounding outlined in Chapter 3 and contains discussion about how the measurement model was developed. Based on various models from behavioral studies (presented in Chapter 3) as the theoretical underpinnings for this research study, planning consideration factors were identified which became the constructs for this research. The identified constructs were based on the TAM and other behavioral studies models (Chapter 3). Initially, 11 constructs were identified with at least four to six items per construct. The 7- point Likert was used to measure each construct. The eleven constructs with items, together with some biographical information, were compiled into a measurement instruments which was pre-tested in three phases, sampling 15, 73 and 55 participants respectively, to validate the content validity and reduce ambiguity and language errors on the latent variables. the final data collection for the study consisted of 768 participants, which was a number above the recommended 483 participants based on the overall approximate South African population. In this chapter, the research focused on Stages 1 to 3 of the Structural Equation Modelling approach.

Chapter 6 and 7 of this research study detailed the evaluation of both the measurement model and structural model respectively. Through careful evaluation, both models were found to be significant. Of the 16 construct relationships tested and evaluated, only four constructs were found not to be significant (which about 25 percent non-significance). About 75 percent of the variables identified in the various models and behavioral studies were found to be consistent with what other researchers regard as important and relevant planning consideration factors in relation to the implementation of smart meters within the South African populace. As presented in Chapters 6 and 7, not all the constructs that were measured were found to be significant in the final research model, with 12 out of 16 structural relationships shown to be relevant (Chapter 7).

In Chapter 8, recommendations for planning considerations were discussed and various electricity stakeholder and value propositions for smart metering technology were suggested. The Business Model Canvas provided an artifact that could be used as a strategic management tool that describes how businesses can create, capture and deliver value propositions to relevant consumer segments such as residential users. However, for a business to become relevant in delivering the value propositions, identification of the relevant factors that can be incorporated into the planning considerations for smart meter implementation was vital.

Section 9.3 presents the empirical findings of how the research questions were answered and the research objectives achieved.

9.3 Summaries of the empirical research findings

This section presents a summary of the empirical findings and answers each of the research questions (RQ) in detail.

> ***RQ1****: What are the consumer-centric factors that influence the attitude and intention to accept and use technology?*

This research question was concerned with identification of consumer-centric factors that influence attitude and intention to accept and use technology. Key findings related to RQ1 are discussed below.

A generalized reasoning approach was used to identify the factors that may influence attitude and behavioral intention to accept and use technology in general. Although, the factors that influence attitude and behavioral intention to accept and use technology are widely accepted in the literature (Section 3.2.1), smart meter technology for managing electricity is a fairly new technological innovation for the citizens of South Africa. The use of information from various studies done in the

United States of America and Europe was important for providing a foundation for identifying consumer-centric factors within the smart meter domain (NIST Report 7628, 2010). From the American and European perspectives, environmental awareness, trust, perceived risk, perceived usefulness and perceived ease of use were the most prevalent factors affecting technology acceptance (Park et al.2014).

Identifying key factors impacting smart meter implementation in countries that are leading this innovation was vital for selecting customer-centric factors. However, for the purposes of this study, further review of the literature on smart meter status in South Africa, together with results from pre-testing of the measurement instrument (Chapter 5) were important for narrowing the focus to the South African context and hence selecting factors specifically relevant to this context. Factors such as social norms, facilitating conditions, perceived value, monetary cost and privacy risk were further identified as exogenous factors that affect attitude and intention to accept technology in general (Chapter 3).

Since smart meter technology in South African is in an early stage of implementation for both private and business users, the failure of municipalities to manage general functionality and accurate billing and to guarantee protection of personal information has made both smart meter users and non-smart meter users distrustful of this technology. Consequently, it has become difficult to promote the perceived value and usefulness and cost saving to electricity consumers who have a negative attitude towards accepting smart meter technology.

Apart from the benefits that smart meters offer such as cost effectiveness and flexibility in time of use, smart meter users feel that smart meter providers do not give them any option to opt out of the installation of smart meters in their premises because this is a requirement based on Regulation notice R773. Regulation R773 makes it mandatory for smart meters to be installed at premises where the electricity consumption is above 1000kWh. This regulation leaves no room for electricity consumers to exercise a choice in accepting and using smart meters or not, thereby, infringing on freedom of choice regarding their behavioral and personal information privacy. In addition, to help with identification of the consumer-centric factors that should be considered in technology acceptance and use, various models and theories on technology acceptance were reviewed (Chapter 3). The TAM was found to be the best to use as a basis for customer-centric factor identification.

As discussed in Chapter 5, 11 factors or constructs were identified for investigation in this research study. These included: Perceived Usefulness, Perceived ease of use , Trust in Technology, Trust in Service Provider, Trust in Legal system, Personal Consciousness, Community

Consciousness, Monetary Cost, Perceived Value, Privacy Risk and Behavioral Intention. In order to identify the relevant factors that affect smart meter implementation, evaluation of pretest data showed that Trust in Legal system and Trust in Service Provider, together with Personal Consciousness and Community Consciousness were hypothetically insignificant hence they were dropped from the study. Although the data collected suggested that Trust in Smart Meter Service Provider was insignificant, it is logical to reason that, the more the consumers trust the service providers, the more they are unlikely to doubt the proposal for electricity management using smart grid technology. As much as smart meter technology seems to assist in addressing energy demand and supply management, billing technicalities and electricity theft, participants felt that implementation of smart meters is costly as the smart meter providers always charge more than their normal consumption. The researcher wanted to identify the relevant contribution of the variants of Social Norms (Personal consciousness and Community Consciousness), however, the factor was found to be insignificant.

After removal of all the items below a cutoff of 0.7, the model was reassessed for reliability, homogeneity and convergent validity, discriminant validity and factor loading. All the test results achieved acceptance metrics. Factor loadings were all above 0.7, AVE values above 0.5 and as for discriminant validity, all constructs were loading high on themselves in comparison with loading on other constructs. The structural hypothesis testing of the structural model showed at significance of p-value <0.001 and p-value <0.05. Thereafter, the final measurement instrument was designed with the aim of using it to collect the final data set for the research study. The final data was tested for measurement model fit, construct validity and structural model fit, as discussed in Chapters 6 and 7 respectively. Identification of relevant consumer-centric factors provided the answer to RQ1. RQ2 was answered through a modelling process using structural equation modelling.

> ***RQ2**: How can these consumer-centric factors be incorporated into a smart meter technology acceptance and adoption model?*

Research Question 2 was answered through the process of modelling the consumer-centric factors (identified through answering RQ1) into a smart meter technology acceptance and adoption model. The modelling of these factors followed the six stages of structural equation modelling (SEM) (Chapters 4 to 7). Using the statistical modelling technique, SEM, each factor identified was considered a latent variable that was measured through the construct items developed. The constructs: perceived usefulness and perceived ease of use, facilitating conditions, trust in technology, social norms, perceived value, privacy risk, monetary cost, attitude and behavioral intentions all had at least four items to evaluate whether or not the participants were in agreement with the proposed identification of factors that may influence the implementation of smart meters (Chapter 5)

Based on the SEM results, the goodness-of-fit indices for both the measurement and structural models showed that the data collected was in line with the proposed predictions for the study. Tables 6.9 and 7.2 respectively contain details of the model evaluation results that were used to confirm that the factors identified (RQ1) were successfully modelled. This accomplishment provided the answer to RQ2. In addition, the construct validity (Section 6.9.3), factor loadings (Section 6.9.4 and Table 6.11), AVE and construct reliability (Section 6.9.8 and Tables 6.12, Table 6.13 and 6.14) were all found to be statistically significant, achieving the recommended cut-off of 0.7. The measurement model validity assisted in identifying factors that are significant in modelling for smart meter technology acceptance. Though initial factor loadings for facilitating conditions (FC2), privacy risk (PR2) and perceived usefulness (PU2, PU4, PU5 and PU6) were found to have some items below 0.7, only perceived usefulness was reconstructed for the final data collection process because it had only two items left for measurement. As for facilitation conditions and privacy risk, no reconstruction was done as they each had at least 3 items per construct.

Final data collocation was based on a measurement model developed through evaluation with 10 construct and at least 56 items. After data collection and entry, structural relationships were proposed and evaluated, and it was confirmed that the constructs identified on RQ1 and RQ2 respectively were in line with the behavior of the data collected (Table 7.2). Out of the 16 proposed hypotheses, only three were found to be non-significant, that is, 13 were significant (Table 7.3). This outcome is proof of the validity of the predicted factors and their importance for planning considerations in the South African context. The goodness-of-fit for both the measurement model and the structural model achieved acceptance levels. The 13 significant consumer-centric factors verified through answering RQ2 were used to formulate the planning considerations for smart meter implementation in South Africa. A more detailed discussion about answering RQ3 is provided below.

***RQ3**: Which are the most significant consumer-centric factors that are pivotal in the acceptance and use of smart meter technology within the South African context?*

This section summarizes the findings for RQ3 that were based on the RQ2 outcomes and discusses how each of the twelve significant hypothesis were found to be relevant in the planning consideration for smart meter acceptance within the South African context. The Business Model Canvas (BMC) (Section 8.2) was used as a framework for reporting the recommended planning consideration guidelines based on the accepted hypothesis (Table 7.3). Mapping of the planning considerations to the BMC created a simple graphic tool to assist with strategic planning for smart meter implementation.

According to Osterwalder and Pigneur (2010), the BMC consists of nine components that are used to deliver value propositions to various customer segments. In this research, only seven of the components were found to be relevant for recommendations for planning considerations for smart meter implementation. This is because the BMC for this study was designed from a smart meter provider's perspective in relation to the creation of value propositions relevant to the various smart meter customer segments. In this regard, the two BMC components: key activities and key resources were deemed irrelevant.

Answering RQ3 was accomplished through the process of using the BMC to develop recommendations for planning considerations, as documented in Chapter 8. The outcome of this process was five generalized planning considerations, namely, customer segments, benefits communication, partnerships, value identification and customer attitude (Section 8.4). These generalized planning consideration guidelines were given codes (such as G1 - G5) for easy representation in the BMC model. Discussion of these five planning consideration guidelines is provided in the sections below.

9.3.1 Planning consideration 1: Customer segments.

The G1 (Customer segments) planning consideration suggests that for the smart service provider to understand the value proposition they are offering to their customers they need to identify the various customer segments involved. Although the smart meter survey questionnaire did not ask questions specifically related to establishing customer segments, based on the G1 recommendation, the descriptive statistics can be used to point in the direction of potential smart meter customer segments. The following demographic characteristics were relevant: educational level, income level and smart meter user status. Associated with customer segments are channels that enable connection and communication with particular segments, the need to have various channels to cater for these customer segments becomes vital in improving smart meter acceptance (Section 8.4.1). Suggested channels include, instructional videos, advertisements, demonstrations videos, training workshops, dedicated helpdesks, web portal dashboards and educational awareness campaigns. Which channels are used depends on the customer segment targeted.

9.3.2 Planning consideration 2: Partnerships.

In addition to the various channels mentioned above, partnerships between smart meter service providers and relevant key partners such as the SABC and website development companies become important because the smart meter service providers might not have all the relevant skill and knowledge to leverage certain channels, for example, websites or web portals. The recommendation of planning consideration G2 addresses the short coming.

9.3.3 Planning consideration 3: Benefits communication.

Perceived usefulness was found to be significant in improving smart meter acceptance. Trust in technology, perceived ease of use and monetary cost were found to directly influence perceived usefulness of smart meter acceptance within the South African context (Section 8.4.2.1). These findings were also consistent with those of other researchers (Davis et al.1987; Venkatesh et al.2012). Therefore, for smart meter providers to enhance smart meter acceptance through perceived usefulness, there is a need to guarantee confidentiality, to be honest with transactional data that is processed through the smart meters and to ensure that billing is accurate as compared to the post-billing system the customers are currently using. As evident from feedback during the data collection phase, most South African smart meter customers had issues with trusting the smart meter providers, especially the municipalities and private electricity providers with regards to billing methods and operational transparency. The recommendations of planning consideration G3, G3a and G3b provide suggested ways through which perceived usefulness can be improved (Section 8.4.2.1 to 8.4.2.3).

9.3.4 Planning consideration 4: Value identification.

The G4 planning consideration suggests that perceived value of smart meters is determined by perceived usefulness, monetary cost and privacy risk. Perceived usefulness needs to be communicated to the customer segments in order to improve smart meter acceptance (Section 8.4.3.1). Smart meter customers may consider smart meters to be valuable if they can derive more benefits than risks or harm from using them (Chi et.al.1991). Hence, the perceived benefits that smart meter customers may derive need to be greater than the risks they may suffer. This needs to be communicated to targeted customer segments explicitly, otherwise, if they experience things differently there may be damage to the trust relationship (Section 8.4.2.2).

Privacy risk assessment in smart meter technology implementation is too technical for the general electricity customer to evaluate whether or not their personal information is protected and used as per their consent. Hence, smart meter providers must be able to publish or provide policies and practice the best practices they have in place to reduce the risks of misuse and mishandling of customer personal information in their custody (Section 8.4.3.2). Viewed in another way, to increase value is to build trust as trust building becomes a vital component in reducing high perceived privacy risk.

9.3.5 Planning consideration 5: Customer attitude.

The G5 planning consideration suggests that attitudes towards smart meter acceptance is directly influenced by trust in technology and perceived usefulness. The more benefits the smart meter customers derive in managing electricity such as billing accuracy, fault detections and diverse billing options and easy monitoring of electricity usage, the more they will be positively inclined towards smart meter acceptance (Section 8.4.4.1). On the other hand, the failure by smart meter providers to guarantee personal information protection might have an effect on their attitude towards smart meters. Since electricity data may contain information that could be sold to third parties without a user's consent, there is a need to educate users about their privacy rights which might be important in improving the customer's judgment thereby enhancing their attitude towards smart meters.

This research study managed to answer the research questions and meet the objectives identified in Chapter 1. For RQ1, a generalised reasoning approach was employed in order to identify the factors that influence technology acceptance and use through an extensive literature review process (documented in Chapters 2 and 3). Chapter 2 was fundamental in creating a platform for understanding what smart girds and smart meters are, their benefits and challenges and the statues in South Africa. As part of the literature review, Chapter 3 documents the process to review and evaluate widely accepted technology acceptance models and theories. The outcome of this process was the choice of the TAM as the fundamental research framework, with the addition of supplementary factors such as trust in technology, privacy risk, monetary cost, perceived value, facilitating conditions and social norms.

Thereafter, a quantitative methodology approach was chosen that used structural equation modelling to objectively evaluate the factors through the power of statistical analysis. Based on the data collected, the SEM statistical analyses significantly confirmed validity of the following factors: perceived ease of use, perceived usefulness, attitude, privacy risk, monetary cost, perceived value, facilitating conditions, social norms and behavioural intentions. Only relationship structural relationship between perceived ease of use and attitude, perceived usefulness and behavioral intention and facilitation conditions and behavioral intention was found to be non-significant in influencing the smart meter consumers, therefore, it was eliminated in the final proposed model. This process assisted the research to address RQ2 for this study.

Finally, the RQ3 was answered by recommending the planning considerations via the BMC as the reporting tool. Five planning consideration guidelines were put forward based on the statistical significance of the hypotheses proposed in the study (Section 9.2.1to 9.2.5). In order for service providers to be able to reach their intended electricity customers, customer segments identification was recommended as the first planning guideline. If the smart meter provider or utility company is able to identify their customers, it becomes easier to identify the channels through which the value proposition can be communicated. For example, for customers who are educated and are computer literate, the use of social media, and other technological platforms becomes an easy way to communicate the benefits and value which smart meters bring. Whereas the uneducated and computer illiterate might need different channels to communicate relevant information about the benefits and smart meter value in their electricity management.

9.4 Contribution of the research.

This research study has made several contributions to behavioral studies in a number of ways. Most significant is the contribution to knowledge about the implementation of pervasive computing technologies such as smart meter acceptance and use in developing countries. This section discusses the research contributions from two perspectives, namely, theoretical perspectives and practical perspectives.

9.4.1 Theoretical contributions

From the theoretical perspective, this research contributes most importantly to the pervasive technology domain with a rich empirical study that assists technology innovators, utility companies and policy makers to understand the consumer-centric factors that might affect technology acceptance and use. Since most of the behavioral models and theories were developed a long time ago (such as the TRA, TPB and TAM (Davis et al. 1989)), their application and use in identifying factors that influence smart technology acceptance and use might not be adequate or relevant. The rapid change in technology and user technology interactions has impacted significantly on the way technology is viewed. Hence, the proposed theoretical model developed in this study presents new empirical knowledge that can be refined further in technology acceptance and use studies in the future.

In addition, this study contributed in the model development literature and design. Various theoretical models were identified to assist in developing a competing model for this study. Based on an extensive literature review (Chapter 3), the TAM was identified as a fundamental research framework. However, since smart meter technology is a new technological advancement, the TAM was found to be inadequate to help understand and identify factors that affect user behavior to accept and use pervasive technology. Therefore, this study contributed to the model development literature by integrating other relevant variables to supplement the TAM inadequacy. In view of smart meter technology, the factors that were found relevant and incorporated into the TAM for the study model development were: privacy risk (PCT), facilitating conditions and monetary cost (UTAUT), social norms (TPB), trust, perceived value (Chapter 2). Therefore, the proposed model output in this study confirms a new contribution to the body of knowledge.

Another theoretical contribution that emanated from this study is an enrichment of the African literature about smart meter technology acceptance modelling. From the literature review, it is evident that most smart grid and smart meter roadmaps and studies on technology adoptions acceptance, implementations and post-implementation have been conducted either in the United State of America or European countries. Considering that these are developed countries which have better electricity grid infrastructure, better electricity policies, high level technical skills, a high sense of environmental consciousness and high privacy appetite, the situation is different in developing countries like South Africa. It is, therefore, meaningful that the results of this study, which focuses on a South African situation, can contribute or can be used as a reference model in understanding the African smart meter consumer's perspective. Therefore, results can be adapted by other African countries for the planning consideration recommendations for smart meter implementation as opposed to using American or European views which are far from the African setting.

9.4.2 Practical contributions

Section 9.4.1 discussed the theoretical contribution to the body of knowledge and the existing literature on the technology acceptance and use for planning consideration for smart meter implementation in South Africa. The practical contributions of this research focus on the actual use of the findings in formulating planning considerations that can motivate electricity consumers towards acceptance of smart meters.

The first practical contribution of this study is that the findings provide smart meter providers, utility companies and municipalities with a starting point for identification of consumer-centric factors that need to be considered in motivating electricity consumers to accept and use smart meter technology, a stage which is critical in the formulation of planning considerations for smart meter implementation. The consumer-centric factors identified will assist the smart meter providers to understand the value propositions they can motivate, perceptions they need to set right and incentives that they can implement to achieve a higher acceptance. For example, smart meter consumers in America and Europe may consider privacy as a critical consumer-centric factor in their decision to accept smart meters whereas the African consumers does not. Therefore, the value propositions and incentives become different. Since, smart meter implementation in Africa is still in its infancy stages, this research can be used by government policy makers and utility companies as literature to assist in understanding the benefits and challenges they need to guard against in order to get better acceptance. Considering the challenges in developed countries, the choice for consumers to opt out of smart meter installation affords a consumer the choice to be part of a metering system or not. This is a situation that is different when it comes to South Africa.

The use of the BMC as a value proposition reporting tool and as a research output artifact will provide smart meter providers and utility companies with a simpler and more graphical process to be able to identify the various types of customers they have, partners they need and value propositions they need to communicate through diverse channels. For example, customers from lower income bracket might need subsidies from the government in order for them to afford electricity. Therefore, the government becomes a partner in subsiding such consumers. The SABC becomes another partner who can assist in reaching out with smart meter awareness campaigns, through their TV or radio platforms. The five BMC resultant planning considerations guidelines suggested in this research can be useful to smart meter providers or fine-tuned to suit their consumers, thereby reducing costs in conducting similar research within the smart meter or pervasive computing technologies field.

Finally, the empirical evidence, key findings and recommendations from this research can be used as a motivation in policy development or the guidelines can be used within pervasive technology regulation and implementation.

9.5 Limitations of the study

As much as the quantitative research process used aimed at obtaining reliable empirical results applicable to the social enquiry under investigation, some potential limitations were identified. Hence, the interpretation of these results and application thereof should be used with caution. This study investigated the consumer-centric factors and then formulated planning consideration for smart meter implementation in South Africa.

Firstly, data collected for this study was focused only on the South African population with the assumption that the participants have a bit of knowledge and understanding of what smart meters are, and their potential benefits and challenges. In reality, during the data collection phase, it was discovered that some consumers confused smart meters with prepaid meters. Therefore, a description of what smart meters are assisted participants to eradicate the confusion between smart meters and prepared meters as it might impact on the participant's responses. This had to be done during the data before the final data collection in order to develop improve the accuracy of the measurement instrument was developed.

The data collected from this research was targeted at South Africa as country, but only three Gauteng Province municipalities (City of Tshwane, City of Johannesburg and Ekurhuleni Metropolitan Municipality) constituted approximately 86% of the consumer's responses with only 14% representing the other provinces. It was evident that the data collected did not represent all targeted consumers and also has a potentially limited diversity of perceptions on smart meter implementation. Therefore, a more inclusive study with data collection from other municipalities would enable better generalisability of the research findings.

Owing to time and financial resources, the study used a purposive and cluster sampling strategy. The purposive sampling strategy is non-probability sampling where the researcher chooses the participants in the study on their judgement and experience (Etikan et al.2016). Though it is a cost-effective sampling technique, non-probability sampling is susceptible to bias and lower reliability of the findings. Purposive sampling was part of the decision about which municipalities to consider for data collection, whereas cluster sampling methods were used to identify the major municipalities to target participants.

The research study followed a quantitative research approach, Hence, some qualitative data collected could not be interpreted using SEM. Therefore, incorporation of qualitative methodology of data collection and analysis could have improved the overall research findings and understanding of the consumer perspectives.

Sample sizes are very important when it comes to quantitative research studies in comparison to qualitative studies. Small sample size has a serious impact on the power of statistics and the quality of the results (Creswell, 2012). This study obtained 705 electricity consumer responses, which was acceptable for statistical analysis using SEM (Hair et al. 2017). Though the sample size of 705 consumer responses is acceptable (Krejcier, 1970; Hair et al. 2010), considering that the electricity consumer population of 31 million in the South Africa, a much larger sample size with better representation from all cities in South Africa could have generated more accurate results, and thereby ensured a better generalisation of the research findings to other provinces.

The research focused mainly on the residential electricity consumer's perceptions and excluded the business or commercial users. Consideration of other stakeholders in the study could have added value to the research findings and value propositions for planning consideration for smart meter implementation.

The Business Model Canvas was used as a reporting and strategic management tool for the formulation of planning consideration guidelines for smart meter implementation in South Africa. The use of other models in the reporting and recommendation of planning consideration guidelines might be necessary in the future in order to verify and validate the BMC.

9.6 Further Research

This research used South Africa as a case study which is a developing country and, as such, a marginalized area in academic research., It also provided understanding of planning considerations for smart meter implementation, perceptions and direction for developed countries researchers to follow for future research.

This study followed a quantitative research inquiry approach to the social phenomena in which consumer-centric factors that affect smart meter implementation are investigated and provide planning consideration recommendations within the pervasive technology domain. As much as the identification of the factors can be predicted using the SEM technique, understanding consumer behavior and how it can be motivated needed some interviews in order to provide more insight into attitude and behavioral intention. Therefore, conducting this research using a mixed method might bring more understanding to some of the attitudes and behaviors since the participants might relate better through an interview as compared to strictly SEM statistical analysis for a complex social phenomenon. The study was conducted with an objective to generalize the findings to other pervasive computing technologies in future. Evaluating the applicability of the research proposed model to other similar pervasive technologies like smart cities opens another door for future research. As the research was only conducted in South Africa as a country, conducting the same research in multiple countries within Africa can assist an evaluation of the extent to which the factors affecting smart meter technology acceptance and use can be generalized within the African context. Finally, as much as smart meters may bring better consumer management of electricity consumption, the comments from data collection phase suggested that most participants were not aware of smart meters, hence there is a need for more awareness and campaigns and education for reducing smart meter implementation resistance.

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APPENDIX 1: CONSTRUCT ITEMS

CONSTRUCT	ITEM	MEASUREMENT	ADAPTED SOURCE
Trust in technology (TT)	**TT1**	Smart meter technology is trustworthy.	Miltgen et al.2013 Belanche et al.2012 Joubert & Belle, 2013.
	TT2	Smart meter technology is dependable.	
	TT3	Smart meter technology is credible in managing electricity demand and supply	
	TT4	Smart meter technology has a good reputation in the electricity in the electricity industry.	
	TT5	Smart meter technology improves reliable electricity supply.	
	TT6	Smart meter technology records electricity billing information accurately.	
Trust in the smart meter provider (TP)	***TP1***	*The smart meter service provider is honest in their use of my smart meter data. ** *	*Joubert & Belle, 2013*
	TP2	*The smart meter service provider is truthful about the collection and use of my personal data. ** *	
	TP3	*The smart meter service provider implements the smart meter technology with the consumer's best interests at heart, not their own. ** *	
	TP4	*The smart meter service provider is competent in managing electricity distribution through smart meter technology. ** *	*Krasnova & Veltri.,2010*
Trust in the legal system (TL)	***TL1***	*I generally think that existing laws (our legal system) protect my personal data. ** *	
	TL2	*I generally think that existing laws (our legal system) protect me against the misuse of my smart meter data. ** *	
	TL3	*I generally think that existing laws (our legal system) are good enough to make me feel comfortable with using smart meter technology. ** *	
	TL4	*I generally think that existing laws (our legal system) prevent unauthorized access to my information/data collected through smart meter technology. ** *	
Perceived usefulness (U)	**PU1**	Smart meter makes it easier for me to monitor and adjust my electricity usages.	Self-developed
	PU2	*Smart meter makes it easier to take advantage of many electricity tariff options.* **	Gefen et al.,2003
	PU3	Smart meter makes it easier to manage electricity usage.	Self-developed

	PU4	Smart meter makes it easy for me to get timely billing information.	Davis et al.1989
	PU5	Smart meter makes it easier for me to use electricity efficiently.	
	PU6	*Smart meter makes it easier for my electricity disconnections/interruptions to be restored.* ******	
Perceived ease of use (EU)	**EU1**	I find it easy to use smart meter. *	Gefen et al.2003
	EU2	I find it easy to learn how to operate smart meter. *	Willis, 2009 Lee et al.2001
	EU3	I find it easy to get the smart meter do what I want it to do. *	
	EU4	It does not require any mental effort to use smart meter. *	
Privacy risk (PR)	***PR1***	*I think smart meter technology makes it easier for my home to be monitored.* ******	Self-developed
	PR2	*I think smart meter technology makes me lose my freedom.* ******	Self-developed
	PR3	*I think smart meter technology makes it easier for me to be monitored without my knowledge*******	Self-developed
	PR4	I think smart meter technology makes it easier for my personal data to be misused for market research and advertising without my knowledge.	Xu et al.2011
	PR5	*I think smart meter technology allows easy sharing of my personal data without my knowledge.* ******	
	PR6	I think smart meter technology allows easier access to my personal data without my knowledge.	
	PR7	I think smart meter technology makes me vulnerable to criminals.	Self-developed
	PR8	I think smart meter technology put my privacy at risky.	Xu et al.2011
Monetary cost (MC)	**MC1**	Smart meter technology is expensive to a consumer like me. *	Agarwal et al.2010
	MC2	Smart meter technology makes me pay more than the old manual system. *	
	MC3	Smart meter technology cause me to incur a higher cost than the old manual system. *	
	MC4	Smart meter technology will make me pay more money unnecessarily. *	Self-developed
Perceived value (PV)	**PV1**	Smart meter technology provides good value.	Venkatesh et al.2012 Agarwal et al.,2010
	PV2	Smart meter technology is worthwhile considering.	
	PV3	Smart meter technology provides me more benefits than disadvantages.	
	PV4	I appreciate what smart meter technology can do for me.	
	AT1	I think using smart meters is a good idea***	

Attitude (AT) **	**AT2**	I think using smart maters is a wise idea***	Belanche et al.,2012
	AT3	I think using smart meters would be a pleasant experience. ***	
	AT4	Generally, I like the idea of using smart meters. ***	
Facilitating conditions (FC)	**FC1**	I will easily access information about the use of smart meter technology. *	Sanchez-Prieto et al.2016
	FC2	I will easily get instructions on smart meter use in my home language. *	Venkatesh et al. 2012
	FC	I will easily get guidelines on how use smart meters. *	
	FC3	I can easily get support when I have difficult using smart meter technology. *	
	FC4	I think it will be easy to install smart meter in my home. *	Micheni et al.2013
Social norms (SN)***	**SN1**	I will be happy to have a smart meter installed in my home. ***	Taneja et al.2014
	SN2	I will volunteer to have a smart meter installed in my home. ***	Taneja et al.2014
	SN3	I am comfortable with having a smart meter installed in my home. ***	Taneja et al.2014
	SN4	I am positive about a city-wide roll-out of smart meters. ***	Venkatesh et al.2012
	SN5	I support the installation of smart meters in the city. ***	Venkatesh et al.2012
	SN6	I will be happy to have a smart meter installed in my home. ***	Venkatesh et al.2012
*Personal consciousness (PC) ****	***PC1***	*I will support smart meter technology use because my family supports it.* **	*Taneja et al.2014*
	PC2	*I will support smart meter technology use because my friends supports it.* **	
	PC3	*I will support smart meter technology use because my colleagues supports it.* **	
	PC4	*I will support smart meter technology use because people important to me say it helps save the environment.* **	*Park et al.2014*
	PC5	*I will support smart meter technology use because people important to me think it is the right thing to do.* **	*Venkatesh et al.2012*
	PC6	*I will support smart meter technology use because I believe it is the right thing to do.* **	
	CC1	*I will support the use of smart meter technology because my community thinks it is good to manage and distribute electricity.* **	

*Community consciousness (CC)***	***CC2***	*I will support the use of smart meter technology because my community thinks it prevents electricity theft.* ****	*Lee et al. 2001*
	CC3	*I will support the use of smart meter technology if my political affiliate party supports it.* ****	
	CC4	*I will support the use of smart meter technology if my community thinks it saves electricity.* ****	
	CC5*	*Overall, I will support the use of smart meter technology if my community thinks it saves the environment.* ****	
Behavioral intention to use smart meters (BI)	**BI1**	I am will be happy to have smart meter install at my home.	Xu et al.,2011
	BI2	I am will favorable to have a smart meter installed in my home.	Xu et al.,2011
	BI3	I will volunteer to have a smart meter installed at my home.	Venkatesh et al.2012 Kaushik et al. 2015
	BI4	I am comfortable to have a smart meter installed in my home.	
	BI5	*I plan to have smart meter installed at my home***	
	BI6	I support the installation of smart meters in the city.	
	BI7	I am positive about a city-wide roll-out of smart meters.	

NB: Reworded construct items in the final questionnaire, dropped constructs and items** and added construct and items****

APPENDIX 2: CONSTRUCT ITEMS

CONSTRUCT	ITEM	MEASUREMENT	ADAPTED SOURCE
Trust in technology (TT)	**TT1**	Smart meter technology is trustworthy.	Belanche et al.2012
	TT2	Smart meter technology is dependable.	
	TT3	Smart meter technology is a credible in managing electricity demand and supply	Thatcher et al.2009
	TT4	Smart meter technology has a good reputation in the electricity in the electricity industry.	
	TT5	Smart meter technology improves reliable electricity supply.	Belanche et al.2012
	TT6	Smart meter technology records electricity billing information accurately.	Self-developed
Perceived usefulness (U)	**PU1**	Smart meter makes it easier for me to monitor and adjust my electricity usages.	Davis et al.1989
	PU3	Smart meter makes it easier to manage electricity usage.	Self-developed
	PU4	Smart meter makes it easy for me to get timely billing information.	Gu et al.2009
	PU5	Smart meter makes it easier for me to use electricity efficiently.	
Perceived ease of use (EU)	**EU1**	I will find it easy to use a smart meter.	Davies et al.1989,
	EU2	I will find it easy to learn how to operate the smart meter.	
	EU3	I will find it easy to get the smart meter to do what I want it to do.	
	EU4	It will not require any mental effort to use the smart meter.	
Privacy risk (PR)	**PR1**	I think smart meter technology makes it easier for my personal data to be misused for market research and advertising without my knowledge	Krasnova & Veltri, 2010, Dinev et al.2006
	PR2	I think smart meter technology allows easier access to my personal data without my knowledge.	Dinev et al.2006
	PR3	I think smart meter technology makes me vulnerable to criminals.	Self-developed
	PR4	I think smart meter technology put my privacy at risky.	Taneja et al.2014
Monetary cost (MC)	**MC1**	Smart meter technology will make me pay more money unnecessarily.	Self-developed
	MC2	Smart meter technology will make me pay more than the old manual system.	Kim et al.,2007

	MC3	Smart meter technology will cause me to incur a higher cost than the old manual system.	Agarwal et al. 2010
	MC4	Smart meter technology will be expensive to a consumer like me.	
Perceived value (PV)	**PV1**	Smart meter technology provides good value.	Agarwal et al.,2007
	PV2	Smart meter technology is worthwhile considering.	
	PV3	Smart meter technology provides me more benefits than disadvantages.	
	PV4	I appreciate what smart meter technology can do for me.	Kim et al.,2007,
Attitude (AT)	**AT1**	I think using smart meters is a good idea	Belanche et al. (2012)
	AT2	I think using smart maters is a wise idea	
	AT3	I think using smart meters would be a pleasant experience.	
	AT4	Generally, I like the idea of using smart meters.	
Facilitating conditions (FC)	**FC1**	Gaining access to information about the use of smart meters will be easy.	Self-developed
	FC2	Obtaining instructions for smart meter use will be easy.	Fathema et al.2015
	FC	Obtaining guidelines on how to use smart meters will be easy.	
	FC3	I can easily get support when I experience difficulties using smart meters.	Venkatesh et al.2012
	FC4	Gaining access to information about the use of smart meters will be easy.	Self-developed
Social norms (SN)	**SN1**	I will be happy to have a smart meter installed in my home.	Taneja et al.2014
	SN2	I will volunteer to have a smart meter installed in my home.	
	SN3	I am comfortable with having a smart meter installed in my home.	
	SN4	I am positive about a city-wide roll-out of smart meters.	Venkatesh et al.2012
	SN5	I support the installation of smart meters in the city.	
	SN6	I will be happy to have a smart meter installed in my home.	
Behavioral intention to use smart meters (BI)	**BI1**	I am will be happy to have smart meter install at my home.	Xu et al.2011
	BI2	I intent to have a smart meter installed in my home.	Venkatesh et al.2012
	BI3	I will volunteer to have a smart meter installed at my home.	Kaushik et al, 2015
	BI4	I am comfortable to have a smart meter installed in my home.	
	BI5	I am positive about a city-wide roll-out of smart meters.	
	BI6	I support the installation of smart meters in the city.	Micheni et al.2013

APPENDIX 3: CONSTRUCT DEFINITIONS

CONSTRUCT	DESCRIPTION	REFERENCE
Trust in Technology	System trust as the overall assessment of the trustworthiness of a system which requires "special and profound expertise. Expert's‟ assessment of the trustworthiness of a system might differ from that of an „ordinary‟ consumer.	Joubert & van belle, (2013)
	Trust in it as the subjective probability by which organizations believe that the underlying technology infrastructure is capable of facilitating transactions according to their confident expectations." Trusting beliefs in a specific technology is reflected in three beliefs: functionality, helpfulness, and reliability	Thatcher, 2009
	Trust as the willingness of the user to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party.	Mayer et al.1995
	The user's assessment of a technology's ability to deliver on the promise of its objective characteristics.	
Perceived usefulness	Perceived usefulness is defined as the prospective user's subjective probability that using a specific application will his increase his or her job performance within an organization context	Davis et al, 1989
	Perceived usefulness refers to the degree to which an individual believes that use of technology will enhance his performance	Abdulkadir et al, 2013
Perceived ease of use	Perceived ease of use is defined as the degree to which the user perceives the effort required to use a particular technology will be to be effortless.	Davis et al.1989
	Perceived ease of use refers to the degree to which one believes that using an information system is free from effort.	Abdulkadir et al, 2013
	Privacy risk is defined as the expectation of losses associated with the disclosure of personal information on Facebook	Xu et al.2011

Perceived privacy risk	Perceived privacy risk can be described as the potential loss of control or disclosure to personal information without consumer consent	Wunderlich et al.2012
	Privacy risk as the expectation of loss due to information disclosure on Facebook	Taneja et al.,2014
	Privacy risk refers to the potential loss due to fraud or a hacker compromising the security of an online bank user.	Azouzi, 2009
Monetary Cost	The perceived financial resource is defined as the extent to which a person believes that he/she has financial resources needed to use m-banking	Bong-Keun & Yoon, 2013
	Perceived financial cost (PFC) refers to the degree which an individual believes that use of m-banking services is costly.	Abdulkadir et al.,2013
	Perceived cost is referred to as the consumers' belief of the cost regarding the new technology usage.	
	The price represents the amount of economic outlay that a person has to give up in exchange for a good or service.	Agarwal et al.,2007
Perceived Value	Perceived value can be defined as one's overall assessment of the utility of a product or service based on his or her assessed comparison of the trade-off between perceived benefits (utility) and perceived sacrifices (typically, cost considerations)	Hazen et al.,2015
	Perceived value means that an overall consumers' subjective evaluation of benefit (what is received) and cost (what is given).	Chi et al.,1991
	Value has been defined in several ways in the literature. Summarized by Zeithaml (1988), value has four meanings – 1) value is low price, 2) value is whatever one wants in a product, 3) value is the quality that the one receives for the price paid, and 4) value is what the consumer gets for what he gave. Taken these meaning together, the value represents 'consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given.'	Agarwal et al.,2007
	They were no clear definition of perceived value rather their study suggested that perceived value (perception of value) as the differentiation between the perception of sacrifice and benefits. Their study emphasis that potential adopters may become adopters of a technology if the	Roger et al.,2006

	perceived benefits to outweigh the costs of obtaining that technology.	
	Based on the Value-based adoption model, defined perceived value as a weighted result determined by perceived benefits and perceived sacrifices. If perceived sacrifices are constant, the perceived value of new technology tends to be higher when the perceived benefits increase.	Xiong, 2013
	Adapting Zeithaml's definition into their study defined the perceived value of information disclosure as the individual's overall assessment of the utility of information disclosure based on perceptions of privacy risks incurred and benefits received.	Xu et al.,2011
Facilitating Conditions	Facilitating conditions can be defined as the extent which consumers' perceives that the resources and support required to perform a behavior is available.	Ghalandari, 2012
	Facilitating conditions can be is the degree to which a person believes that an organizational and technical infrastructure exists to support the use of a system.	Micheni et al.2013
	Facilitating conditions is defined as perceived enablers or barriers in the environment that influence a person's perception of ease or difficulty of performing a task.	Fathema et al.2015
	Facilitation condition refers to consumers' perceptions of the resources and support available to perform a behavior.	Venkatesh et al.2012
Attitude	Attitude is defined as an individual's positive or negative evaluation of performing a particular behavior	Kim et al.2009
	Attitude is defined as the degree to which the performance of the behavior is positively or negatively valued by an individual.	Fishbein & Ajzen, 1975
Social Norms	The social norm is defined as the perceived social pressure to engage or not to engage in a behavior	Fishbein & Ajzen, 1975.
	as the individual's perception that most people who are important to him/her think he/she should or should not perform the behavior in question	Fishbein & Ajzen, 1975.
	Social norm/influence have perceived social pressure on individuals to perform a behavior.	Gaffar et al. 2013
	Similar to social norms, social influence is the extent to which consumers perceive that important others (e.g.,	Venkatesh et al.2012

	family and friends) believe they should use a particular technology	
	Social norms can be defined to represent the expectation of other people regarding the performance of a particular behavior, thus representing how a person is influenced by the perception of others such as family and friends.	Pantano & Pietro, 2012
Behavioral Intentions	Behavioral intention as the measure of an individual strength to perform a specific behavior.	Fishbein & Ajzen, 1975.
	Behavioral intention is defined as the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior.	Fathema et al.2015
	Behavioral intention can be referred to as the degree an individual indicates how much effort is willing to try in order to perform a specific behavior.	Ajzen, 1991

APPENDIX 4: INITIAL QUESTIONNAIRE

RESEARCH TITLE: **A PLANNING FRAMEWORK FOR IMPLEMENTING SMART METER TECHNOLOGY WITHIN THE SOUTH AFRICAN CONTEXT.**

Dear Participant,

I am kindly inviting you to participate in my Ph.D. research study survey. The aim of the study is to formulate a framework that can assist in the planning of implementing smart meter technology in the South African context.

I would appreciate it if you can complete this survey.

The survey specifically asks your opinion regarding smart meters. There are no right or wrong answers; all questions are opinion-based. Your participation in this study is voluntary and you are free to withdraw your participation from this study at any time. The survey should take approximately 15 - 25 minutes to complete.

There are no risks associated with participating in this study. The survey collects no personal identifying information of any participant. All responses to the survey will be recorded anonymously and remain confidential. Results will only be reported in the aggregate.

While you will not experience any direct benefits from participation, information and opinions that will be gathered in this study may benefit the municipality policy makers, technology innovators, and the public during future technology implementations.

If you have any questions regarding the survey or this research project in general, please contact Mr. Tonderai Muchenje and/or his promoter, Prof. RA Botha. Their e-mail addresses are tonderaimuchenje@gmail.com and reinhardta.botha@nmmu.ac.za, respectively.

By completing and submitting this survey, you are indicating your consent to participate in the study.

Your participation is appreciated.

Thank you very much for your time and support.

Please start with the survey now by clicking on the NEXT button below to begin

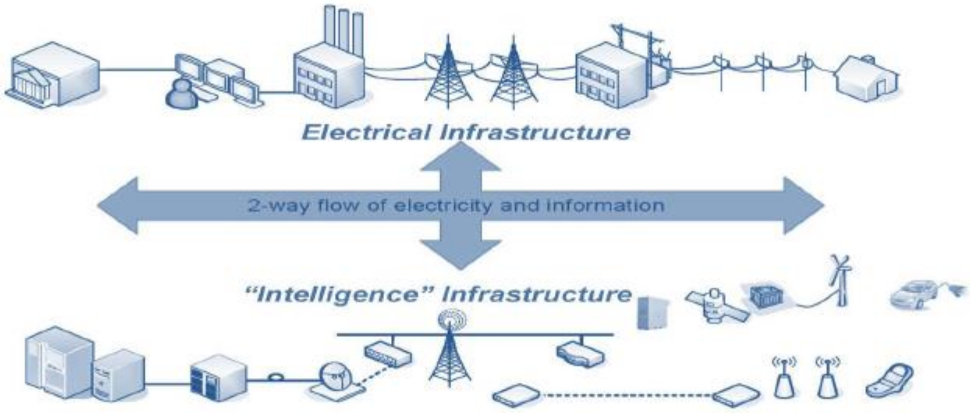
THIS SECTION PROVIDE YOU WITH AN UNDERSTANDING TO TERMINOLOGY

What is a Smart Meter?

A smart meter is a modern system that can collect and analyze and stores detailed energy usage digitally send meter readings to your energy supplier. The measurement is done automatically without human interaction in intervals of 15 minutes to an hour. The measured information is send and displayed to customers' using various interface platforms such as web-based customer portals, smart phones, tablets and customer interface units (CIUs).

What is a Smart Meter Technology?

A smart meter system is the integration of intelligent information and communication technology into electric transmission and distribution networks. The smart system delivers electricity to customers using two-way digital technology. **See image below**



GENERAL QUESTIONS

GQ.1. Please select your gender.

1. Male
2. Female

GQ.2. Please select the area where you live?

1. Within City of Tshwane
2. Outside City of Tshwane

GQ.3. What is your highest level of education?

1. No schooling

2. Some schooling
3. Matric
4. Certificate
5. Diploma
6. Undergraduate degree (including Hons degree)
7. Prograduate degree (Masters & Doctorates)
8. Others

GQ.4. Select your age group?

1. 18 - 25
2. 25 - 35
3. 36 - 45
4. 46 - 50
5. > 60

GQ.5. What is your average annual income per year?

1. Less than R 149 000
2. R 150 000 - R 299 000
3. R 300 000 - R 449 000
4. R 450 000 - R 599 000
5. R 600 000 - R 749 000
6. R 750 000 - R 899 000
7. More than R 900 000

GQ.6. Who is your smart meter service provider that supplies and manages your electricity?

1. Tshwane Metro
2. Johannesburg Metro
3. Cape Town Metro
4. Durban Metro
5. Other

THE QUESTIONS BELOW ARE SPECIFICALLY ASKS YOUR OPINION AND EXPERIENCE REGARDING SMART METER TECHNOLOGY.

MQ.1. Please indicate the extent to which you agree or Disagree with each of the following statements. Indicate your response on the scale 1 to 7 (where strongly Disagree = 1 and Strongly Agree = 7)

Smart meter technology...........

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
is trustworthy.	❏	❏	❏	❏	❏	❏	❏
is dependable.	❏	❏	❏	❏	❏	❏	❏
is a credible in managing electricity demand and supply	❏	❏	❏	❏	❏	❏	❏

has a good reputation in the electricity in the electricity industry?	❑	❑	❑	❑	❑	❑	❑
improves reliable electricity supply.	❑	❑	❑	❑	❑	❑	❑
records electricity billing information accurately.	❑	❑	❑	❑	❑	❑	❑

MQ.2. Please indicate the extent to which you Agree or Disagree with each of the following statements. Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

The smart meter service provider...........

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
is honest in their use of my smart meter data.	❑	❑	❑	❑	❑	❑	❑
is truthful about the collection and use of my personal data.	❑	❑	❑	❑	❑	❑	❑
implements the smart meter technology with the consumer’s best interests at heart, not their own.	❑	❑	❑	❑	❑	❑	❑
is competent in managing electricity distribution through smart meter technology.	❑	❑	❑	❑	❑	❑	❑

MQ.3. Please indicate the extent to which you Agree or Disagree with each of the following statements. Indicate your

response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

I generally think that existing laws (our legal system) ....

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
protect my personal data.	❑	❑	❑	❑	❑	❑	❑
protect me against the misuse of my smart meter data.	❑	❑	❑	❑	❑	❑	❑
are good enough to make me feel comfortable with using smart meter technology.	❑	❑	❑	❑	❑	❑	❑
prevent unauthorized access to my information/data collected through smart meter technology.	❑	❑	❑	❑	❑	❑	❑

MQ.4. Please indicate the extent to which you Agree or Disagree with each of the following statements. Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
I find it easy to use smart meter.	❑	❑	❑	❑	❑	❑	❑
I find it easy to learn how to operate smart meter.	❑	❑	❑	❑	❑	❑	❑
I find it easy to get the smart meter do what	❑	❑	❑	❑	❑	❑	❑

I want it to do.							
It does not require any mental effort to use smart meter.	❏	❏	❏	❏	❏	❏	❏

MQ.5. Please indicate the extent to which you Agree or Disagree with each of the following statements. Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

Smart meter...........

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
makes it easier for me to monitor and adjust my electricity usages.	❏	❏	❏	❏	❏	❏	❏
makes it easier to take advantage of many electricity tariff options.	❏	❏	❏	❏	❏	❏	❏
makes it easier to manage electricity usage.	❏	❏	❏	❏	❏	❏	❏
makes it easy for me to get timely billing information.	❏	❏	❏	❏	❏	❏	❏
makes it easier for me to use electricity efficiently.	❏	❏	❏	❏	❏	❏	❏
makes it easier for my electricity disconnections/interruptions to be restored.	❏	❏	❏	❏	❏	❏	❏

MQ.6. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

I think smart meter technology...........

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
makes it easier for my home to be monitored.	❏	❏	❏	❏	❏	❏	❏
makes me lose my freedom.	❏	❏	❏	❏	❏	❏	❏
makes it easier for me to be monitored without my knowledge	❏	❏	❏	❏	❏	❏	❏
makes it easier for my personal data to be misused for market research and advertising without my knowledge.	❏	❏	❏	❏	❏	❏	❏
allows easy sharing of my personal data without my knowledge.	❏	❏	❏	❏	❏	❏	❏
allows easier access to my personal data without my knowledge.	❏	❏	❏	❏	❏	❏	❏
makes me vulnerable to criminals.	❏	❏	❏	❏	❏	❏	❏
put my privacy at risky.	❏	❏	❏	❏	❏	❏	❏

MQ.7. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

Smart meter technology...........

	Strongly	Disagree	Somewhat	Neither Agree or	Somewhat	Agree	Strongly

	Disagree		Disagree	Disagree	Agree		Agree
is expensive to a consumer like me.	❑	❑	❑	❑	❑	❑	❑
will make me pay more money unnecessarily.	❑	❑	❑	❑	❑	❑	❑
makes me pay more than the old manual system.	❑	❑	❑	❑	❑	❑	❑
cause me to incur a higher cost than the old manual system.	❑	❑	❑	❑	❑	❑	❑

MQ.8. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
Smart meter technology provides good value.	❑	❑	❑	❑	❑	❑	❑
Smart meter technology is worthwhile considering.	❑	❑	❑	❑	❑	❑	❑
Smart meter technology provides me more benefits than disadvantages.	❑	❑	❑	❑	❑	❑	❑
I appreciate what smart meter technology can do for me.	❑	❑	❑	❑	❑	❑	❑

MQ.9. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
I can easily access information about the use	❑	❑	❑	❑	❑	❑	❑

of smart meter technology.							
I can easily get training material on smart meter technology in my home language.	❑	❑	❑	❑	❑	❑	❑
I can easily get support when I have difficult using smart meter technology.	❑	❑	❑	❑	❑	❑	❑
I think it will be easy to install a smart meter in my home.	❑	❑	❑	❑	❑	❑	❑

MQ.10. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

I will support smart meter technology use...........

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
because my family supports it.	❑	❑	❑	❑	❑	❑	❑
because my friends support it.	❑	❑	❑	❑	❑	❑	❑
because my colleagues support it.	❑	❑	❑	❑	❑	❑	❑

because people important to me say it helps save the environment.	❏	❏	❏	❏	❏	❏	❏
because people important to me think it is the right thing to do.	❏	❏	❏	❏	❏	❏	❏
because I believe it is the right thing to do.	❏	❏	❏	❏	❏	❏	❏

MQ.11. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree or Disagree	Somewhat Agree	Agree	Strongly Agree
I will support the use of smart meter technology because my community thinks it is good to manage and distribute electricity.	❏	❏	❏	❏	❏	❏	❏
I will support the use of smart meter technology because my community thinks it prevents electricity theft.	❏	❏	❏	❏	❏	❏	❏
I will support the use of smart meter technology if my political affiliate party supports it.	❏	❏	❏	❏	❏	❏	❏
I will support the use of smart meter technology if my community thinks it saves electricity.	❏	❏	❏	❏	❏	❏	❏
Overall, I will support the use of smart meter technology if my community thinks it saves the environment.	❏	❏	❏	❏	❏	❏	❏

MQ.12. Please indicate the extent to which you Agree or Disagree with each of the following statements: Indicate your response on the scale 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7)

	Strongly	Disagree	Somewhat	Neither	Somewhat	Agree	Strongly

	Disagree		Disagree	Agree or Disagree	Agree		Agree
I am happy to have smart meter install at my home.	❑	❑	❑	❑	❑	❑	❑
I am favorable to have a smart meter installed in my home.	❑	❑	❑	❑	❑	❑	❑
I will volunteer to have a smart meter installed at my home.	❑	❑	❑	❑	❑	❑	❑
I am comfortable to have a smart meter installed in my home.	❑	❑	❑	❑	❑	❑	❑
I am positive about a city-wide roll-out of smart meters.	❑	❑	❑	❑	❑	❑	❑
I support the installation of smart meters in the city.	❑	❑	❑	❑	❑	❑	❑

MQ.13. Is there any question (s) above that made you feel offended or excited.

Comments or Suggestions

THANK YOU FOR YOUR SUPPORT AND PARTICIATION

APPENDIX 5: INITIAL PRE-TESTING

Pre-testing Study: Questionnaire Reporting

The pilot study was conducted with the help from people who are using smart meters within the City of Tshwane metropolitan area. The participants included friends, colleagues, church mates, and other research colleagues. The aim of the pilot study was to find out if the questions were understood the same way and voiced correctly for the participants in order to measure what we intend to measure.

All participants were asked to give consent before participation in the pilot study. The researcher and the participants went through the questionnaire while the comments were being recorded in the process. In other cases, some participants requested the questionnaire document and made feedback comments and their recommended suggestions.

Comments on the Questionnaire: Consent Letter

The first section of the questionnaire was a consent letter. The consent letter highlighted the title of the research study as: "*A planning framework for implementing smart meter technology within the South African context*". About 13.3% of participants (two participants) commented on the title. The participants suggested extending the jurisdiction of the study to include the whole South Africa not the only City of Tshwane. Considering the purpose of the pilot study, the comments were not relevant as the concerns were addressing the sample size of the study which is dealt with in detail in our research methodology section. Therefore, I did not decide to change anything in the title since the comments did have relevance in addressing the clarity and ambiguity or wording of questions.

Some participants (7% = 1 participant) requested to clarify in the first sentence of the consent letter, "*We invite you to participate in our Ph.D. research survey. The study will formulate a framework that can assist in the planning of implementing smart meter technology in the South African context"* The participant could not understand who is referred to as "We", therefore suggested to reword the sentence to say: "You are invited to participate in a Ph.D. research survey. I considered the suggestion, but we rather rephrased the statement to *You are kindly inviting you to participate in my Ph.D. research study. The aim of the study is to formulate a framework that can assist in the planning of implementing smart meter technology in the South African context.*

One participant (7%) also commented on the last two sentences of the consent letter: *Please start with the survey now by clicking on the NEXT button below to begin.* The participant also provided a suggestion rewording of the statement to indicate that the participant accepts the terms before completing the survey. The participant input was considered as in brings consent aspect from the participant before completing the questionnaire. Therefore, the statement was rephrased better to *Please indicate that you accept the terms by ticking the checkbox below. To begin, click on the NEXT button below*

Additional Information: Terminology and Understanding of Smart Meters and Smart Meter Technology

Approximately 40% of the participants requested more information on the *functionality of smart meter* and also smart meter *images* they are familiar with. I decided to include more information on the functionality of smart meters and also better images participants can relate with.

<u>Comments on the Questionnaire: Demographics</u>

This section deals with questions relating to the demographics of the participants. Several questions were asked to ascertain the age, gender, income, geographic location and highest educational level.

One participant requested to include *"Others"* ***on the question on gender***, suggesting that transgender, bisexual, lesbians and gays as Reponses. I decided not to take the suggestion since most of the researchers have refer to gender as male and female (Park et al. 2014; Li, 2016; Hsu & Yen, 2012). The response was not relevant as it will also be addressed in the research methodology chapter.

On the question of the highest educational level, 33% of the participants suggested that the responses such as a *senior certificate, diploma, degree, Postgraduate* are limiting since some participants may not fall in those categories. Therefore, in considering the options, the suggestion to include the following responses: *no school, some school, primary school, secondary (matric) certificate, diploma, degree and Masters & Doctorates and Others*. The consideration was based on the fact that, some smart meter homeowners or users might have not even gone to school and might not be accommodated on the previous categories. Therefore, accommodating everyone will provide the closer overview of general educational levels of the smart meter populace under study.

On the question of the age: *How old are you? Select your age group*. One (7%) participant suggested starting the age range from 25 ending with > 60 years. I decided not to change the starting and ending ages since it is already covered in the age range provided in the questionnaire. The same participant also suggests using one question on age question instead of two. The according to the participant, the two question seems to ask two different things, the first question: *How old are you?* Asks for an exact age while the second question: *Select your age group,* asks for the age ranges. Therefore, instead of using two question on the age question, I decided to use one question: *Select you to age your age group* since it is the mostly used in research **(**Al-Ghaith et al.2010; Park et al.2014**)**.

On the question of salary: *What is your salary per year?* Three participants (20%) were suggested that the question is rephrased since the phrase "salary *per year*" mainly refers to the individuals who are employed only whereas there are people who are using smart meters may be self-employed, unemployed who might not necessary get a salary. Based on the suggestion above, I decided to rephrase the question to: *What is your average monthly income?* The rephrased question will then address the employed, unemployed and self-employed issue on the initial question. Taking into consideration that some individual might not know their yearly income, therefore an average monthly income might be easier to estimate but we rather used the mostly used socio demographic to; *what is the annual income per year*?

Comments on the Questionnaire: Model measurement questions

This section of the questionnaire discusses the questions on proposed measurement model. The measurement model identified 11 constructs (refer to proposed measurement model chapter) which were measured using a set of questions (items).

On the question on Trust in the municipality (Question 7): Three participants suggested that all question on Trust in municipality be rephrased to incorporate other service providers such as Eskom in the provision of smart meter services. I accepted the submission and rephrased the all the questions in the section to start as follows: "*The smart meter service providers ……"* The use of the word "*municipality*" might limit the scope of our smart meter participants thereby losing some invaluable information from other smart meter providers which might useful in the implementation planning of the technology.

On the question on Trust in the legal system (Question 8): Three participants were not clear on the existing laws referred to the question, and suggested that we specify laws such as Consumer protection Act of 2008, Protection of Personal Information Act of 2013, Electronic Communication Act of 2002, Electricity Law etc. I decided not to make any changes to the phrase "*Existing laws*" to specific laws. The purpose of the questions in this section is to measure the overall view of the relevant existing laws in protecting individuals while using the smart meter technology.

On the question of Trust in the legal system (Question 10d): One participant suggested rephrasing of the question: S*mart meters make it easier for my electricity disconnections to be restored*. The participants suggested that the word "disconnections" to some participants reflect a negative non- electricity payment connotation and may lead to a biased response, while the service provider view disconnection as non-supply of electricity. Therefore, I decided to take into account both views above and include the word "*interruptions*" in the statement to: S*mart meters makes it easier for my electricity interruptions or disconnections to be restored.*

On the question on Trust in the legal system (Question 12a): One participant requested the statement: smart *meter technology is expensive for a consumer like me,* to be rephrased as it suggests that other questions were not referring to the participant. Therefore, rephrased the statement to read: smart *meter technology is expensive.*

On the question of Trust in the legal system (Question 13a): About four participants were concerned about the statement: *Smart meter technology provides good value*. They could not understand what was referred to be as *"value".* The participants wanted the statement to be specific about the value smart meter portrait to provide. I decided not to change anything in the statement, the question is measuring the smart meter value in general. Some of the value specific aspects such as money value is covered on in Question 12. We will rather revisit some questions and rephrase to accommodate the concerns. For example, the Question 10 on benefits (usefulness) can accommodate statements on convenience and peace of mind provided for when smart meter provides. The suggestion will be: *Smart meters make the* *loading of units more convenience than the old manual system, Smart meter makes me be at peace when managing my electricity bills.*

On the question on Trust in the legal system (Question 15d): One participant commented on the statement: *I will support smart meter technology use because people important to me say it helps save the environment,* to be rephrased to read: *I will support smart meter technology use because people important to me are of the opinion that it helps say it helps save the environment".* I did not change the statements because all the questions are based on the opinion of the participants.

On the question on Trust in the legal system (Question 16c): Two participants commented on the statement *will support the use of smart meter technology if my political affiliate (political party, e.g. ANC, DA, EFF) supports it*. The participants wanted the examples of the political parties on the question to be removed as it can create indirect bias from the participants. I decided not to remove the examples of political parties in our view helped a wide range of participants to understand the question better rather than creating bias. Since some of our participants may not understand the word "*affiliate"*.

On the same question, the participants wanted question responses to accommodate the individuals who to not below to a political party. I decided to not change the responses because the question is trying to measure if the political parties can influence a decision to support or not to support. Therefore, even if the participants does not belong to a political party, responses options provided are adequate to warranty a response.

Overall General comment from participants: Most of the questions were generally easy to understand. In cases the participants requested additional responses to answers provided, one last question will be provided for to hear general feelings on the questionnaire. The last question will allow the participants to write their own responses and the question will read like: *Is there any question above excited/ upset you. If so which and Why?*

APPENDIX 6: ETHICAL APPROVAL

Nelson Mandela Metropolitan University
for tomorrow

School of ICT
Tel. +27 (0)41 504 3179
E-mail: ReinhardtA.Botha@nmmu.ac.za

12 April 2017

To whom it may concern

Confirmation of registration for Tonderai Muchenje.

This letter serves to confirm that Mr Tonderai Muchenje with student number 214397172, is currently registered for a PhD in Information Technology in the School of ICT at Nelson Mandela Metropolitan University.

I am his Supervisor. His working topic is: A FRAMEWORK FOR INCORPORATING PRIVACY CONSIDERATIONS IN TECHNOLOGY IMPLEMENTATION PLANNING WITHIN THE SOUTH AFRICAN CONTEXT

The research proposal has received ethical clearance from the neccesary bodies at the university with the reference number H17-ENG-ITe-001.

Any further questions can be directed at me per email to ReinhardtA.Botha@nmmu.ac.za
Regards

Reinhardt A. Botha
Professor: Information Technology

APPENDIX 7: APPROVAL LETTER FROM CITY OF TSHWANE

CITY OF TSHWANE
IGNITING EXCELLENCE

City Strategy and Organisational Performance

Room CSP23 | Ground Floor, West Wing, Block D | Tshwane House | 320 Madiba Street | Pretoria | 0002
PO Box 440 | Pretoria | 0001
Tel: 012 358 1673 / 082 603 0215 |
Email: AnishaD@tshwane.gov.za | www.tshwane.gov.za | www.facebook.com/CityOfTshwane

My ref: Research Permission/ Muchenje
Contact person: Pearl Maponya
Section/Unit: Knowledge Management

Tel: 012 358 4559
Email: PearlMap3@tshwane.gov.za

Mr. Tonderai Muchenje
1445C Starkey Street
Waverly
0186

Date: 12 June 2017

Dear Mr. Muchenje,

RE: A FRAMEWORK FOR INCORPORATING PRIVACY CONSIDERATIONS IN TECHNOLOGY IMPLEMENTATION PLANNING WITHIN THE SOUTH AFRICAN CONTEXT.

Permission is hereby granted to Mr Tonderai Muchenje, a PhD in Information Technology candidate at Nelson Mandela Metropolitan University to conduct research in the City of Tshwane Metropolitan Municipality.

It is noted that the research study aims to formulate a framework for incorporating rational -based factors in the acceptance of smart meter (pervasive) technology implementation planning within the South African context. The City of Tshwane further notes that all ethical aspects of the research will be covered within the provisions of the Nelson Mandela Metropolitan University Research Ethics Policy. You will be required to sign a confidentiality agreement form with the City of Tshwane prior to conducting research.

Relevant information required for the purpose of the research project will be made available upon request. The City of Tshwane is not liable to cover the costs of the research. Upon completion of the research study, it would be appreciated that the findings in the form of a report and or presentation be shared with the City of Tshwane.

Yours faithfully,

....
Anisha Dharumrajh (Ms.)
ACTING GROUP HEAD: CITY STRATEGY AND ORGANISATIONAL PERFORMANCE

City Strategy and Organisational Performance • Stadstrategie en Organisatoriese Prestasie • Lefapha la Thulaganyo ya Tiro le Togamaano ya Toropokgolo • UmNyango wezokuSebenza namaQhinga aHlelweko ka Masipala • Kgoro ya Lesenopenkanyo la Toropokgolo le Bodiragatši bja Masepala • Muhasho wa Vhupulani ha Ḓorobo khulwane na Mashumele • Ndzawulo ya Maqhinga ya Dorobakulu na Matirhele ya Masipala • Umnyango Wezeqhinga Ledolobha Nokusebenza Kwesikhungo

APPENDIX 8: CONFIRMATION FOR REGISTRATION

Nelson Mandela Metropolitan University
for tomorrow

School of ICT
Tel. +27 (0)41 504 3179
E-mail: ReinhardtA.Botha@nmmu.ac.za

12 April 2017

To whom it may concern

Confirmation of registration for Tonderai Muchenje.

This letter serves to confirm that Mr Tonderai Muchenje with student number 214397172, is currently registered for a PhD in Information Technology in the School of ICT at Nelson Mandela Metropolitan University.

I am his Supervisor. His working topic is: A FRAMEWORK FOR INCORPORATING PRIVACY CONSIDERATIONS IN TECHNOLOGY IMPLEMENTATION PLANNING WITHIN THE SOUTH AFRICAN CONTEXT

The research proposal has received ethical clearance from the neccesary bodies at the university with the reference number H17-ENG-ITe-001.

Any further questions can be directed at me per email to ReinhardtA.Botha@nmmu.ac.za
Regards

Reinhardt A. Botha
Professor: Information Technology

APPENDIX 9: FINAL QUESTIONNAIRE

RESEARCH TITLE: A PLANNING FRAMEWORK FOR IMPLEMENTING SMART METER TECHNOLOGY WITHIN THE SOUTH AFRICAN CONTEXT

Dear Participant,

I am kindly inviting you to participate in my Ph.D. research study survey. I am a Ph.D. student at Nelson Mandela Metropolitan University. The aim of the study is to formulate a framework that can assist in planning the implementation of smart meter technology in the South African context.

I would appreciate it if you could complete this survey. The survey specifically asks your opinion regarding smart meters. There are no right or wrong answers; all questions are opinion-based. Your participation in this study is voluntary and you are free to withdraw your participation from this study at any time. The survey should take approximately 15 – 25 minutes to complete.

There are no risks associated with participating in this study. The survey collects no personal identifying information of any participant. All responses to the survey will be recorded anonymously and remain confidential. Results will be reported in the aggregate only. While you will not experience any direct benefits from your participation, information and opinions that will be gathered in this study may benefit the municipality policy makers, technology innovators, and the public during future technology implementations.

Please note that ethical clearance with reference number **H17-ENG-ITe-001R** has been granted for this research.

If you have any questions regarding the survey or this research project in general, please contact Mr. Tonderai Muchenje and/or his promoter, Prof. RA Botha. Their e-mail addresses are tonderaimuchenje@gmail.com and reinhardta.botha@nmmu.ac.za, respectively.

By completing and submitting this survey, you are indicating your consent to participate in the study. Your participation is appreciated.

Thank you very much for your time and support.

Please start with the survey now by ticking inside the **AGREE BOX** below to begin[1*].

☐ I Agree

[2**]

THIS SECTION PROVIDES EXPLANATIONS OF RELEVANT TERMS

What is a Smart Meter?

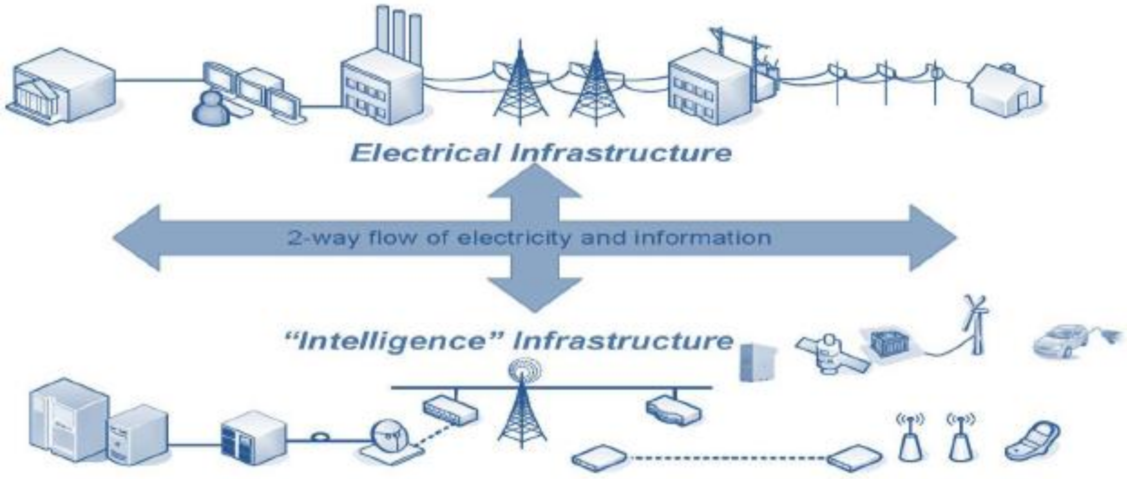
A smart meter is a modern system that can digitally collect, analyze, and store detailed energy usage information and send meter readings to your energy supplier. The measurement is done automatically without human interaction at intervals of 15 minutes to an hour. The measurement information is sent and displayed to customers using various display interface platforms, such as web-based customer portals, smartphones, tablets, and customer interface units (CIUs).

[1*] This will only available to the participants will completed questionnaires electronically

[2**] This will only available for the hard copy questionnaires distributed to non-internet access participants

What is a Smart Meter Technology?

A smart meter system integrates intelligent information and communication technology into electric transmission and distribution networks. The smart meter system delivers electricity to customers using two-way digital technology. See image below.



GENERAL QUESTIONS

GQ.1. Please select your gender:

1. Male
2. Female

GQ.2. Please select the area where you live:

1. City of Tshwane (Pretoria)
2. City of Johannesburg
3. City of Cape Town
4. Ekurhuleni Metropolitan Municipality (East Rand)
5. City of eThekwini (Durban)

6. Nelson Mandela Metropolitan Municipality (Port Elizabeth)
7. Mangaung Municipality (Bloemfontein)
8. Buffalo City (East London)
9. Other __________

GQ.3. What is your highest level of education?

1. No schooling
2. Some schooling
3. Matric
4. Certificate
5. Diploma
6. Undergraduate degree (including Hons degree)
7. Postgraduate degree (Masters or Doctorates

GQ.4. Select your age group:

1. 18 - 25
2. 26 - 35
3. 36 - 45
4. 46 - 50
5. > 50

GQ.5. What is your average annual income per year?

1. Less than R 150 000
2. R 150 000 - R 299 999
3. R 300 000 - R 449 999
4. R 450 000 - R 599 999
5. R 600 000 - R 749 999
6. R 750 000 - R 899 999
7. More than R 900 000

GQ.6. Who is your smart meter service provider that supplies and manages your electricity?

1. Tshwane Metropolitan
2. Johannesburg Metropolitan
3. Ekurhuleni Metropolitan
4. Cape Town Metropolitan
5. eThekwini Metropolitan
6. Non- Metropolitan
7. Eskom
8. Private company
9. Other ___________

GQ.6. Are you currently using smart meter in your home?

1. Yes
2. No

[3*] **There is a branching between the current smart users and non-current users.**

AS A CURRENT SMART METER USER, PLEASE ANSWER THE QUESTIONS BELOW AS IF YOU HAVE MOVED INTO A HOUSE WITHOUT A SMART METER BUT HAVE THE OPTION TO HAVE A SMART METER INSTALLED.

MQ.1. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

[3*] **Branching on the question was afforded to participants depending on the Question 6.**

	Strongly Disagree	2	3	4	5	6	Strongly Agree
I will find it easy to use a smart meter.	❑	❑	❑	❑	❑	❑	❑
I will find it easy to learn how to operate the smart meter.	❑	❑	❑	❑	❑	❑	❑
I will find it easy to get the smart meter to do what I want it to do.	❑	❑	❑	❑	❑	❑	❑
It will not require any mental effort to use the smart meter.	❑	❑	❑	❑	❑	❑	❑

MQ.2. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

	Strongly Disagree	2	3	4	5	6	Strongly Agree
Gaining access to information about the use of smart meters will be easy.	❑	❑	❑	❑	❑	❑	❑
Obtaining instructions for smart meter use will be easy.	❑	❑	❑	❑	❑	❑	❑
Obtaining guidelines on how to use smart meters will be easy.	❑	❑	❑	❑	❑	❑	❑
I can easily get support when I experience difficulties using smart meters.	❑	❑	❑	❑	❑	❑	❑

MQ.3. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

The smart meter will...

	Strongly Disagree	2	3	4	5	6	Strongly Agree
make it easier for me to monitor and adjust my electricity usage.	❑	❑	❑	❑	❑	❑	❑
make it easier to manage electricity usage.	❑	❑	❑	❑	❑	❑	❑
make it easier for me to get timely billing information.	❑	❑	❑	❑	❑	❑	❑
make it easier for me to use electricity efficiently.	❑	❑	❑	❑	❑	❑	❑

MQ.4. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

Smart meter technology will...

	Strongly Disagree	2	3	4	5	6	Strongly Agree
make me pay more money unnecessarily.	❑	❑	❑	❑	❑	❑	❑
make me pay more than the old manual system.	❑	❑	❑	❑	❑	❑	❑
cause me to incur a higher cost than the old manual system.	❑	❑	❑	❑	❑	❑	❑
be expensive to a consumer like me.	❑	❑	❑	❑	❑	❑	❑

MQ.5. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

I think smart meter technology will…

	Strongly Disagree	2	3	4	5	6	Strongly Agree
allow easy access to my personal data without my knowledge.	❑	❑	❑	❑	❑	❑	❑
make it easy for my personal data to be misused for market research and advertising without my knowledge.	❑	❑	❑	❑	❑	❑	❑
make me vulnerable to criminals.	❑	❑	❑	❑	❑	❑	❑
put my privacy at risk.	❑	❑	❑	❑	❑	❑	❑

MQ.6. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

	Strongly Disagree	2	3	4	5	6	Strongly Agree
Smart meter technology has high value.	❑	❑	❑	❑	❑	❑	❑
Smart meter technology is worth considering.	❑	❑	❑	❑	❑	❑	❑
Smart meter technology will provide me with more benefits than disadvantages.	❑	❑	❑	❑	❑	❑	❑
I appreciate what smart meter technology will do for me.	❑	❑	❑	❑	❑	❑	❑

MQ.7. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

I think smart meter technology…

	Strongly Disagree	2	3	4	5	6	Strongly Agree

is trustworthy.	❏	❏	❏	❏	❏	❏	❏
is dependable.	❏	❏	❏	❏	❏	❏	❏
is credible when managing electricity demand and supply.	❏	❏	❏	❏	❏	❏	❏
has a good reputation in the electricity industry.	❏	❏	❏	❏	❏	❏	❏
improves the reliability of my electricity supply.	❏	❏	❏	❏	❏	❏	❏
records electricity billing information accurately.	❏	❏	❏	❏	❏	❏	❏

MQ.8. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

I will support smart meter technology use...

	Strongly Disagree	2	3	4	5	6	Strongly Agree
because my family supports it.	❏	❏	❏	❏	❏	❏	❏
because my friends support it.	❏	❏	❏	❏	❏	❏	❏
because my colleagues support it.	❏	❏	❏	❏	❏	❏	❏
because people important to me say it helps save the environment.	❏	❏	❏	❏	❏	❏	❏
because people important to me think it is the right thing to do.	❏	❏	❏	❏	❏	❏	❏
if my community thinks it saves electricity.	❏	❏	❏	❏	❏	❏	❏

MQ.9. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

	Strongly Disagree	2	3	4	5	6	Strongly Agree
I think using smart meters is a good idea.	❑	❑	❑	❑	❑	❑	❑
I think using smart meters is a wise idea.	❑	❑	❑	❑	❑	❑	❑
I think using smart meters would be a pleasant experience.	❑	❑	❑	❑	❑	❑	❑
Generally, I like the idea of using smart meters.	❑	❑	❑	❑	❑	❑	❑

MQ.10. Please indicate the extent to which you Agree or Disagree with each of the following statements.

Indicate your response on a scale of 1 to 7 (where Strongly Disagree = 1 and Strongly Agree = 7).

	Strongly Disagree	2	3	4	5	6	Strongly Agree
I will be happy to have a smart meter installed in my home.	❑	❑	❑	❑	❑	❑	❑
I intend to have a smart meter installed in my home.	❑	❑	❑	❑	❑	❑	❑
I will volunteer to have a smart meter installed in	❑	❑	❑	❑	❑	❑	❑

my home.							
I am comfortable with having a smart meter installed in my home.	❑	❑	❑	❑	❑	❑	❑
I am positive about a city-wide roll-out of smart meters.	❑	❑	❑	❑	❑	❑	❑
I support the installation of smart meters in the city.	❑	❑	❑	❑	❑	❑	❑

MQ.11. Do you have any opinions or suggestions regarding the question(s) above?

....

....

....

....

....

APPENDIX 10: SAMPLE FOR A POLICE STATION

From: Tonderai Muchenje

1445c Starkey Avenue,

Pretoria, 0186

To: Station Commander

SAPS Mabopane Station

Mabopane

12 January 2017

TO WHOM IT MAY CONCERN

Dear Station Commander.

RE: REQUEST TO CONDUCT SURVEY WITHIN YOUR PREMISES

I am writing the letter requesting a permission letter to conduct my PhD research survey with your staff within the premises of SAPS Mabopane.

My name is Tonderai Muchenje a Lecturer at Tshwane University of Technology. I am currently doing my PhD in Information Technology with Nelson Mandela Metropolitan University. My research topic is: **A Framework for Incorporating Privacy Considerations in Technology Implementation Planning within The South African context**.

I have already have an Ethical Clearance Letter from the university with regard to my data collection.

Feel free to contact me on the following email addresses: s214397172@nmmu. ac.za or tonderaimuchenje@gmail.com

Regards

Tonderai Muchenje

Cell: 083797 4472; Tel: 012 382 0539