Customer value associated with electric smart meters in South Africa.

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DECLARATION

I, **<u>Desmond Mabilo</u>**, declare that this research article is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Desmond Mabilo

Signed at ……… **Plettenberg Bay (Western Cape)**………………………………………

On the ………**28th**…………………….. day of ……**April**………………… 20**23**….

DEDICATION

This research is dedicated to my wife Itumeleng Lepelesana Mabilo and my daughter Onalerona Mabilo.

To my wife Itumeleng, thank you for your sacrifice and bearing with me through my studies, thank you for believing in me and continuously encouraging me, I love you.

To my daughter Onalerona, whatever you do trust in God always, and go all the way. Daddy loves you.

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- I would like to thank the Lord Jesus Christ, for granting me strength and wisdom through the research process.

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ABSTRACT

Problem definition: Electric smart meters are gaining popularity in utilities and municipalities across the globe as a smart grid driver introducing various benefits to utilities such as security of revenue and the reduction of resources waste, among other factors. However, various studies across the globe indicate mixed responses on the value that electric smart meters bring to end customers. In this study, the customer value associated with electric smart meters is interrogated in the context of residential South African customers.

Academic/Practical relevance: The theory of customer value which is premised on the difference between the benefits and costs of electric smart meters is adopted. The benefits and costs of electric smart meters are looked at from an operations management perspective, where the benefit elements are the five external operations performance objectives (Speed, Cost, Quality, Flexibility and Dependability) and the cost element refers to the costs that customers incur to access or utilise the capabilities of smart meters.

Methodology: A quantitative research methodology is utilised to determine the customer value of electric smart meters. Because operations performance objectives cannot be measured directly as well as the costs, a Structural Equation Model (SEM) is utilised to set the benefits and cost elements as latent variables indicated by various responses from a survey distributed to a total of 365 respondents.

Results: The resulting analysis through SEM indicated that South African residential customers find value in electric smart meters. The value is driven mainly by the Speed, Cost and Dependability capabilities of electric smart meters. Customers are found to be neutral with regard to the Flexibility and Quality capabilities of electric smart meters. The main cost element of smart meters affecting customer value is observed as the internet or data fees in South Africa, which is a requirement to fully benefit from the capabilities of smart meters. Lastly, it is observed that there is no difference in the customer value for the different customer groups based on gender and age.

Managerial implications: This study provides insight relevant to municipalities, utilities and organisations operating, planning to introduce or deploy residential electric smart metering infrastructure in South Africa to consider the value that electric smart meters bring to customers. These organisations should ensure that the dominant electric smart metering functions (Speed, Cost and Dependability) are visibly implemented to achieve maximum customer satisfaction and impact. Furthermore, it is worth noting the negative impact caused by high internet or data costs on the value of electric smart meters to residential South African Customers.

Keywords: Electric Smart Meters, Customer Value, Operations Performance Objectives, Structural Equation Modelling (SEM).

1. INTRODUCTION

1.1 Purpose of the study

The purpose of this study is to determine the customer value of electric smart meters by residential customers in South Africa. Furthermore, the study will determine dominant electric smart metering technology functions that create value for residential customers in South Africa. Lastly the study will further identify whether there are significant differences in values by the different residential customers in South Africa.

1.2 Context of the study

Smart metering technologies are described as a technology composed of a near real-time two-way communication between smart electricity metering devices at consumer premises and data management systems residing at utility premises or the cloud (US Department of Energy, 2016). Furthermore, smart metering technologies enable utilities the capability to provide visibility to their customers their energy consumption and associated events in a near real-time fashion. This data is mainly provided to consumer using web portals, mobile applications and In-home displays using capabilities of the internet to access data residing in the utility data centres or cloud infrastructure (US Department of Energy, 2016).

Following global trends, several South African municipalities have been considering the deployment of electricity smart meters and smart metering systems (Advanced Metering Infrastructure) to improve revenue management, reduce electricity losses, address billing and credit control issues, promote efficiency and improve service delivery to customers (SEA, 2015). The implementation of these smart metering projects in South Africa has been seen in the City of Johannesburg, the City of Tshwane, the Nelson Mandela Bay Municipality, and the eThekwini Municipality (SEA, 2015; Zyl, 2018).

According to a report published by Grand View Research in the year 2018, the smart meter market is expected to grow at the Compound Average Growth Rate (CAGR) of about 5.1% from 2018 to 2025 (from $54.1 million in 2017 to $79,5 million by 2025) (Nhede, 2018; Zyl, 2018). Furthermore, (Nhede, 2018; Zyl, 2018) state that smart meters are gaining popularity among South African users due to introduced benefits such as prepayment and easy-to-use functions. On the other hand (Ball, 2019) states that according to energy professionals in a survey by the Energy Institute, smart meters only benefit companies and not consumers.

Smart meters are not understood to add value to consumers as they do not provide opportunities for consumers to reduce their bills (Ball, 2019). Furthermore (Völker, Reinhard, Faustine, Pereira, 2021), state that the use-cases of electric smart meters have customer benefits that are far less than the benefits experienced by utilities or the grid in general. Based on this uncertainty on the value that smart metering technologies bring to consumers; research is undertaken to identify Customer Value associated with electric smart meters in South Africa for residential customers.

1.3 Problem statement

The main research problem is to empirically identify the customer value associated with electric smart meters in South Africa. Identifying the customer value associated with electric smart meters in South Africa will assist utilities, municipalities and city planners in deploying electric smart metering technologies in a manner that not only benefits utilities as stated by (Ball, 2019; Völker et al., 2021b) but also benefits customers in South Africa.

1.3.1 First sub-problem

The first sub-problem of the study is to determine the customer value of electric smart metering functions in South Africa.

1.3.2 Second sub-problem

The second sub-problem of the study is to identify the dominant customer value amongst the different electric smart metering technology functions.

1.3.3 Third sub-problem

The third sub-problem of the study is to identify if there is a difference in customer value of smart metering technologies for different customer types.

1.4 Significance of the study

The literature reviewed did not identify research investigating the value associated to electric smart meters for residential customers in South Africa. This research, therefore, contributes to the body of knowledge by providing insight on the identified gap. The research findings are aimed to provide insight to managers and leaders of electricity utilities and municipalities to adopt smart metering technologies that also address the specific needs of customers in South Africa. Prior to the roll-out of smart metering technologies, South African utilities and municipal leaders can communicate these benefits that align to the needs of customers, thus eliminating any scepticism that may arise as that observed in similar economies such as Indonesia (Chou & Yutami, 2014).

1.5 Delimitations of the study

The following do not form part of the study:

- Research on other types of smart meters, such as water, gas etc. Only electric smart meters are considered.
- Utilities and municipalities outside the borders of South Africa.

Furthermore the study does not cover any research methodology outside the following:

- Quantitative empirical study based on survey questionnaire distributed to South African residential customers.

1.6 Assumptions of the study

The following assumptions are made in the study:

- Respondents to the survey questions will answer honestly.

2. LITERATURE REVIEW

2.1 Introduction

The aim of this section is to outline from the literature the definition of electric smart meters and associated functions. This discussion will also cover how electric smart metering technologies are implemented by various nations across the globe, the benefits realised, and the challenges encountered. This discussion is, thereafter, followed by a presentation of management theories from the literature that is applicable to addressing the research problem identified in this study.

The management theories identified are the theory of customer value and the five operations management performance objectives. Through the literature review of electric smart meters, their functions and implementation across the globe, research questions are developed. The literature review of management theories are to develop a guiding principle to answer the research questions and address the problem statement.

2.2 Electric Smart Meters

2.2.1 Background

Electric smart meters are an evolved technology which began as devices installed in private households, commercial buildings, industrial sites and other areas measuring electricity with rotating disc devices with mechanical displays (Völker et al., 2021). This technology required utilities to deploy persons to collect readings from different sites using paper-based capturing of consumer electricity consumption, leaving room for human error. The rise of digital technologies gave birth to smart meters, with capabilities of measuring electricity accurately and transferring electricity consumption to utility IT systems through telecommunications technologies (US Department of Energy, 2016; Völker et al., 2021). Electric smart metering technologies enable utilities the capability to provide visibility to their customers their energy consumption and associated events in a near real-time fashion. This data is mainly provided to consumer using web portals, mobile applications and In-home displays using capabilities of the internet to access data residing in the utility data centres or cloud infrastructure (US Department of Energy, 2016). On Figure 1 is an end-to-end utility information technology systems and load control capabilities enabled by an electric smart meter technology, introducing various benefits to both utilities and their customers.

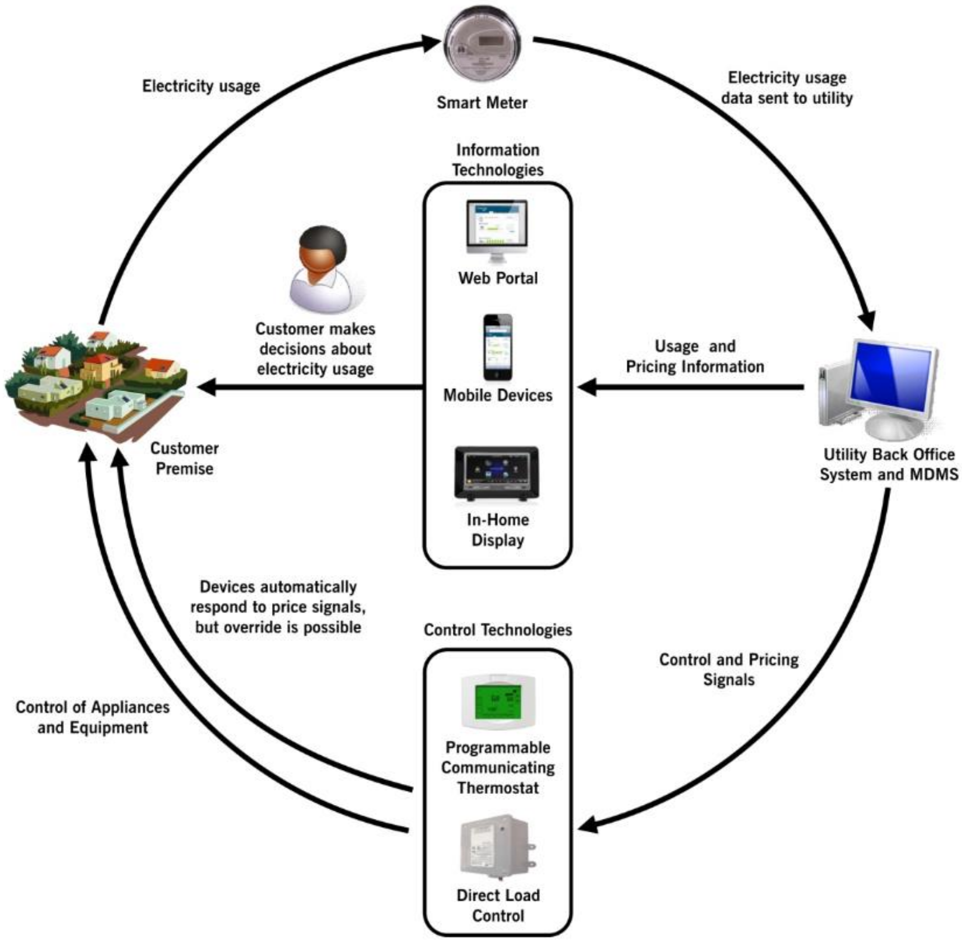

Figure 1: Electric smart meter enabled utility information technology functions. Adapted from Advanced Metering Infrastructure and customer systems. Results from the Smart Grid Investment Grant Program. By US Department of Energy, 2016 (https://www.energy.gov/sites/prod/files/2016/12/f34/AMI%20Summary%20Report_09-26-16.pdf)

2.2.2 Benefits

Smart metering technologies are considered the first step that needs to be taken by countries in pursuit of sustainable development and energy efficiency (Chou & Yutami, 2014). In a report by Gill & Judith (2008), smart meters provide the benefits listed below.

- Accurate customer billing
- Reduced electricity bills due to better feedback on usage to customers
- Flexibility to use either pre-pay or post-pay
- Less carbon emission
- Advanced tariffs

Many economies globally are seen investing in smart metering technologies that report energy usage of the consumers and provide feedback to consumers on their energy usage with the aim of changing their behaviour to reduce energy consumption (Echeverri et al., 2017; Mogles et al., 2017). In economies such as India, smart meters have been deployed to overcome the challenges of the Indian power system, such as billing inefficiencies, theft, unreliable energy delivery and distribution companies' financial problems (Chawla, Kowalska-Pyzalska & Skowrońska-Szmer, 2020). These features show that smart meters not only benefit utilities, but also provide an advantage for consumers by allowing them to save costs, on electricity usage by being nudged to behave differently with regards to their electricity usage. Consumers can also be left at ease, by being provided an efficient billing systems and early detection of any electricity supply problems.

In a report by a House of Commons Science and Technology Committee, published in the year 2016, it is outlined that smart meters realise benefits for both consumers and utilities and energy providers as well as the society (Sovacool, Kivimaa, Hielscher & Jenkins, 2017). Table 1 below summarises the different benefits.

Table 1: Smart meter benefits

Customers	Utilities and Energy Providers	Society
Easy switching between energy suppliers	Savings from eliminated sites visits for data collection	Enable optimisation of electricity generation and network management
Accurate billing	Reduced call centre traffic, due to less inaccurate-billing query issues	Visibility of the network, eliminating the need for increased reserve generation
Reduced debt accumulation, realised by near real-time billing	Theft detection and optimal management of debt	Innovation and development of new business models and entrants
		Enabling the initiatives to meet climate change requirements (e.g., reduced carbon emissions).

Adapted from Vulnerability and resistance in the United Kingdom's smart meter transition. By Sovacool, Kivimaa, Hielscher & Jenkins, 2017, *Energy Policy*, *109*, p. 767–781

Although the benefits are presented in the three categories, the benefits realised by the utilities and energy producers can be of value to consumers. Such may include reduced call centre traffic, resulting in reduced waiting time for customers when making queries. Meeting climate change needs could be a valuable need for customers as well. (Sovacool et al., 2017) state that there are more than 67 benefits of smart meter functions that overlap across the personas listed in Table 1. Based on this, research on customer value of different smart meter functions by residential customers in South Africa is found to be necessary to understand the need with a South African context.

2.2.3 Challenges

Due to limited awareness, knowledge and understanding of smart meter technology, consumers in economies such as Indonesia have shown some hesitance in the adoption of smart meters in their buildings (Chou & Yutami, 2014). The scepticism and hesitation have hindered progress in a journey for energy efficient lifestyles by consumers by not leveraging the benefits of smart meter technologies. To ensure progress, smart metering technologies need to be presented in a way that addresses the needs (including latent) of consumers.

In a study by Lineweber (2011), a survey was undertaken on the important benefits of smart meter functions. It was discovered that there is large gap in the implementation of smart grid technologies, where the benefits are not clearly communicated to and understood by the consumers in the United States. The limitation in communication of the smart grid technologies resulted from an approach that sought to educate consumers about smart grid technologies in a shallow fashion, not focussing on communicating the downstream benefits of smart metering technologies. As a result, consumers could only see a fancy technology without deep insights on the benefits they can realise from it. This gap contributed to consumers not finding value and rejecting smart grid and smart metering technologies developed not only for the utility benefits but also customers' benefits as well. Based on this, a clear communication with deep insights on the downstream benefits of smart metering technologies relevant to the consumer group is necessary for the success of smart metering technologies implementation. Understanding of this relevant downstream functions is therefore essential.

2.3 Customer Value

Customer value emerges from the perspective of marketers and customers, described as a theory which determines the value that customers see, experience, and perceive of a product (Woodside, Golfetto & Gibbert, 2008). Customer value is further described as the ability for companies to create and add value to goods and services they deliver to customers, this value can be delivered at four value points namely, *Service, Quality, Image and Price* (SQIP) (McFarlane, 2013). The success of this value lies in the reaction of the customer to the value delivered, which makes the customer central to the success of the value. Customer value is also influenced by the costs that customers incur in acquiring goods or services, and this results in customer value described by the formula below (Woodside et al., 2008).

Customer Value = Sum of benefits – Sum of Costs incurred

Customer value is also described as not just a marketing and customers' concept, but it also can be adopted as an organisation-wide strategy and management approach to gain competitive advantage in the market (Setijono & Sandberg, 2005). They further argue that quality and operations management activities in organisations have a great influence on customer perceived value. This implies that the performance of quality management and operations management initiatives can influence the value perceived by customers.

In the case of the deployment of electricity smart meters by utilities, it is essential that a positive perceived value by customers is realised, such as creating opportunities for electricity savings and meeting other customer preferences and needs (Albani, Domigall & Winter., 2017). Although utilities may realise benefits from electricity smart meters, not meeting customer preferences and needs poses a danger to utilities such as the rejection of electricity smart meters, as observed in economies such as Indonesia, USA etc. (Chou & Yutami, 2014; Lineweber, 2011). In a study on German household customers, Gerpott & Paukert (2013) performed an empirical analysis to determine the customers' willingness to pay for smart meters based on three perceived smart meter benefits listed below:

- Usefulness of consumption feedback
- Trust in data protection

- Environmental awareness

This resulted in trust in data protection and consumption feedback as main drivers for changing consumer behaviour in electricity usage and increased the willingness to pay for smart metering technologies. This study focussed on only a few electricity smart metering benefits, leaving the question of whether the willingness to pay would increase or decrease if more of the electricity smart metering benefits were considered. Therefore, a more comprehensive study considering much more if not all smart metering benefits is considered here, amongst these functions the dominant smart metering functions need to be determined as well. From a South African context similarly to other economies, determining the dominant smart metering functions will help with addressing critical needs of consumers, and as a result deliver them ensuring customer satisfaction in a focussed manner.

In a study by Barnicoat & Danson (2015), it was discovered that the older generation in Scotland, who are on the low-income band, have high value for smart meters due to the consumption feedback enabling them to change their behaviour to save electricity. Based on this, determining the value perceived by different customer types (based on varying age and gender) is required in the South African context to understand if there would be any challenges of varying customer values by different customer types in South Africa. Varying customer types add to the complexity in implementation, if not prepared the situation can be much unfavourable.

2.4 Performance measurement

Introducing smart metering technologies is an exercise that requires substantial capital investment that involves the replacement of existing equipment and the acquisition of new technology (Echeverri et al., 2017). To ensure benefits and prevent losses from substantial capital investments such as smart metering technologies, the adoption of operations management principles is necessary, to ensure that the operations meet the needs intended by measuring the performance using concepts such the 5 operations performance objectives. The ability to respond to customer needs is a crucial part in ensuring operations preparedness (Slack, Alistair, Robert, Hemmanth & Khomotso, 2017). Furthermore, Setijono & Sandberg (2005) state that customer value has a direct relationship with quality and operations management activities in organisations. The output of quality and operations management activities influence the customer value. Knowing customers' needs and challenges is very crucial for operations and quality managers to enable them to determine what they need to do to deliver a successful operation service (Slack et al., 2017).

Due to the substantial capital investment required to introduce smart metering technologies, it is crucial that utilities possess an optimal level of operations management preparedness. Operations preparedness is achieved when the smart metering technologies meet the performance objectives of both the utilities and customers referred to by Slack et al. (2017) as the internal and external performance objectives. Due to the perceived limited focus and benefits of smart metering technologies to customers espoused by Ball (2019) and Völker et al. (2021), this study is undertaken with a focus on the external performance objectives which address the benefits to customers.

2.4.1 Performance objectives

Both external and internal performance objectives in an operations environment such as in the adoption of smart metering technologies can be determined by five elements, namely Speed, Quality, Flexibility, Dependability and Cost as depicted on Figure 2 (Slack et al., 2017).

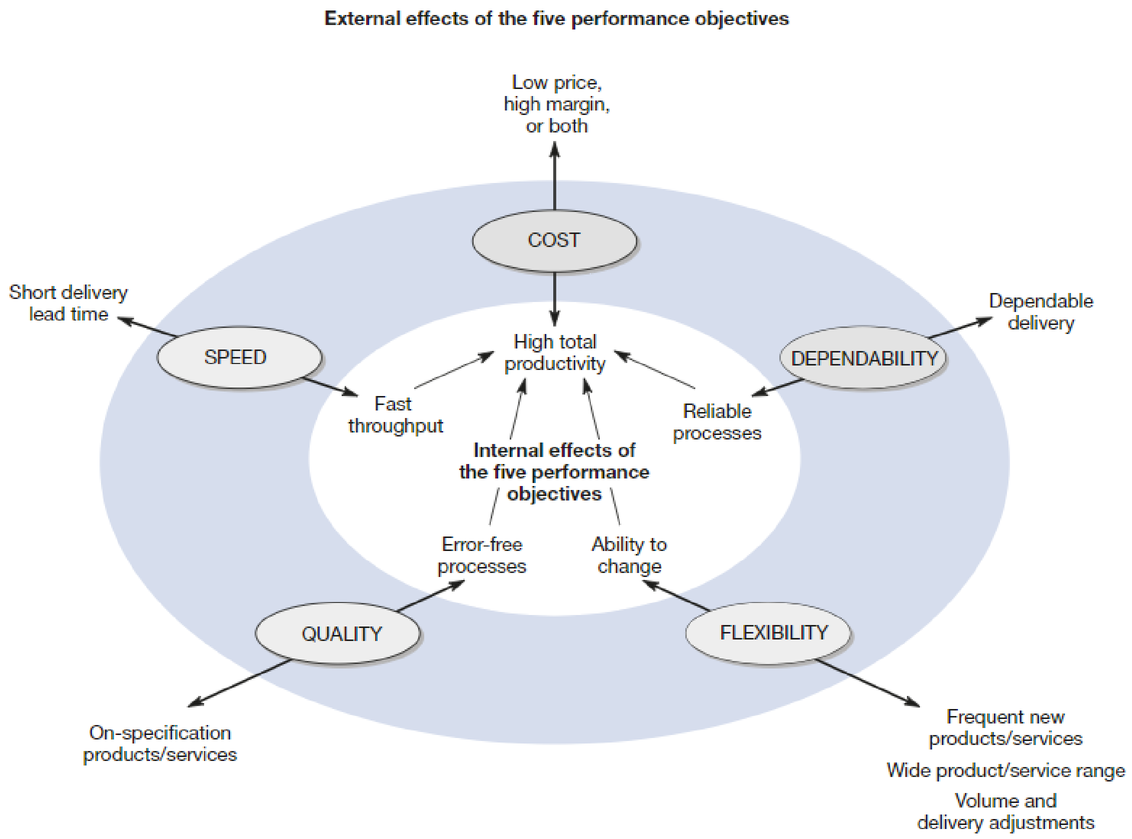

Figure 2: 5 Performance Objectives of Operations Management. Adapted from *Operations Management: Global and Southern African Perspectives* (3rd ed.), by Slack, N., Alistair, B.J., Robert, J., Hemmanth, S., & Khomotso, P, 2017, Pearson.

Speed refers to the elapsed time between a customer requesting a product or service and the delivery thereof (Slack et al., 2017). From a smart metering perspective, speed can be considered as the time it takes for a consumer to receive feedback from the smart meter on their consumption (Echeverri et al., 2017; Mogles et al., 2017). Traditionally consumers did not have the opportunity to get feedback on their electricity consumption, but only received one reading at the end of the month mainly for the purpose of billing (Gill & Judith, 2008).

Quality refers to consistent conformance to customer expectations on the product or service delivered resulting in either satisfaction or dissatisfaction (Slack et al., 2017). From a smart metering perspective, quality can represent the quality of consumption readings by the smart meter, this can include less estimations in readings used for billing (Gill & Judith, 2008).

Dependability refers to doing things on time for customers, exactly when they are needed and in the correct format (Slack et al., 2017). From a smart metering perspective, this element can look at on-time delivery of their electricity bills (Gill & Judith, 2008). Dependability can also be represented by the accuracy of consumption readings which customers use to change their behaviour in electricity consumption to reduce their bills (Echeverri et al., 2017; Mogles et al., 2017). Incorrect reporting can cause consumers to be frustrated when their change in behaviour does not produce an impact on electricity bills.

Flexibility refers to the ability of an operation to accommodate changing customer needs depending on circumstances (Slack et al., 2017). From a smart metering perspective this considers the opportunity for customers to change their usage patterns, such as the ability for customers to choose whether to use electricity in a post-paid or prepaid fashion, as well as flexible tariffs such as Time of Use (TOU) (Gill & Judith, 2008), where customers have the flexibility to access different electricity rates based on the hour or days when electricity is used.

Cost refers to the provision of opportunities for customers to acquire goods and services and receiving good value (Slack et al., 2017). From a smart metering perspective, opportunities can be created for consumers to pay less for electricity by creating tariffs that have reduced pricing during off-peak periods (Echeverri et al., 2017; Mogles et al., 2017). Consumers can plan and reserve their heavy load electricity usage for off-peak periods and save on electricity costs. Through feedback on their electricity usage, consumers can also identify appliances that contribute to high electricity usage and change to more energy efficient appliances.

2.5 Customer value and performance measurement

In an article by (Amini, Falk, Schmitt, 2014), a quantitative analysis of consumer perceived value deviation was undertaken. In this article consumer perceived value (CPV) of two different tablet PCs is analysed wherein the CPV construct is derived from benefits and costs elements. The CPV components of the benefit and the cost elements are depicted Figure 3.

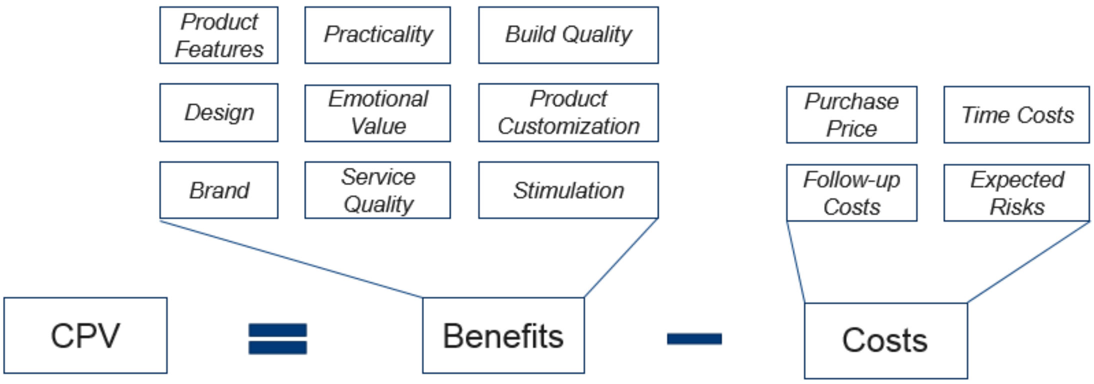

Figure 3: CPV Construct and its Contributing Elements. Adapted from Quantitative Analysis of the Consumer Perceived Value Deviation. By Amini, P, Falk, B, & Schmitt, R, 2014, Procedia *CIRP*, *21*, 391–396.

In this study the Customer Perceived Value of electric smart meters is analysed, the benefits elements are considered as the identified five performance objectives (Speed, Quality, Flexibility, Dependability and Cost) of electricity smart metering technologies. The costs element is composed of the costs associated with using smart metering technologies such data usage in viewing and downloading historical data on mobile devices, the cost associated with using electricity services from utilities, instead of using other alternatives such the installation of solar and battery storage at customer premises (Naidoo, 2021). Figure 4 demonstrates the five performance objectives through which Customer Value relationship as a concept can be used to understand and answer the research questions of this study.

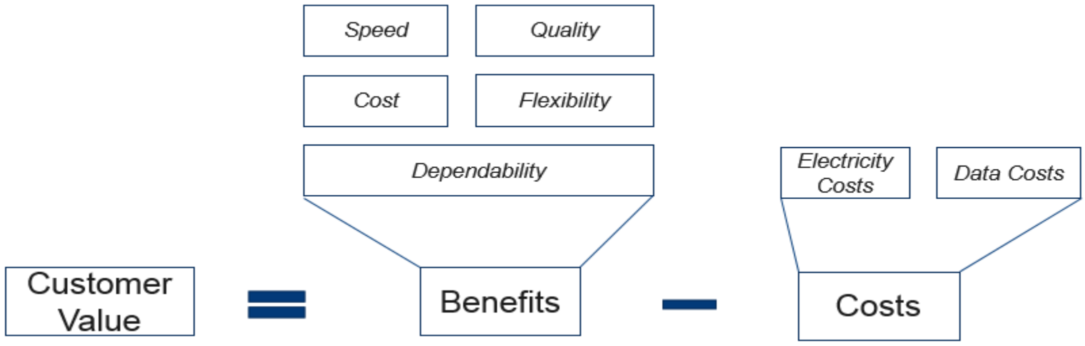

Figure 4: Customer Value Relationship with Performance objectives as corresponding elements.

From Figure 4, the Customer Value associated with electric meters can be represented by the below equation:

$$CV = \frac{1}{n} \sum_{i=1}^{n} x_i * BE_i - \frac{1}{m} \sum_{j=1}^{m} y_j * CE_j \qquad (1)$$

Where CV = Customer Value; BE and CE are the benefit and cost elements, respectively; n and m are the number of benefit and cost elements respectively; and x and y are the weights corresponding to the benefit and cost elements relating to the customer value, respectively (Amini et al., 2014).

In the study by (Amini et al., 2014), the Customer Perceived Value is the key construct with a causal relationship with the benefits and costs elements described by equation 1. The benefits and costs elements were not directly measured, rather other attributes describing the elements could be measured. A Structural Equation Model was constructed to describe the key construct (CPV), with the benefit and cost elements as latent variables.

In this study the same applies, the perceived Customer Value is identified as the key construct where a Structural Equation Model (SEM) is constructed with the 5 performance objectives and the cost elements as the latent variables. On Table 2 is the list of benefit and cost elements and corresponding smart metering functions they are described based on the insights gathered.

Table 2: Smart metering functions describing the benefit and cost elements of the CPV construct

Benefit Elements (Operations performance objectives)	Smart metering functions describing benefit elements
Speed	Near real-time feedback on electricity usage
	Consistent periodic generation of electricity bills (No delays due to missing collection of consumption reading)
Quality	Accurate customer billing (significant reduction in estimated billing)
	Carbon emission reporting (triggering customers fro carbon emission awareness)
	Advanced tariff and visibility to customers
	Automatic meter reading (elimination of manual meter reading by utility personnel)
Flexibility	Historical electricity usage and forecast, allowing consumers to budget electricity usage.
	Flexibility to use either pre-pay or post-pay methods
	Innovation and development of new business models and entrants
	Alerts on behaviour change to prevent load shedding
	Advanced tariffs enabling integration of renewable energy (such rooftop solar)
Dependability	Theft detection and optimal management of debt to protect financial health of utilities.
	Better management and optimization of electricity generation and network management for reliable electricity delivery.
	On time delivery of electricity bills.
	Alerts on electricity outages before they occur.
	Alerts on low electricity credits.
Cost	Reduced electricity bills, triggered by near real-time electricity usage feedback.
	Advanced tariffs visible to customers with different rates based on time of day (Peak, Off-peak)
Cost Elements	**Smart metering functions describing cost elements**
Costs	Cost of electricity
	Cost of internet services to access electric smart metering functions (Web or Mobile devices)

Based on the above, the first research question arising from the first sub-problem is derived as follows:

- What is the customer value associated with electric smart metering functions in South Africa?

This first question will determine if there is positive or negative customer perceived value by South African residential customers responsible for monitoring and or purchases of electricity. This question aims to determine if claims made by (Ball, 2019) and (Völker et al., 2021a) that the negative perception on the Customer value of electric smart meters, is applicable to South African residential customers.

Furthermore in a study by (Kaufmann et al., 2013) it was identified that smart metering can provide a variety of services and that the different services contribution to the customer perceived value and willingness to pay varies. Furthermore in a study by (Muchenje & Botha, 2021) to identify Consumer-centric factors for the implementation of smart meter, it was identified that there are 10 consumer centric factors that were significant to smart meter customers. Based on this, the second research question is developed which aims to determine if smart metering functions grouped according to the 5 performance objectives (Speed, Quality, Flexibility, Dependability and Cost) contribution to customer value differ amongst South African residential customers. Furthermore the questions also seek to determine the dominant smart metering functions contributing to the customer value. Below is the hypothesis arising from this question:

> ***H0: Null Hypothesis*** – Smart metering functions contribute equally to customer value.
>
> ***H1: Alternate Hypothesis*** – Smart metering functions' contributions to customer value vary.

In a study by (Barnicoat & Danson, 2015), it was discovered that the older generation in Scotland, who are on the low-income band, have high value for smart meters due to the consumption feedback enabling them to change their behaviour to save electricity. Based on this insight, a further question is developed to understand the customer value of different customer types and to determine if there is difference in the customer value of the different customer types. In this case the different customer types are identified based on age (18-24, 25-34, 35-55 and above 55 years) and gender (Male and Female). Below is the hypothesis developed for this 3 research question:

- Is there a difference in the customer value of smart metering technologies by different customer types?

  H0: Null Hypothesis – There is no difference in the customer value associated with electric smart meters by different customer types.

  H1: Alternate Hypothesis – There is a difference in the customer value associated with electric smart meters for different customer types.

2.6 Conclusion of literature review

To address the problem identified for this study, entailing determining the customer value of electric smart meters by residential customers in South Africa, a thorough literature review of electric smart meters functions is obtained. Based on the obtained functions, benefits and challenges of electric smart meters are outlined, furthermore insights based on implementation of smart metering technologies in other economies across the globe are obtained.

To respond to the identified problem, the theory of customer value is adopted which derives customer value based on the difference between the benefits and costs of electric smart meters to consumers. From the literature review it is discovered that introducing smart metering technologies, costs organisations to substantial capital investments. In order to ensure optimal results, operations management principles must be adopted. Therefore, the benefit elements of the customer value of electric smart meters are considered from an operations management perspective, described by the 5 external operations performance objectives (Speed, Quality, Flexibility, Cost and Dependability), the cost elements are considered as the costs incurred in accessing the capabilities of functions of electric smart meters.

Based on the described literature review and consideration of the identified problem, the below research questions are developed.

- What is the customer value associated with electric smart metering functions in South Africa?
- What is the dominant smart metering technologies functions contributing to customer value?

    H0: Null Hypothesis – Smart metering functions contribute equally to customer value.

    H1: Alternate Hypothesis – Smart metering functions' contributions to customer value vary.

- Is there a difference in the customer value of smart metering technologies by different customer types?

    H0: Null Hypothesis – There is no difference in the customer value associated with electric smart meters by different customer tes.

    H1: Alternate Hypothesis – There is a difference in the customer value associated with electric smart meters for different customer types.

3. RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this study is to identify electric smart metering technology functions that create value for residential customers in South Africa. This section discusses the research design and methodology undertaken to fulfil the purpose of the study, by answering the questions below:

- What is the customer value associated with electric smart metering functions in South Africa?
- What is the dominant smart metering technologies functions contributing to customer value?
- Is there a difference in customer values of smart metering technologies by the different customer types?

Furthermore, this section will outline, the population, sample size, sample method, the survey instrument, how data will be collected and analysed as well as the validity and reliability of the survey instrument to be used.

3.2 Research method

In this study an empirical research methodology is adopted, which is described as a systematic observation approach employing naturalism, behavioural and explanation to gather evidence, using scientific procedures to answer research questions. There are two types of empirical research methodologies, namely the qualitative and quantitative methods. In this research a quantitative methodology is adopted, which is described as a methodology where the data collected must be quantified, this methodology involves numbers (Scherbaum & Shockley, 2015). A pragmatists paradigm is adopted in this research due to the nature of the problem at hand which considers an introduction of technology that demands change in how customers can interact with their electricity measurement devices.

The quantitative methodology is chosen in this study to statistically answer the research questions described as follows:

- What is the customer value associated with electric smart metering functions in South Africa?
- What is the dominant smart metering technologies functions contributing to customer value?

- Is there is a difference in customer values of smart metering technologies by the different customer types?

3.3 Research design

Research design entails the approach that one takes in executing research based on data collection and associated tools involved in the process of answering the research questions (Miller & Salkind, 2002). Research design is composed of two components namely, data collection and analysis.

In this research a descriptive approach will be undertaken which involves developing the research questions before the research is conducted, followed by data collection to gather information from respondents to answer the research questions developed, outlined in the research method. This method is suitable for this study in that it requires one to get an understanding of the perceived value of electric smart metering technologies. This study requires the development of questions relating to the benefits and costs of smart metering technologies and thereafter presenting them to respondents in a manner that it is not leading the respondents to specific answers.

3.4 Population and sample

3.4.1 Population

The population for this research is composed of South African household owners and tenants responsible for payment and or monitoring and tracking of electricity usage in their households. This population is described as 85% of the South African households (17.16 million) (World Bank, 2019), translating to a population of 14,6 million households.

3.4.2 Sample and sampling method

A sample is considered in cases where it is not possible to collect data from the entire population to answer research questions. This limitation arises mainly due to the lack of resources and time to collect data from all cases in a population (Taherdoost, 2016). Furthermore, sampling can be achieved through two techniques. First, probability sampling or random sampling which is described as a sampling method where every item in the population has a chance of being included in the population (Taherdoost, 2016). Secondly, there is non-probability or non-random sampling which is generally used in experimental or trial research and does not represent the target population (Ayhan, 2011).

In this research, a snowball non-probability/non-random sampling method was undertaken – described as a sample method where sample participants are used to encourage others to participate in the study (Ayhan, 2011; Taherdoost, 2016). The sampling was undertaken by sending structured questionnaire through an email to individuals meeting the criteria of participants (South African household owners and tenants responsible for electricity payment and or monitoring and tracking). To ensure that the desired sample size is reached, respondents were requested to forward the questionnaire email to individuals in their network who meet the criteria of respondents.

3.5 Sample size

Sample size is a very critical component in making inferences about a population from a sample in an empirical research study, free from sample errors or biases. This raises the need to calculate accurately the minimum required sample in the proposed research (Taherdoost, 2017) for it to be representative of the population.

Below is a formula for calculating sample size for categorical data which is fitting for the research that is undertaken in this study, equation 2 is for an unlimited sample and equation 3 is for a finite sample:

$$n = \frac{p(100-p)z^2}{E^2} \qquad (2)$$

$$n' = n/(1 + \frac{p(100-p)z^2}{E^2N}) \qquad (3)$$

Where *n and n'* are the sample size, *P* is the percentage occurrence of a state or condition, *E* is the percentage maximum error and *Z* is the value corresponding to level of confidence required (Taherdoost, 2017).

For this research the following parameters are used, the value of P is set to 50% as the output of the research is not obtained, where in such cases the selected value is accepted. The value of E is the margin of Error set to 5%. A 95% confidence interval is selected, and this corresponds to a value of Z as 1.96 and the population size used is 14.6 million. This results in a sample size of 385.

3.6 The research instruments

The main goal of the research is to determine the customer value associated with electric smart meters in South Africa. The following equation, derived from the literature, represents Customer Value (Woodside et al., 2008).

Customer Value = Sum of benefits – Sum of Costs incurred

In this study the customer value of electric smart meters as considered as the main construct with the benefit elements described as the 5 external performance objectives (Speed, Flexibility, Cost, Dependability and Quality) and the cost incurred being the identified costs of data and electricity to the consumer. Both the benefit and cost elements cannot be directly measured through sending a survey questionnaire to respondents. Rather these elements can be described by other elements. This introduces complexity to the formula to determine Customer Value.

To successfully determine Customer Value, a multivariate statistical technique is proposed. The statistical multivariable technique employed here is the Structural

Equation Model (SEM), to describe and determine Customer Value. This is similar to a study performed to determine the Customer Perceived Value of tablet PCs where the both the benefits and cost elements could not be determined and SEM is adopted (Amini, Falk, Schmitt, 2014). SEM is described as a powerful multivariate technique increasingly found in scientific investigations to test and evaluate multivariate causal relationships, with capabilities to test direct and indirect effects on pre-assumed causal relationships (Fan, Chen, Shirkey, John, Wu, Park & Shao, 2016). In contrast to regression, the structural model represents a causal link rather than a mere empirical association (Stuart, Mednick & Bockman, 2000). SEM is a combination of two statistical methods, namely Confirmatory Factor Analysis (CFA) and Path Analysis (Fan et al., 2016).

3.6.1 Path Analysis

A Path is developed to quantify and explain the causal relationship amongst multiple variables (Fan et al., 2016). This is used to confirm and quantify the relationship between the customer value and the latent variables described by the CFA and the measured variables. From the developed Customer Value equation, the structural equation below is developed indicating the path analysis.

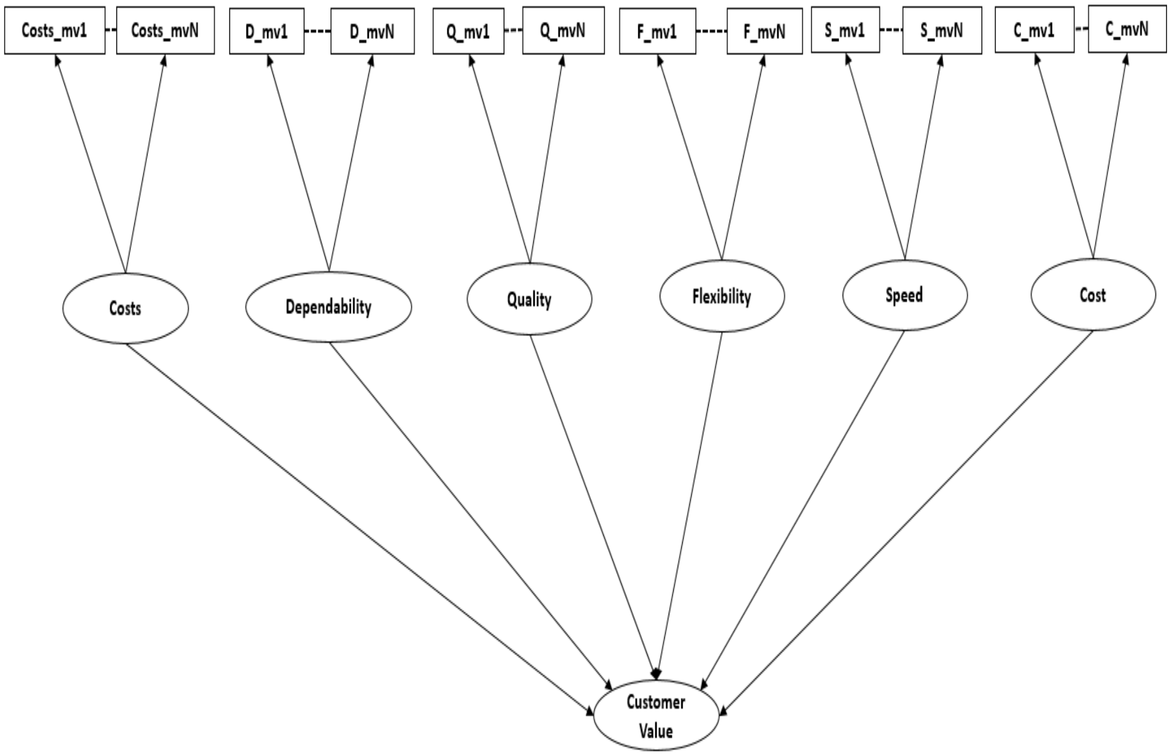

Figure 5: Electric Smart Meter Customer Value Structural Equation Model path diagram

From the structural equation, there are latent variables identified which cannot be measured but are described by other measured variables. To determine the effect of this relationship a Confirmatory Factor Analysis (CFA) is applied. The identified latent variables are Cost, Flexibility, Speed, Dependability, Quality and Costs.

3.6.2 Confirmatory Factor Analysis (CFA)

Confirmatory Factor Analysis (CFA) is a method used for estimating the latent variables based on correlated datasets of the measured variables (Fan et al., 2016). The latent variables will be determined from the data that will be collected through the survey questions, which will contain variables that describe the latent variables described by the SEM indicated in Figure 6. Through the CFA the weighting of the benefit and cost element will be determined. The CFA will also ensure accuracy in the development of the SEM by including error co-efficient of the description of the latent variables with the measured variables.

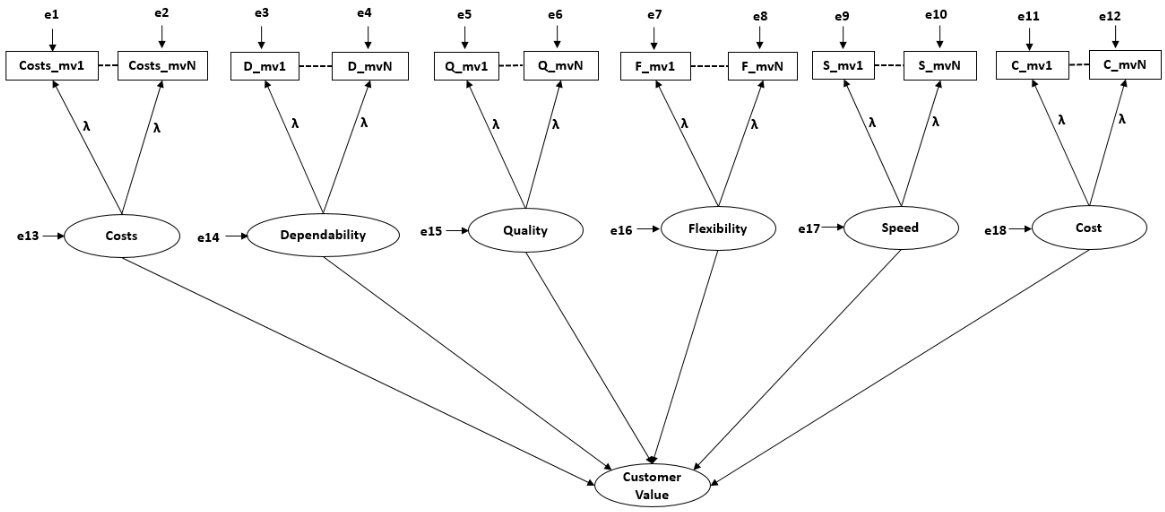

Figure 6: Electric Smart Meter Customer Value Structural Equation Model CFA

3.7 Data analysis and interpretation

In a study to determine the Customer Perception Value of tablet PCs, the Structural Equation Model (SEM) was adopted to develop an equation with latent variables and measured variables to describe the Customer Perception Value. Post developing the model, polar diagrams were utilised providing a graphical view of the elements that contribute more to the customer perception value and the elements that contribute less to customer value were also represented on the polar diagrams (Amini et al., 2014).

In this research, the same approach will be undertaken, that is, adopting the Structural Equation Model to develop a model that represents the relationship between Customer Value and the other latent variables (5 performance objectives, and data and electricity cost) and the associated measured variables. The data analysis process of the SEM will be undertaken through "*lavaan*", a statistical software package running on R. Through lavaan both the Path analysis and Confirmatory Factor Analysis (CFA) will be determined. R as well as Microsoft Excel Statistical tools are used to answer the other research questions which require the application of descriptive statistics. Furthermore, polar diagrams are used to provide a graphical representation of the different categories of customer value answering the research questions.

3.8 Validity and reliability

This section describes the validity and reliability of the research instrument.

3.8.1 Validity

To ensure the external validity of the research instrument, a literature review composed of peer reviewed articles is conducted providing groundwork and management theories, used to structure the research questions to appropriately answer the problem at hand. To ensure internal validity, which is described as the relationship between at least two variables, the SEM is developed covering the relationship between the Customer Value, the latent variables and the measured variables.

3.8.2 Reliability

In a study to determine Customer Perception Value (CPV) of tablet PCs, a Cronbach Alpha and the composite reliability (CR) of each of the cost and benefit elements was considered to validate the reliability of the relationship. This resulted in within range values, providing confidence in the reliability of the instrument (Amini et al., 2014). In this study the same approach is undertaken which entails determining the Cronbach Alpha and composite reliability of the measured variables making up the latent variables that describe the customer value variable.

3.9 Ethical considerations

3.9.1 Anonymity of participants

The identity of all the participants were not requested when they responded to the study. The participants responded to questions through an online survey which did not record the identity details of the respondents including the IP address of the computer or mobile device through which participants responded to questions (Scherbaum & Shockley, 2015).

3.9.2 Permission to conduct the study

An ethics clearance form was completed with details of the research study to provide context to the ethics committee to determine whether or not the research violates any ethical restrictions. Data collection for this study commenced only once the ethics clearance certificate was granted.

4. PRESENTATION OF RESULTS

4.1 Introduction

The purpose of this study is to identify electricity smart metering functions that create value for residential customers in South Africa. In this section the results obtained from the statistical analysis of the data collected through the online survey is presented. The results will be presented in a fashion that follows the research question identified, described as follows:

- What is the customer value associated with electric smart metering functions in South Africa?
- What is the dominant smart metering technologies functions contributing to customer value?

- Is there is a difference in customer values of smart metering technologies by the different customer types?

The results of the research stem from the research questions obtained from the literature review which was broken down into a set of survey questions developed to elicit information to address the problem statement. The survey questions were composed of the following categories:

1. Demographic data – Gender and Age (Categorical data)
2. Values of smart metering functions (Likert scale)

The data collected was composed of 365 responses, 12 responses were rejected due to incorrect completion by the respondents, and this resulted in a sample comprising 353 participants for this research. The participants in the survey consisted of 44.7% female and 55.3% male, with an age group consisting of 27.9%, 29.9%, 33,4% and 8.8% for the ages 35-55, 25-34, 18-24 and above 55 years, respectively. Figure 7 summarises the distribution of the different customer types that responded to the survey.

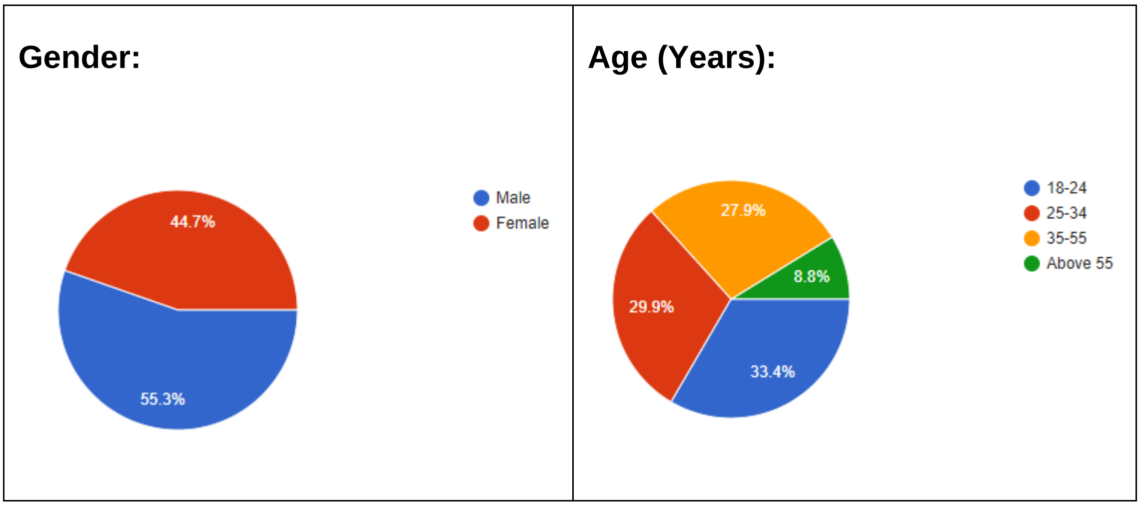

Figure 7: Electric smart meter customer value Respondent distribution according to gender and age.

The responses to the questions were based on a Likert scale described as follows:

1. Strongly Agree = 5
2. Agree = 4
3. Neutral = 3
4. Disagree = 2
5. Strongly Disagree = 1

On Table 3 below is the list of questions categorised according to the latent variables they describe.

Table 3: List of Survey Questions describing latent variables for the study.

Latent Variables	Questions
Speed	1.1 If it were possible, it will be important for you to know how much electricity you are using on daily basis.
	1.2 If it were possible, it will be important for you to know the electricity charges applied on your electricity usage on daily basis.
Quality	2.1 If it were possible, it will be important for you to get invoices with up to date information on your electricity usage any time you request them.
	2.2 If it were possible, it will be important for you get bills with accurate electricity usage information from the electricity provider.
	2.3 If it were possible, it will be important for you to know your contributions to Carbon Emissions, and meeting Climate change targets based on electricity usage?
	2.4 It is important for you to know how you are billed for your electricity (You want visibility of your tariff charges).
	2.5 If your electricity supplier were to send its employees to your house to collect electricity usage readings from your meter, you would be comfortable with the reads collected manually (recorded on a notebook).
Flexibility	3.1 It is important for you to accurately budget for your electricity usage.
	3.2 If it were possible, it will be important for you to have the option to choose between post-paid (use first and pay after) and prepaid (pay first and use after).

	3.3 If it were possible, it will be important for you to know how other customers are using electricity.
	3.4 You would be comfortable if your electricity provider were to send its employees to your house to take meter readings every month.
	3.5 Will you change your electricity usage if you know it will prevent load shedding in your area and other areas?
	3.6 Will your need to install a Solar PV (photovoltaic) increase if you would have knowledge of your excess electricity exported to the grid and be compensated for the exported electricity?
Dependability	4.1 If it were possible, it will be important for you, for customers stealing electricity (illegally tampering with the electricity meter) to be disconnected?
	4.2 If it were possible, it will be important for you to know when there is and will be electricity outage in your area?
	4.3 If it were possible, it will be important for you to be alerted when your electricity credit is low?
	4.4 You are okay with having load shedding as long as it does not impact important events in your life.
Cost	5.1 You will change how you use electricity if there is chance to save on electricity.
	5.2 You will change your daily electricity usage routine, if there is a chance to save on electricity costs.
Costs	6.1 Your electricity bill is high.
	6.2 If you were to get regular updates on your mobile device on your electricity usage and status of electricity usage in your area, you would be concerned about the cost of data to access this information.

In the next sections is the statistical results of the data, categorised as per the research questions identified.

4.2 Research Question 1

The first research question is identified as follows:

- What is the customer value associated with electric smart metering functions in South Africa?

To answer this question statistical analysis of the data collected is undertaken. To answer this question a Structural Equation Model described by the data collected was developed. The developed model is described by the below formula.

$$CV = \frac{1}{n}\sum_{i=1}^{n} x_i BE_i - \frac{1}{m}\sum_{j=1}^{m} y_j CE_j$$

Where BE is the benefit element and CE is the Cost Element (Amini et al., 2014).

4.2.1 Structural Equation Modelling

The Structural Equation Model is developed to determine the Latent variables (Speed, Cost, Quality, Flexibility, Dependability and Costs) described by the appreciation and/or dislikes of the different smart metering functions and attributes detailed on the survey questions, where participants responded to, based on a 5-point Likert scale.

The developed SEM to describe the latent variables and corresponding weightings is described below on Figure 8. This model was generated using Lavaan, Structural Equation Modelling tool on R.

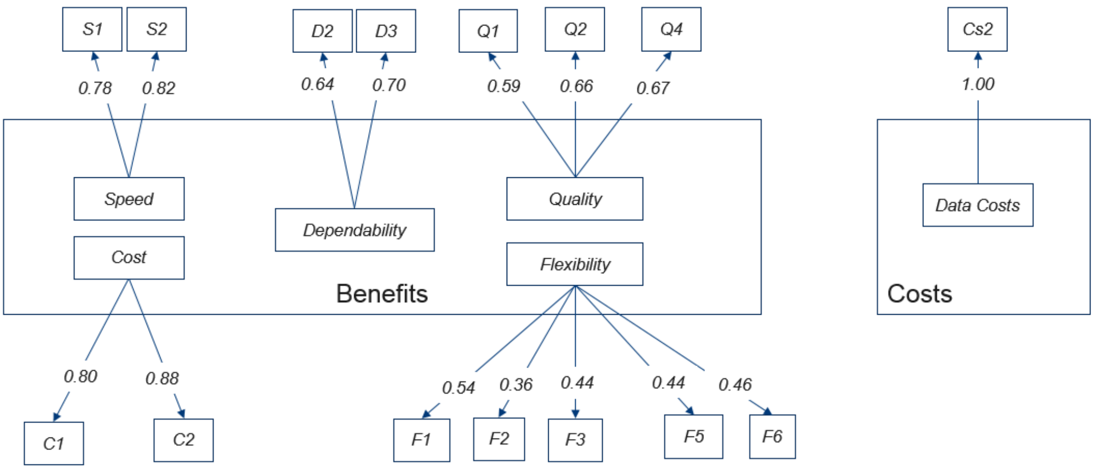

Figure 8: Structural Equation Model of the electric smart meter Customer Value Construct.

Initially the cost element of the customer value model was described by two variables, the Data Costs and Electricity Costs. During data analysis, the electricity cost element was eliminated as it is not necessarily related to the electric smart metering capabilities, and it did not add value in the resulting SEM. The electricity cost here was the per Kilowatt hour cost and not necessarily the total bill that customers receive from the utility.

In Table 2 below is the resulting model evaluation which indicates an acceptable fit of the developed model for customer value, with the obtained values corresponding to the guided values indicated in the parameters column for a model fit.

Table 4: Electric smart meter Customer Value Structural Equation Model Evaluation

Measurement	Parameter	Value
Badness of fit	Root mean square error of approximation (RMSEA) < 0.06 (0 perfect fit)	0.059
	Chi-square test	0
Goodness of fit	Comparative it Index (CFI) - Close to 0.95	0.924
	Tucker Lewis Index (TLI) >0.90	0.895

4.2.1.1 Reliability Analysis

The exercise of developing the Structural Equation Model or the measuring instrument requires the analysis of the reliability of the model. To do this the Cronbach Alpha and Composite Reliability of the each of the latent variables is considered. The Cronbach Alpha will determine if the different constructs describing the latent variables produce similar scores. The Composite Reliability will determine the overall reliability of a collection of heterogeneous but similar items. Table 5 demonstrates the resulting reliability of the developed SEM.

Table 5: Evaluated reliability of the developed electric smart meter Customer Value SEM.

Latent Variable	Cronbach's Alpha	Composite Reliability
Speed	0.777	0.777
Quality	0.669	0.668
Flexibility	0.541	0.528
Dependability	0.598	0.626
Cost	0.825	0.828

Typically, the Composite Reliability and Cronbach Alpha should be 0.7 and 0.8, respectively. The results obtained indicate that Quality, Flexibility and Dependability have lower values than the required critical level tests. These results are after attempts to improve the reliability of latent variable which previously were much worse. With regards to Costs, two questions were used to describe it, and this resulted in poor reliability due to one of the questions. The improvement involved elimination of the variables or questions that were set to describe the latent variables. The below is the list of questions that were eliminated for the different latent variables first listed on Table 3. For costs, only one item remained which removed the necessity to perform a reliability and considering the item as a latent variable. The reliability therefore considered only the 5 performance objectives (Speed, Quality, Flexibility, Dependability and Cost).

Table 6: Eliminated questions to improve SEM reliability.

Latent Variables	Eliminated questions from the SEM to improve reliability
Quality	2.2 If it were possible, it will be important for you get bills with accurate electricity usage information from the electricity provider.
	2.5 If your electricity supplier were to send its employees to your house to collect electricity usage readings from your meter, you would be comfortable with the reads collected manually (recorded on a notebook).
Flexibility	3.4 You would be comfortable if your electricity provider were to send its employees to your house to take meter readings every month.
Dependability	4.1 If it were possible, it will be important for you, for customers stealing electricity (illegally tampering with the electricity meter) to be disconnected?
	4.4 You are okay with having load shedding as long as it does not impact important events in your life.
Costs	6.1 Your electricity bill is high.

To improve further the reliability of the SEM, the above eliminated questions can be restructured to enable responded to give reliable feedback.

4.2.1.2 Validity Analysis

The exercise of developing the SEM requires the analysis of the validity of the model. To do this the Convergent validity is undertaken which compares the factor loadings of the latent variables to the value of 0.7. The factor loading should be greater than 0.7 to confirm the validity of the developed model. Table 7 presents the resulting validity analysis of the developed model. Again here the Flexibility factor loadings are below 0.7 compromising on the validity of the model, this will require further extension and future research.

Table 7: Evaluated validity of the developed electric smart meter Customer Value SEM.

Latent Variable	Convergent Validity *Factor loadings (>0.7)*
Speed	Yes
Quality	Yes
Flexibility	No (0.47;0.57;0.45;0.53)
Dependability	Yes
Cost	Yes
Costs Data	Yes

4.2.1.2 Descriptive Statistics

The resulting descriptive statistics are based on the computed Customer Value from the developed SEM. From equation 1 the Customer value is expected to range from 5 to – 5 depending on how the smart metering technologies are rated. From Table 9 the customer value (- 0.2) is based on the aggregate means of the obtained latent variables and the cost variable listed below on Table 8.

Table 8: Means of the obtained variables (including latent) and cost elements.

Variable	Mean
Costs (Cost of data)	3.32861
Speed	3.7238
Quality	2.99336
Flexibility	1.896
Dependability	3.157
Cost	3.797

Table 9: Descriptive statistics of electric smart meter Customer Value

Customer Value	
Mean	- **0.215238149**
Standard Error	0.070890922
Median	-0.3808
Mode	-1.602
Standard Deviation	1.331919494
Sample Variance	1.774009537
Kurtosis	-1.100107553
Skewness	0.384614904
Range	4.591333333
Minimum	-2.193333333
Maximum	2.398
Sum	-75.97906667
Count	353
Confidence Level (95.0%)	0.139423035

4.3 Research Question 2

The second research question is, what is the dominant smart metering technologies functions contributing to customer value? The hypothesis of this research question is described below.

> ***H0: Null Hypothesis*** – Smart metering functions equally contribute to Customer Value
>
> ***H1: Alternate Hypothesis*** – Smart metering functions' contributions to customer value vary.

To answer this question first the descriptive statistics of the different latent variables describing the different smart metering functions is determined together with the ANOVA which compares the variances of the different latent variables. On **Error! Reference source not found.** are the results of the hypothesis testing based on ANOVA determining whether the different smart metering functions' (based on the SEM latent variables, Speed, Quality, Flexibility, Dependability and Cost) contribution to customer value is the same or it varies. The Null Hypothesis suggests that the different functions contribute equally towards the customer value, and the Alternate Hypothesis is that there is a difference. A Single Factor ANOVA is considered here due to multiple groups (>2) that need to be compared. This resulted in a **P-Value of 0 < 0.05** which suggests that there is a significant difference at 5% confidence. This means there is a difference in the contribution of the different smart metering functions towards customer value, so the null hypothesis is rejected.

Table 10: Hypothesis testing of different smart metering functions on Customer Value

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Speed	353	1314.5	3.723796	0.198659
Quality	353	1056.6567	2.9933617	0.084343
Flexibility	353	669.188	1.8957167	0.057698
Dependability	353	1114.56	3.1573938	0.088795
Cost	353	1340.2	3.7966006	0.278943

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	***P-value***	*F crit*
Between Groups	825.4706	4	206.368	1456.496	**0**	2.3769 8
Within Groups	249.3704	1760	0.14169			
Total	1074.841	1764				

Below is the means of the 5 operations performance objectives determined based on the developed SEM. This indicates the dominant element which is the Cost followed by Speed.

Benefit element	**Mean**
Speed	3.7238
Quality	2.99336
Flexibility	1.896
Dependability	3.157
Cost	3.797

4.4 Research Question 3

The third research question is to determine if there is a difference in customer values of smart metering technologies by the different customer types?

> ***H0: Null Hypothesis*** – There is no difference in the customer value associated with electric smart meters by different customer types.
> ***H1: Alternate Hypothesis*** – There is a difference in the customer value associated with electric smart meters by different customer types.

The hypothesis considers two categories of customer types, first based on gender, and then on age. To answer the question that considers gender, a Hypothesis testing using the t-Test was undertaken since it is a comparison of two variables. To answer the question that considers age, a single factor ANOVA was used to do the hypothesis testing. Both hypotheses testing were done on the obtained Customer Value which resulted from the model developed by the SEM.

On Table 11 are the results of the hypothesis testing based on the t-Test to determine whether there is a difference in customer value of smart metering technologies between male and female. The Null Hypothesis suggests that there is no difference, and the Alternate Hypothesis is that there is a difference. A two-tail test was applied resulting in a **P-Value of 0.61 > 0.05** which suggests that there is no significant difference at 5% confidence. This means there is no difference in customer value between male and female, so the null hypothesis is accepted.

Table 11: Customer Value Hypothesis testing based on gender

t-Test: Two-Sample Assuming Equal Variances		
	Male	*Female*
Mean	-0.182036	-0.254833126
Variance	1.6982266	1.87266262
Observations	192	161
Pooled Variance	1.7777416	
Hypothesised Mean Difference	0	
df	351	
t Stat	0.510923	
P(T<=t) one-tail	0.3048631	
t Critical one-tail	1.6492064	
P(T<=t) two-tail	**0.6097262**	
t Critical two-tail	1.9667456	

Table 12 presents the results of the hypothesis testing based on single factor ANOVA to determine whether there is a difference in customer value of smart metering technologies between different age groups (18-24, 25-34, 35-55 and above 55 years). The Null Hypothesis suggests that there is no difference, and the Alternate Hypothesis is that there is a difference. A Sigle Factor ANOVA was applied here due to multiple groups (>2) that had to be compared. This resulted in a **P-Value of 0.537 > 0.05** which suggests that there is no significant difference at 5% confidence. This means there is no difference in customer value between the different age groups, so the null hypothesis is accepted.

Table 12: Customer Value Hypothesis testing based on age group

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Age 18-24	119	-40.4889333	-0.3402431	1.667469815
Age 25-34	105	-8.6592	-0.0824686	1.684776935
Age 35-55	99	-18.7178667	-0.1890694	1.947471712
Above 55	30	-8.11306667	-0.2704356	1.991422526

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	***P-value***	*F crit*
Between Groups	3.8696	3	1.2898789	0.7254	**0.53738**	2.63049
Within Groups	620.58	349	1.7781711			
Total	624.45	352				

4.5 Summary of Results

The statistical results of the 3 research questions identified to understand the customer value associated with electric smart meters are presented. First a model to describe the customer value was developed using the Structural Equation Model (SEM), this resulted in an acceptable fit. The obtained model lacks in reliability due to the latent variables “Flexibility, Quality and Dependability”. The validity of the model is also compromised by the “Flexibility latent variable”. Due to this limitation a further enhancement is recommended on the model in future research.

With these limitations the first research question resulted in customer value of smart electric meters obtained as a mean of -0.21 on a scale of 5 to -5, where 5 indicates maximum positive value and -5 being maximum cost.

The second research question resulted in the rejection of the Null Hypothesis , which suggested that the different latent variables describing different smart metering functions contribute equally to customer value. This was tested using a Single Factor ANOVA which resulted in a P-value of 0 (<0.05) suggesting that there is a significant difference between the contributions of the latent variables towards the customer value at 5% confidence. Furthermore its was identified based on the means of 5 performance objectives deduced from the SEM that Speed and Cost are the dominant functions contributing to customer value

The third question resulted in the Null Hypothesis being accepted. The null hypothesis stated that there is no difference in customer value for different customer types. The test first considered the aggregate customer value for different customer types based on gender, and the t-Test was performed resulting in a P-Value of 0.61 > 0.05 which suggests that there is no significant difference at 5% confidence between male and female customer groups. A second test was performed considering different customer types grouped according to age (18-24, 25-34, 35-55 and above 55 years). A Single Factor ANOVA resulted in a P-Value of 0.537 > 0.05 which suggests that there is no significant difference at 5% confidence between the different age groups.

5. DISCUSSION OF RESULTS

5.1 Introduction

The aim of this section is to provide a discussion of the results presented in Chapter 4 and demonstrate how these results provide answers to the research questions presented. The discussion of these results also undergoes a comparison with literature to identify any similarities and deviations.

The results obtained from the survey responses with an almost equal distribution between male and female, the age group distribution is almost equal except for the older generation (above 55 years) accounting for less than 10% and the other age groups (18-24, 25-34 and 35-55) accounting for approximately one third each. The results were based on a sample size of 353.

5.2 Results

5.2.1 Research Question 1

The first research question identified for the study was to determine the customer value associated with electric smart metering functions in South Africa. This is the main question of the study which seeks to determine whether the perceived costs of a smart meter outweigh the benefits as described by the formula below.

Customer Value = Sum of benefits – Sum of Costs incurred

The benefits of having a smart meter were determined by posing numerous questions to the respondents to rate their like or dislike of the different features of smart meters based on five external operations performance objectives (Setijono & Sandberg, 2005). Due to the inability to collect data from respondents directly for the five performance objectives, the Structural Equation Model (SEM) was employed with the five operations performance objectives as the latent variables. The developed SEM resulted in a fitting model – validation and reliability tests resulted in positive results with a compromise due to the Flexibility, Dependability and Quality latent variables. Even with this compromise, the resulting model is sufficient to provide an indication of the perceived customer value of electric smart meters in South Africa.

On a scale of 5 to -5, the obtained aggregate perceived customer value is slightly below average at -0.2, this indicates that South African electricity residential customers do not necessarily have a complete dislike of smart meters. This suggests that communication of smart meters to South African residents would not result in mass rejection or scepticism as observed in other similar economies such as Indonesia and USA (Chou & Gusti Ayu Novi Yutami, 2014; Lineweber, 2011) if the available features are appropriately communicated and made available to customers. Furthermore, the resulting Customer Value is as a result of a combination of five benefits, therefore an average benefit also suggests that there are some smart metering features which are not important specifically for the South African customers and yet others are important for them.

In a study by (Muchenje & Botha, 2021) on determining consumer centric factors for the implementation of smart meters in South Africa, it was observed that not all smart metering features presented to customers were appealing, but among the features presented elements such as cost, ease of use, social norms, attitude, trust in technology played a significant role. This study indicated that South African consumers showed differing interests on smart metering technologies compared to the European and American economies (Muchenje & Botha, 2021). In the next section is a research question which seeks to understand the smart metering features that are particularly important to South Africa customers.

Furthermore, the resulting customer value is also influenced by the cost of having a smart meter and accessing the features of the smart meter. One of the main costs identified is the need for customers to have mobile data or internet, to access the features, such as viewing historical consumption data, receiving alerts and notifications. Respondents rated the cost of data, on average, between neutral (3) and agree (4) on a scale of 1 to 5 which indicates that data costs are a concern to South African customers. The response on data costs is in line with the concerns reported in South Africa, that despite the reduction of tariffs which reduced the cost of 1GB from R149 to R99 by two of South Africa’s major telecommunication companies, the cost of data is still found to be very high (Chinembiri, 2020).

5.2.2 Research Question 2

The second research question for this study was to determine the dominant smart metering functions that influence customer value. This is mainly on the benefits of the smart metering function, as previously described the benefits of electric smart metering functions are described by the five external operations performance objectives. Since this cannot be directly measured or data on it collected through a survey, it is computed by the Structural Equation Model described in the first research question. In this case the idea is to understand which of the latent variable/s has a dominant contribution towards the customer value.

The statistical analysis utilising the Single Factor ANOVA indicates that the latent variables do not equally contribute towards Customer Value. This is demonstrated by a P-Value of $0 < 0.05$ indicating that there is a significant difference between the contributions of the latent variables towards the customer value at 5% confidence. This result is in line with the finding by (Muchenje & Botha, 2021) which indicates that different factors affect the value of smart meters differently.

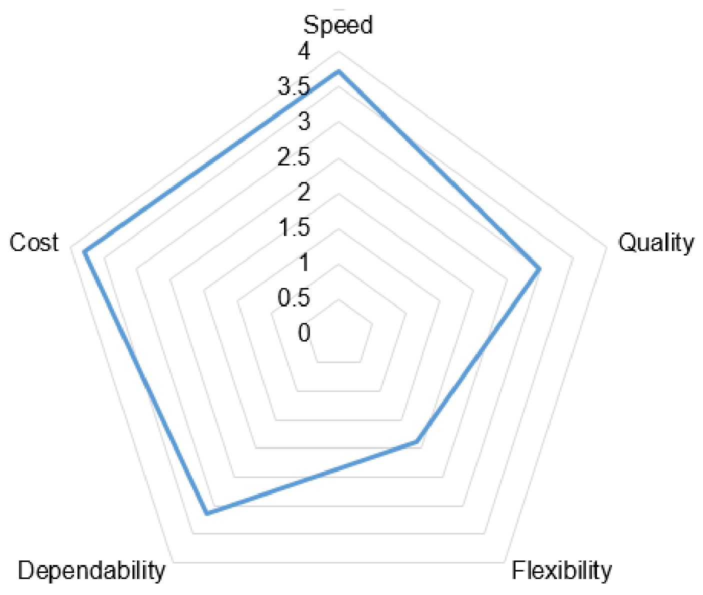

Figure 9: Latent Variables Contributions to Customer Value.

Figure 9 is a polar diagram providing a graphical representation of the contribution by each of the latent variables considered in this study. This result is based on the means of the different latent variables obtained from the SEM computed through the data collected. From the polar diagram it is apparent that the cost reduction feature of electric smart meters which allows customers to save money is an important factor to South African customers. This result suggests that the smart metering features that will allow customers to reduce costs is much needed. This cost reduction feature is about the ability for smart meters to provide information that will trigger them to change their behaviour with regard to electricity usage. This is in line with findings in Scotland where the older generation exhibited a higher willingness to pay for smart meters due to the meters' ability to enable the customer to reduce costs in their electricity usage (Barnicoat & Danson, 2015).

The cost feature is followed by the speed feature which is ranked high as well thus indicating the need by South African customers to utilise the features of smart meters that allow them to receive service speedily. These features include the ability for customers to receive their electricity consumption in a near real-time. Speed also becomes critical to meet the cost reduction need whereby, receiving data in real-time allows the consumer to adjust electricity usage to minimise cost – an opportunity which without the speed factor would be missed.

The speed feature is followed by the dependability feature in the rankings and requirements of the South African consumers. South African consumers rely on the ability of the smart meters to provide information that will enable consumers to adjust their consumption, change their behaviour to prevent unwanted outcomes such as loadshedding or using too much electricity. So, this nudge capability introduced by the smart metering capabilities creates a dependency, meaning incorrect information will result in customers loosing on the opportunity to save on electricity, the opportunity to identify and prevent things going out of hand such as load shedding. Furthermore the dependability opportunity arises from the ability of electric smart metering technologies to provide customers with outage information, to help customers to plan daily activities and avoid interruptions arising from power outages. The other opportunity realised from the dependability feature is the ability to provide billing information in a timely manner and this could prevent the accumulation of debt.

From these results, the Cost, Speed and Dependability features, are the dominant contributors towards a positive Customer Value. The remaining two (Quality and Flexibility), though they are critical for a smart metering operation, rank lower on the value system of South African customers. Table 13 summarises the smart metering features that are critical and dominant in the contribution of electric smart meter customer value. This is in line with what is stated by Sovacool et al (2017), with an exception of the ability to switch between prepaid and post-paid which is covered by the Flexibility feature of electric smart meters.

Table 13: Dominant smart electric metering functions on Customer Value.

Cost	**Speed**	**Dependability**
Ability to get alerts with information to change electricity usage behaviour to save electricity.	Ability to know how much electricity a customer is using on daily/real-time basis.	Ability to know when there is and will be electricity outage in customer's area.
	Ability to know the electricity charges applied on daily basis.	Ability to be alerted when electricity credit is low.
		Ability to participate in minimising or prevent load shedding (minimising electricity usage)

It is also worth noting that South Africa customers considered, Flexibility as a factor that is not important to them as an electric smart meter. In the case of quality, respondents indicated a neutral response in general. Table 14 shows the Flexibility and Quality features that respondents were presented with.

Table 14: Non-critical smart electric metering functions on Customer Value.

Flexibility	**Quality**
Ability to accurately budget for electricity usage	Ability to get invoices with up-to-date information on electricity usage any time it is requested
Ability to choose between post-paid (use first and pay after) and prepaid (pay first and use after)	Ability to get bills with accurate electricity usage information from the electricity provider
Ability to know how other customers are using electricity	Ability to know and see how customers are billed for their electricity (Visibility of tariff charges to customers)
Ability to know how much excess electricity is exported to the grid for customers with renewable energy sources (e.g. PV)	

5.2.3 Research Question 3

The third research question is to determine if there is a difference in customer value of electric smart meters by different customer types where age and gender are the differentiators. From the statistical results it was established that there is no difference in the perceived customer value of electric smart meters by the different customer groups that are differentiated by age and gender as the groups have similar customer value for electric smart meters.

This result differs with the findings by (Barnicoat & Danson, 2015) which indicated that the older generation in Scotland in the low income band had different customer value of smart meters with a strong willingness to pay for smart meters due to the ability for smart meters to provide feedback on consumption triggering change is consumption behaviour.

As a result of the award winning electrification programme, the Integrated National Electrification Programme (INEP), 87% of South African households have been provided with access to electricity, however affordability still remains an issue due to the high levels of poverty with close to 50% of South African households using electricity with a combination of other energy sources such firewood, paraffin and gas for cooking (Simisha, Reddy, Wolpe & Radebe , 2017). Based on this finding, it is apparent that South African customers are mainly on the low-income side. Because majority of South African households are on the low income side, their response to opportunities brought by technologies such as electric smart meters are rather influenced by this low income status and this is consistent across all customer groups (male and female; young, mid and old age). This also gives rise to opportunities for utilities as it will not encounter challenges of varying customer needs that need to be taken care of differently. One solution can be adopted based on the findings for research question 2 and meet the needs of residential South African customers.

5.3 Summary of Results Discussion

From the results obtained, a slightly below average customer value is observed. Initially, this may be interpreted as a similar view to (Ball, 2019) that states that smart meters do not add value to customers but only to companies and utilities. Based on the analysis performed, it has been established that customers find value in the smart meter functions described by the latent variables Speed, Cost and Dependability. Customers are neutral with regard to the quality component that smart metering functions brings on the visibility of electricity consumption. Lastly customers are neutral on the flexibility component that smart metering functions bring.

The other component that negatively influences the customer value for electric smart meters is the cost associated with internet connectivity which is required to access the electric smart meters functions owing to the high cost of data levied by the South African telecommunication providers (Chinembiri, 2020). Based on this result for South Africa, in particular, cost reduction is the main driver in the value that is associated to the electric smart meters, and this is visible in the value that South African customers put on the latent variables that have an influence on cost, such as Speed, Dependability and Cost itself. This response is in line with what is observed on the smart metering deployments that have been taking place in South Africa where it is stated that smart meters are gaining popularity (Nhede, 2018; Zyl, 2018). Based on this, it can be observed that there indeed value in the smart metering technologies to South African customers, what remains a challenge is the cost of the supporting technologies that enable customers to fully access the electric smart metering benefits.

Further analysis also indicated that there is no difference in the perceived value of smart electric meters by the different customer groups (based on gender and age). As opposed to other countries such as Scotland where the older low-income generation found the cost saving feature as a point of trigger for willingness to pay for smart meters (Barnicoat & Danson, 2015).

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The purpose of this study was to determine the customer value of electricity smart meters in South Africa for residential customers. The benefit elements of the customer value were described by five external operations' performance objectives (Speed, Quality, Dependability, Quality and Flexibility) with the cost element described as the cost of accessing smart metering functions by the consumer. Due to the inability to directly measure the five operations' performance objectives through survey, a Structural Equation Model (SEM) analysis was adopted.

Employing SEM involved setting the five operations' performance objectives as latent variables, described as a set of known variables collected through survey questions. The survey resulted in 365 responses; 12 responses were rejected due to incorrect completion by the respondents. A total 353 responses were used for this research. This was sufficient for the population size of South African residential customers. The resulting SEM from the sample data resulted in a satisfactory model fit. For reliability, the results obtained indicated that Quality, Flexibility and Dependability have lower values than the critical level tests. The reliability of the model required was compromised due to the Quality, Flexibility and Dependability elements which indicate the need for further extension to improve the reliability of the model. The validity of the model also resulted in acceptable levels.

Based on the developed model, data collected resulted in a mean customer value that is slightly below average. This result, however, does not necessarily suggest that South African customers do not value electric smart meters, rather it was observed that the customers are sensitive to the internet costs associated with accessing data on their smart meters to realise its benefits. This sensitivity is due to high telecommunications costs in South Africa.

Further analysis of the components of customer value, addressed by the second research question indicated that the contribution of the different latent variables (Speed, Quality, Cost, Flexibility and Dependability) differs. It was established that Speed, Cost and Dependability rank higher as dominant contributors to customer value. Further analysis to address the third research question indicated that there is no difference in the customer value derived by different customer types with regard to gender or age differences.

6.2 Recommendations

Based on the analysis and results of the study, it is observed that even though the obtained customer value is slightly below average, electric smart meters are valuable to South African customers. This was observed in the analysis of the different benefit elements of the customer value, where elements such Speed, Cost and Dependability were rated high by customers indicating their need for those features. It was also observed that customer value was compromised by the related internet costs for accessing the electric smart meter functions by customers.

Based on these findings it is recommended for utilities, municipalities and organisations planning to introduce or deploy electric smart metering infrastructure to focus on implementing smart metering functions relating to the Speed, Cost and Dependability elements. Furthermore, effective communication and guidelines on how to access and utilise these functions should be developed and shared with the customers. The results obtained from the three research questions indicated that there is no difference in the customer value within different customer groups. This factor eliminates the need to customise the service to meet varying customer needs. Utilities are advised to take advantage of this factor.

Further recommendations regarding the improvement or validation of the results should be undertaken, especially the enhancement of the research questions describing the latent variables Flexibility and Dependability and Quality to obtain optimal reliability results. Additionally further cost elements contributing to the customer value can be investigated to ensure that it model does not only rely on one variable being the data costs, doing this can reveal more insight in the customer value when more cost element are put forth to the respondents,

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