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Multi-agent value co-creation and technological innovation in rural water supply in South Africa

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Multi-agent value co-creation and technological innovation in rural water supply in South Africa

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A research report submitted to the Wits Business School in the University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in the field of Innovation Studies

Johannesburg, 2022

ABSTRACT

Lack of access to clean water in rural areas is a challenge affecting billions of people across many developing countries. Although many technological innovations have been developed in response, their adoption is low in rural areas. This study investigates the interactions of multi-agents in co-creating technological innovation designed to address societal challenges in rural areas, using South African case studies.

The literature review suggests that processes involving preparation, co-defining, co-creating and implementing solutions can be used to study the value brought by harnessing the contributions by a variety of actors. The mapping of actors, including their motivations, is highlighted as critical in co-creating sustainable solutions in a typical rural area.

Using two water purification technological innovations, a content analysis of semi-structured interview data, actor-network mapping, and inductive coding of critical information about the current state of rural water supply was undertaken. In particular, the analysis focussed on the value generated by co-creation. In the study, a qualitative approach using a combination of the innovation diffusion theory and technology acceptance model offered an interesting lens for studying technological innovation acceptance and adoption in rural areas.

The study identified that co-creating technological innovations with rural communities led to community empowerment. An added benefit was that the study addressed water supply challenges, improved product design and led to higher technology acceptance and adoption. The study also highlighted a coordinated approach which can be used by government, the private sector and the community for the benefit of all participants, by transferring technology and knowledge in response to societal challenges.

KEYWORDS

Multi-agent value co-creation, innovation for social purposes, rural water supply, water quality, technological innovation, point-of-use water purification technology

DECLARATION

I, **EMMANUEL SAKALA** declare that this research report is my own unaided work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of Innovation Studies at the WITS Business School in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Signature:…………

On the **14th of November 2022**

EMMANUEL SAKALA

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“Innovation – the heart of technological change – is fundamentally a learning process”

(Peter Dicken)

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LIST OF ACRONYMS

CSIR	– Council for Scientific and Industrial Research
DSI	– Department of Science and Innovation
ICT	– Information and Communications Technology
IDP	– Integrated Development Plans
IDT	– Innovation diffusion theory
IP	– Intellectual Property
MAVCc	– Multi-agent value co-creation
MOA	– Memorandum of Agreement
MOU	– Memorandum of Understanding
OECD	– Organisation for Economic Co-operation and Development
R and D	– Research and Development
RO	– Reverse Osmosis
SABS	– South African Bureau of Standards
SANS	– South African National Standard
S-D	– Service Domain
SDG	– Sustainable development goals
SI	– Social Innovation
STI	– Science, technology and Innovation
TAM	– Technology acceptance model
TRA	– Technology reasoned action
UNESCWA	– United Nations Economic and Social Commission for Western Asia
UNICEF	– United Nations International Children's Emergency Fund
VCc	– Value co-creation
WHO	– World Health Organisation
WRC	– Water Research Commission

CHAPTER 1: INTRODUCTION

1.1 CONTEXT OF THE STUDY

According to the WHO/UNICEF (2019), globally, 2.1 billion people do not have portable drinking water, including 785 million that don't have access to water infrastructure are mainly in rural areas. The problem is more severe in Asia and Africa with isolated areas in Europe, North America and Australia where some people are often excluded due to ethnicity or remoteness (Filčák *et al*., 2017; Sadler and Highsmith, 2016). Over 800 000 people die from diarrhoea each year as a result of poor sanitation and unsafe drinking water (WHO, 2022).

Of the 51 million people in South Africa, an estimated 19 million (Macrotrends, 2021) live in rural areas where ~ 74% of the rural population has access to a reliable water supply. This translates to ~ 5 million people still relying on 'unimproved' water sources such as surface water bodies, unprotected wells, and rainwater harvesting (StatsSA, 2017). Not every rural community has access to a functional water supply infrastructure, some have been excluded due to their remoteness, and others have failed due to poor management (Tshikolomo *et al*., 2012), and the lack of maintenance (United Nations, 2014) or vandalism. As water is a critical ingredient for life and a backbone for civilisation, this has triggered some communities to engage in self-supply of water through community-led infrastructural developments or individual means such as rainwater harvesting, manually fetching water from rivers, ponds, wells or boreholes instead of waiting for the government to provide. In such an approach, the term '*bottom-up'* approach can be used. This approach has addressed some of the water shortages (Hofstetter *et al*., 2021), improved ownership and in some cases the community-led infrastructural developments have ultimately united communities through this shared resource. According to Hofstetter *et al*. (2021) and Mackintosh and Colvin (2003), the water quality from this approach often does not follow the prevailing national standards, which raises health concerns. According to Hofstetter *et al*. (2021), the '*bottom-up*' approach is not supported fully by the current South African water statutes (National Water Act and the White Paper on National Water Policy). Through these two statutes, the department of human settlement, water and sanitation is responsible for overseeing the water resources in the country by monitoring, legislative control and enforcing the associated regulations and policies. It further extends that the final point of delivery of water should be managed by the local

governments and municipalities. This approach can be termed '*top-down*' as the government through its agents, policies and regulations monitors and controls how water is delivered and managed down to the end-user including rural areas. The advantage of this approach is that it tries to allocate and deliver water resources in a fair manner that conserves and protects them for future generations. In addition, to ensure that the water supplied is of good quality. In South Africa, this public sector approach to the rural water supply is faced with numerous challenges such as financial and human capacity constraints; aged infrastructure (Malima *et al*., 2021); and the distant geographical location of some rural districts. Even in some instances when funding is available, the government is still struggling to improve the standard of living of rural communities (Martens *et al*., 2021). The Water Act has created a culture of dependency where the government vouches to deliver all the basic services including clean water, free of charge to every citizen. While this is noble and necessary, it has caused communal complacency and is stressing the already stretched fiscus system. This has led to other rural areas failing to get the basic supply and then resorting to taking water from unprotected and unsafe sources of water while waiting for the government's promise.

Due to the gaps in the rural water supply that the '*bottom-up*' and '*top-down*' approaches are failing to fill, individuals, social enterprises, not-for-profit and for-profit enterprises through their humanitarian and/or corporate responsibility initiatives, are addressing them. For example, they are doing this by drilling boreholes and/or delivering water using water trucks to areas in dire need of this essential commodity of life (Cullinan, 2014). Since these actors offer support outside the '*top-down*' and '*bottom-up*' approaches, this approach is termed the '*adjacent-down*' approach in this study. The three approaches are shown in Figure 1. For the sustainability of rural water supply, these three interventions need to be coordinated through an approach (red circle in Figure 1) termed the '*hybrid*' approach which combines these approaches involving multi-agents. This can be done by devising an inclusive approach that integrates all actors to interact for mutual benefits. As pointed out, one of the biggest concerns is water quality, which would require elevating water purification technological innovations for a typical rural setting (Galardi *et al*., 2022; Kohlgrüber *et al*., 2021).

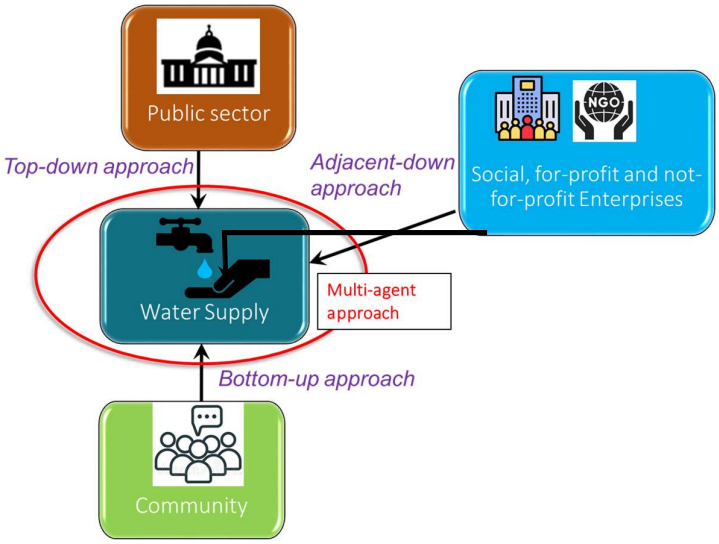

Figure 1: The 'top-down', '*bottom-up*' and '*adjacent-down*' approaches to water supply (Source: Author)

Since technological innovation in the rural water supply is meant to bring development to the entire community, the study was conducted through the lens of innovation for social purpose discourse (Yang and Sung, 2016) with a dimension of multi-agent collaboration.

1.2 PURPOSE OF THE STUDY

The purpose of the study is to gather a detailed understanding of who and how various actors interact to deliver clean water to rural areas in South Africa. It also seeks to establish factors that influence technology acceptance and adoption of innovation for social purposes in rural areas.

1.3 RESEARCH PROBLEM STATEMENT

According to Ragauskaitė and Žukovskis (2019) and Živojinović *et al*. (2019), rural areas need a unique approach to innovation due to unique social challenges such as poverty, complex social dynamics, low literacy rates, and lack of basic infrastructure and services. Hence, they advocate innovation for social purposes as a possible solution.

On the contrary, Bock (2016) indicated that others view innovation for social purposes as a means by which governments shift the responsibilities of rural development to civil societies and communities through the citizen's cooperatives. A similar view is shared by Martens *et al*. (2021) who postulated that the public sector is only good at financing but is unable to initiate innovation for social purposes alone requiring other

actors with some incentives or motivation. The biggest challenge is the identification of actors to interact with. Thus, further affecting the identification of those who should initiate innovations (Windrum *et al*., 2016).

In another research by Jing and Gong (2012), they found that the blended solution between the government and private sector for innovation for social purposes has the potential to yield optimal results. Despite the imposed regulatory hurdles, such offers a solution that can help to create an enabling environment from which organisations, strategies or ideas can be natured to fruition. Since we now live with vast societal challenges, blended solutions that are interconnected, multifaceted and multidisciplinary are required. It has become difficult to solve them without the involvement of many actors in the communities and society (Kumari *et al*., 2019). As there is no one solution to all challenges, and the relative newness of innovation for social purposes, the concept is still weakly conceptualised and lacks a comprehensive theoretical foundation (Kumari *et al*., 2019).

In academic literature, innovation is very important for economic development at firm and national levels. The risk is that there is little agreement in policy-making and innovation research on who and how innovation can be generated outside of the urban environment, particularly in rural areas (Martens *et al*., 2021). According to Yin *et al*. (2020), actors interact to co-create innovation for social purposes but the nature of interaction for co-creating value and what motivates agents to engage is still not well understood in the literature (Babu *et al*., 2020).

These conflicting views and gaps in the literature reflect that the concept of innovation for social purposes in rural areas needs more research. This study seeks to understand how innovation for social purposes can play a role in contributing to solutions for rural water supply in South Africa.

The provision of clean water to rural areas is complex, for which innovation for social purposes cannot tackle alone, requiring integration of technical competencies. These technical competencies include but are not limited to:

- Social science studies on complex social dynamics found in rural areas;
- Water purification technologies such as point-of-use (Farrow *et al*., 2018), solar-powered water filtration (Hendrickson *et al*., 2020; Kain *et al*., 2017), and nanotechnology (Savage and Diallo, 2005) and others;

- Alternation water sources such as drinkable books (Bever, 2015), fog harvest (Park *et al*., 2013);
- Hydrogeology and groundwater exploration;
- Water management and engineering; and
- Environmental protection.

The question is if some or all of these technical competencies or their combinations play a critical role in ensuring a successful rural water supply, and how will the proposed '*hybrid*' approach mobilise agents to participate in a rural context. Hence, there is a need to look at how actors from the commercial, social and government organisations can simultaneously interact to co-create social innovations particularly in water supply in rural areas in South Africa (Babu *et al*., 2020).

1.4 SIGNIFICANCE OF THE STUDY

In rural areas, water plays a very critical role in the livelihood of people living in rural areas. Water is an essential element for human and animal health; agriculture; nutrition and water enable job opportunities in numerous key sectors across the rural economy. Hence, this research seeks to establish how water can become accessible to rural communities by understanding how actors/agents can work and collaborate in the rural water supply.

In Sub-Saharan Africa, approximately 491 million people are without a basic water supply and the major of this figure lives in rural areas (WHO, Unicef, 2017). This research Is significant in coming up with possible solutions meant to address this challenge in Sub-Saharan Africa.

The research also seeks to contribute towards the national development plan and broadly the United Nations Sustainable Development Goals (SDG) aiming at SGD 6 and SGD 17:

- SDG 6 – This SDG involves the inclusion of communities in work or research particularly in water quality and sanitation. Access to clean water by everyone is one of the aims of this SDG that the world is battling with. Thus, the research on rural water supply is timely and relevant, not only to South Africa but to the international development agenda. It is also more important because a large

share of the African population lives in rural areas where access to clean water is poor (WHO, 2022). Understanding how commercial, social and government organisations interact to overcome this challenge is critical because this understanding offers lessons that may be transferred to other contexts.

- SDG 17 – This SDG mainly looks at enhancing partnerships for sustainable development through multi-agent collaborations that organise knowledge sharing, technology, expertise and financial resources. Contribution to this goal will come from the in-depth study of how various actors interact to deliver clean and sustainable water to a rural context in South Africa.

Value co-creation has emerged to be important in the management profession mainly because several so-called 'wicked' problems (Head & Alford, 2015), including access to potable water in remote areas, require inter-actor collaborations for value creation. Fostering and managing these collaborations is not a trivial problem; hence, the insights offered by this research are useful from a management perspective.

Despite the vast literature developed elsewhere, research in the co-creation concept is weakly developed in the South African context with only a few publications having been published in various fields such as education (Rambe *et al*., 2020), Living labs (Habiyaremye, 2020), spiritual research (Capitano and Naudé, 2020) and climate change (Ziervogel *et al*., 2021). The study intends to contribute to knowledge in co-creation application to rural water supply in South Africa and feed the academic and social discourses in the South African context.

The study is important for social enterprises, the private sector, communities and research entities as findings will give guidance on how actors interact in innovation for social purposes in rural areas. It also seeks to contribute to giving guidance on how enterprises/agents can navigate the social dynamics in rural areas.

1.5 RESEARCH QUESTIONS

Using the context and problems given, the study seeks to solve the following research questions in the South African context:

- Who are the key actors necessary for the deployment of water technological innovation in rural areas?

- What motivates actors to participate in co-creating value in the rural water supply?
- How do the actors interact in co-creating value in innovation for social purposes such as water supply in rural areas?
- What are the main factors that influence water technological innovation acceptance and adoption in rural areas?

1.6 DELIMITATIONS OF THE STUDY

Theofanidis and Fountouki (2018) define delimitations in research as the limitations deliberately but realistically set by the researcher, which act as limits or boundaries of study in addressing the research problem and are fully under the control of the researcher. Thus, this study identifies five delimitations:

1. The research explores innovation from innovation for social purposes and technological innovation perspectives.
2. The study is limited to rural areas in South Africa as a prism from which the interaction of many agents to co-create technological innovation can be assessed.
3. The legalities and intellectual property implications of co-creating technological innovations with rural communities were not conducted in this study.
4. Rural water supply involves many aspects such as water quantity, quality, management, engineering and others. This study focuses only on the water quality aspect of the water supply.
5. The innovation in this study is mainly meant for social benefits and does not consider the negative or unintended consequences of innovation (Svarc *et al*., 2011) and social action (Merton, 1936).

1.7 ASSUMPTIONS

The study uses inputs from literature reviews, document analysis and interviews of two communities in South Africa. It assumes that:

1. The communities, public and private service officials and social enterprises will be open and truthful about the social challenges, and their deliberations on the subject matter.

2. All community participants are fully aware of the water quality issues in their communities and the experts interviewed have an in-depth understanding and experience in the rural water supply.

3. The population interviewed was available and all discussed information will be appropriate for publication of the research results with no confidential restrictions on the two case studies.

1.8 DEFINITION OF KEY TERMS

Actor: Members in an innovation system that promote innovation in various stages of its development, ranging from an individual, groups of individuals or organisations depending on the unit of analysis required (Drechsler *et al*., 2019).

Co-creation: A practice in which several participants cooperatively outline and solve societal challenges by jointly choosing and putting together resources to bring about improvement in economic and most importantly social values (De Silva *et al*., 2020).

Innovation: OECD/Eurostat (2005) defines it as "*The implementation of a new or significantly improved product (goods or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations*".

Social enterprises: An organisation that participates in the markets not only for profit but also to create positive environmental and social solutions (Santos, 2012).

Social innovation (innovation for social purposes): The development of new or significantly improved processes, products, services, models and markets aimed at addressing social needs leading to enhanced capabilities and healthier relationships in the use of the resources (Angelidou and Psaltoglou, 2017).

Technological innovation: The bringing of new or significantly improved goods/services and/or the implementation of a new or significantly improved method or production in delivering goods or services (Oslo Manual, 2005).

Rural area: Refers to sparingly populated regions characterised by people who rely on existing resources or survive on migratory labour that is not classified as urban (Statistics South Africa, 2003).

Water quality: A term used to describe water in terms of its chemical, biological and physical characteristics (Schutte, 2006).

1.9 STRUCTURE OF THE REPORT

Chapter One (Introduction): This chapter gives the background information, which forms the foundation on which the research is built.

Chapter Two (Literature Review): In this chapter, the perspective regarding the theoretical and empirical evidence for value co-creation and technological innovation will be discussed and a conceptual framework established.

Chapter Three (Research methodology): An account of the justification of the design and strategy, data collection techniques, presentation and data analysis will be discussed in this chapter.

Chapter Four (Research findings): The findings from the study will be presented.

Chapter Five (Discussion of the research findings): In this chapter, the findings will be discussed in comparison with the literature review and new insights generated.

Chapter Six (Conclusions and Recommendations): Finally, the findings in the study will be tied together and conclusions made, followed by recommendations for future work and implications for technology acceptance in rural areas coined.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Following the background information and water challenges highlighted in the previous chapter, a review of literature on technological innovation and multi-agent value co-creation in the realm of innovation for social purposes was done. A conceptual framework that relates technological innovation acceptance and multi-agent value co-creation was formulated that will be tested in its application towards solving the water quality challenges in rural water supply in South Africa.

2.2 INNOVATION

According to Baumol (2002), since the eighteenth century, most of the economic growth is linked to innovation. In the modern-day, the ability to innovate is one of the most vital aspects that lead to the growth of any enterprise or country. It is also essential for the growth, survival and development of enterprises and for enhancing the competitive advantage (Chigona and Licker, 2008; Petkovska, 2015). The relationship between economic growth and innovation is understood to be a positive and strong one as seen by nations in developed countries promoting innovation in all spheres of life (Harkema and Schout, 2008).

Innovation has countless definitions and interpretations, which alter its usage and its contextualisation across various fields in industry, academia and government (Tidd and Bessant, 2009). From the innovation definition given in chapter one, new products and processes are developed and the adoption and/or develop new types of enterprise and marketing (Baranano, 2003). Thus, the innovation concept extends to the social and organisational realm beyond only economic purposes which is particularly critical for application in Africa where the standards of living are generally low (Van Zyl, 2011).

According to OECD (OECD/Eurostat, 2005), the four types of innovations are:

- Product innovation – Involves bringing new or significantly improved goods or services. This looks at its features for the purpose it is intended to be used;
- Process innovation – Involves the implementation of a new or significantly improved method or production in delivering goods or services. For example, new equipment, automation, techniques and others;

- Marketing innovation – Involves the bringing into fruition of new advertising or selling approaches that involve significant changes in a product in terms of its promotion, pricing, placement, design or packaging; and

- Organisational innovation – Involves the implementation of something new or significantly improved to an organisation.

Of these four types of innovations, Fritsch and Meschede (2001) and *Oslo Manual* (2005) refer to process and product innovation as technological innovations and organisation and marketing innovation as non-technological innovations. This study mainly focuses on technological innovation.

2.3 TECHNOLOGICAL INNOVATION

Scherer (2001) expanded the definition of technological innovation to entail the recognition of new technological possibilities and the organisation of resources (financial and human) that are required to change them into useful processes and products. Achilladelis and Antonakis (2001) described technological innovation as the most dynamic of all industrial activities. Thus, for any technological innovation, it is important to understand what drives it and the factors that affect its adoption and use.

2.3.1 Drivers of technological innovation

Expanding from the definitions of technological innovation, Dosi *et al*. (1988) urge that there is little dispute that technological innovation is imperative for the productivity of industries, firms and society in general. This leads to the need to understand the driving force for technological innovation.

A study done by Achilladelis (1982) and is summarised by Achilladelis and Antonakis (2001) identified seven driving forces for technological innovation as follows:

1. Scientific and technological advances emanating from outside the organisation;

2. Market demand for innovation;

3. Availability or scarcity of raw materials;

4. Response to competition from other companies;

5. Fulfilment of societal needs;

6. Government legislation that affects the research and development (R and D) or competitiveness of innovation; and

7. Existing competency of an organisation in scientific, technological and market.

These driving forces are dependent on each other as seen by the response by firms addressing a number of them at once. The first six are 'external environmental triggered' and affect most research-intensive firms (Achilladelis and Antonakis, 2001).

OECD (2011) recognises that modern economic growth must go together with societal progress. Thus, technological innovation needs to not only contribute to growth in economies but should also respond to societal challenges. This can be done through innovation by multilateral collaboration among various stakeholders and integration of competencies. In addition, public involvement in technological innovation is essential to initiate a paradigm shift, which would contribute to the integration of social value into incentive mechanisms for innovation. To do that, innovation acceptance and its adoption must be understood in the realm of technological innovation.

2.3.2 Technology Acceptance Model

The technology acceptance model (TAM) was originally designed to explain and provide empirical evidence of how users accept a variety of computing technologies. In the model, the technology acceptance is decided by the intention to use, which is controlled by the user's belief and attitude towards a technology. This model can best be explained using the five factors as outlined by Davis *et al*. (1989) and Davis, (1989). These five factors are perceived usefulness, perceived ease of use, external factors, intent of use and usage behavioural: Figure 2 shows how the factors are related to each other.

1. Perceived usefulness is the extent to which an individual believes that using that particular technology would improve their productivity and/or benefits derived from using it.

2. Perceived ease of use is the extent to which using a particular technology will be free of effort to use it.

3. External factors are variables that impact users' perceptions and attitudes towards a new technology that will have an impact on the success of the technology (Monzavi *et al*., 2013). Their impact can be positive or negative.

4. Intent to use factor relates to the acceptance of technology based on the person's perceptions of the specific technology's usefulness and ease of use (Portz *et al*., 2019).

5. Usage behavioural factor explains the actual use of a technology (Portz *et al*., 2019). It can be measured by how many times the technology is utilised (Averweg, 2008).

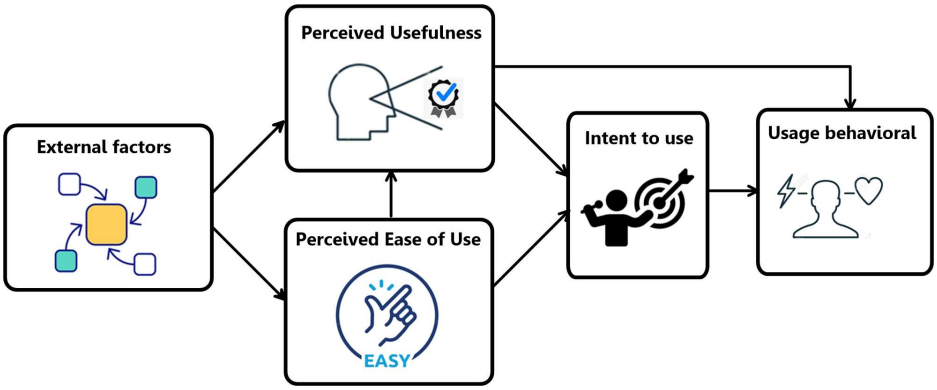

Figure 2:Illustration of the technology acceptance model (Similar to Davis et al., 1989)

The technology acceptance model (TAM) was extracted from the theory of reasoned action (TRA) which aims to explain the factors that influence how computers are accepted by understanding user behaviour (Davis, 1989). In their psychological and sociological research, Fishbein and Ajzen (1975) developed the TRA model. According to Eveland (1986), the process of technology transfer from the creator to the user is dependent on what the user thinks, which is often controlled by his/her feelings, thoughts and interest.

Perceived ease of use and the perceived usefulness of the technology form a strong explanatory power in explaining the user intention towards using a particular technology. Portz *et al*. (2019) suggested that the perceived usefulness and ease of use of a technology are often affected by external factors such as social influences, technology features and the situational condition under which the technology is introduced. In their study, they identified two external factors (computer self-efficacy and anxiety) which do not fall within the TAM theoretical framework. Their research was able to gather in-depth information on how older adults interact with technology with implications for the design of technologies for older adults. Interestingly to note, is that the traditional TAM approach looks at several perception factors which influence

the decision for someone to use technology but has no emphasis on the technology features as a proxy for understanding technology acceptance (Zoellner *et al*., 2008).

Potivejkul *et al*. (2017) used the TAM to understand the influencing factors on ozonation purification technology used in Thai industries. Their results show that acceptance is a critical variable for the use of ozonation technology for water purification.

2.3.2.1 Application of technology acceptance model in South Africa

Averweg (2008) conducted quantitative research to understand how an executive information system is being used in 31 organisations in the KwaZulu-Natal province in South Africa. Questionnaires were used to gather data which was compared to Davis *et al*. (1989) TAM factors. Averweg (2008) results showed that the perceived ease of use factor is important as it influences perceived usefulness which in turn determines whether the executive information system is used or not.

Matikiti *et al*. (2018) did quantitative research to establish factors that influence attitudes towards the use of social media marketing by tour operators and travel agencies in South Africa. Data was gathered using questionnaires from 150 tour operators and travel agencies. Data analysis was done using the one-way ANOVA and multiple regression analysis methods. The results highlighted the internal (managerial support and managers' level of education), external factors (Pressure from competitors) and perceived usefulness influence attitudes towards the use of social media marketing. Technical knowledge was identified as a moderating variable between the relationship between attitude towards social media marketing adoption and level of social media marketing usage.

Ndebele and Mbodila (2022) investigated the factors essential for technology acceptance in teaching and learning at a historically disadvantaged university in the Eastern Cape Province of South Africa. Their research showed that most academic staff still believe and see the value that technology brings to their work. In addition, they are aware that technology use in education improves teaching and learning, and they are willing to use the technology.

In Malaysia, Al-Rahmi *et al*. (2019) studied how students use e-learning systems using a new approach that combines TAM and the innovation diffusion theory. The research combined factors that affect innovation diffusion and theoretical factors for TAM. They

used parameters such as trial-ability, observability, complexity, relative advantages from innovation diffusion theory (IDT) and the perceived ease of use and intent to use. This approach offers another lens through which technology acceptance and diffusion can be viewed in rural water supply research.

2.3.3 Innovation Diffusion Theory

The innovation diffusion theory looks at establishing the factors that contribute to an innovation that is adopted according to the perceived information from the social perspective (Roger, 1983). This approach to understanding how innovation is adopted started in rural sociology research and is now widely used in various disciplines such as ICT, education, health, research, economics, engineering and others.

There as five factors, that affect how an individual or a group of individuals adopt an innovation. Roger (1983), and Roger and Scott (1997) give the following as factors to consider when accessing diffusion (adoption) of innovation:

1. Relative advantage,
2. Compatibility,
3. Complexity,
4. Trial-ability, and
5. Observability.

Relative advantage - The extent to which an individual perceives the innovation as being better than the existing one can affect how an individual or group of individuals receives an innovation. The innovation being introduced can be compared with the superseded one in terms of social status, cost and others. Thus, the more an innovation shows better relative advantages, the better it will diffuse (or be adopted).

Compatibility - This refers to the extent to which an innovation is perceived in terms of its consistency with the existing norms, beliefs, understanding, apriori-knowledge and the requirements of prospective adopters. Innovation should not fundamentally change the existing norms, and beliefs too quickly as this has a bearing on the adoption of that innovation.

Complexity - This factor refers to the difficulty associated with the use and understanding of innovation. This is an opposing factor that needs to be elevated. An innovation that is complex to use tends to be less likely to be adopted when compared to one that is easy and simple to use.

Trial-ability - This factor refers to the extent to which an innovation can be experimented with easily by aspiring adopters. If an innovation is easy to try, the higher the chances that the adopter will use it.

Observability - This factor refers to the extent to which an innovation can be perceived as others see the innovation being used, proving the value extracted from it. This would trigger the one seeing to try the innovation. Thus, an innovation that shows value to others triggers many to adopt the innovation.

Since the application of technology in rural areas for the provision of clean water is meant for the entire community, an understanding of social dynamics and social innovation is important.

2.3.3.1 Application of the Innovation Diffusion Theory in South Africa

Research to understand the use and diffusion of modern ICTs in the government departments in the KwaZulu-Natal province in South Africa was conducted by Mbatha *et al*. (2011). A questionnaire survey targeting 152 managers in key government departments was done. The data collected was analysed using thematic categorisation and tabulation methods. The results show that ICTs have proved to be key catalysts in increasing creativity and general work productivity in government departments. Also, the use of ICTs has brought about a reduction in time and cost in storing, processing and transmitting information, leading to essential reforming of the government and society as a whole.

Through the '*top-down*' approach, the National Department of Health set out to implement several health innovations in 11 health districts in South Africa (Orgill *et al*., 2019). Three case studies were used and 38 interviews were conducted with provincial and district-level managers. The diffusion of innovations model was used to interpret dissemination and diffusion in the districts. The results show that the managers valued the national leadership role as a champion in disseminating innovations through road shows and participation in the inductions of all new managers (Observability). Managers leveraged their existing social networks in the districts and created

synergies between new ideas and existing working practices to enable adoption by their staff (Compatibility). The managers are seeing the relative advantage of the health innovations as they try them which is consistent with Roger (1983) and Roger (2003).

This study by Achieng and Ruhode (2013) investigated the adoption of electronic voting technologies in Cape Town, South Africa to mitigate some of the challenges of manual voting such as non-secure, time-consuming and tedious. On-line questionnaires and in-depth semi-structured interviews were used. The data was analysed using diffusion of innovations theory and thematic analysis. The findings reveal that relative advantage, compatibility and complexity would determine the intentions of South African voters and the electoral management bodies to adopt e-voting technologies. Moreover, the findings also reveal several other factors (usefulness of the technology, ease of use, trust in the technology, resources and infrastructure, and environment) that could influence the adoption process.

2.4 SOCIAL DYNAMICS

Social dynamics involves the study of how individual group members influence a collective response through their interactions and group dynamics (Durlauf and Young, 2001). Social dynamics is a sub-set of complexity science that brings together ideas from other fields such as economics, psychology, sociology, and others (UNESCWA, 2008).

In addition, rural communities normally live by their customs, norms, values and traditions, making social dynamics very complex as compared to urban areas (Kapur, 2019). Despite the complex social structures, communities in rural areas form autonomous associations or community representatives, which can manage and navigate through these complex cultural and social dynamics of their community members. These associations/representatives are often democratically governed (Martens *et al*., 2021) and well organised making it easy to forge a relationship with external enterprises and organisations that seek to bring development to their communities (Martens *et al*., 2021). The introduction of new knowledge and technology to rural areas would require a social-oriented approach which social innovation seeks to address.

2.5 SOCIAL INNOVATION

OECD (2011) defined social innovation as the generation and implementation of new ideas, concepts, organisations and strategies for social needs. In short, it refers to innovation for social purpose, which distinguishes it from the economic relatedness of technological innovation. Social innovation (SI) is intended to contribute to the identification and delivery of new services towards improving the quality of life of individuals and communities. Thus, social innovations aim to address complex social challenges through this solution-based approach.

We now live in a society with new problems and vast societal challenges, which are interconnected, multifaceted and multidisciplinary, social innovation is very important in addressing these challenges and problems. It has become difficult to solve them without the involvement of many actors in the communities and society (Kumari *et al*., 2019). This complex interlocking of problems has pushed society towards social innovation requiring many actors to come up with new solutions to sustain society. Hence, the concept of social innovation is still weakly conceptualised and has no clear definition and lacks a comprehensive theoretical foundation (Kumari *et al*., 2019). Other authors (Moulaert *et al*., 2017) have tried to conceptualise social innovation as an output of collective actions for improving social structures, relationships and empowerment of the entire society. The key aspects of social innovations outlined by Moulaert *et al*. (2017) are learning and knowledge exchange, collaboration, the development of new ideas, collective empowerment, and social change to the generation of solutions to solve societal problems.

The societal challenges that social innovation seeks to solve are very complex and demand the integration of ideas and knowledge by many innovation actors, but the capabilities and resources (financial and human) cannot all be found in one actor, hence, the need to co-create solutions. During resource integration, the means of collaboration, power shift and co-creation determine the mode and approach for social innovation to be used (Kumari *et al*., 2019). This introduces the need for value co-creation as applied to social innovation.

2.5.1 Value co-creation

The value co-creation (VCc) concept is thought to be first presented in the academic literature by Prahalad and Ramaswamy in 2000. Co-creation is based on the business-and-service economy, where customer participation guides how products/services are

developed which has benefits of cost-saving and reduction of market time for products/services. The concept is often referred to as the customer-in-service-dominant (S-D logic) (Kumari *et al*., 2019). Co-creation also emphasizes the essential transformations of society through collective effort done by multi-agents in addressing specific social problems (Moulaert *et al*., 2019). Multi-agent interaction is complex but can be systematic based on the principle of joint growth and complementary advantages. This expands co-creation to not only focus on customers but also on how multi-agent interact to create value in social innovation.

For innovation to strive, the quality of supporting entities such as active knowledge institutions, market policies and the business environment should be good (Petkovska, 2015). In South Africa, through the White Paper on Science, Technology and Innovation (STI), the government strongly supports multi-agent partnerships as a means of strengthening innovation across public, private and civil societies. This is done by intensifying interactions and partnerships and enhancing coherence amongst various actors hoping to improve how innovations meant for social purposes are designed and delivered. This would also contribute to the SDGs with a broader aim of reducing inequality and the number of people below the poverty line through improved public service delivery. The government supports social innovations across the country where the public sector becomes an enabler of innovations through value co-creation and user-led initiatives. It also assists civil societies as a potential source of innovations, mentoring and networking, and as key actors in collaborations. Hence, widening the range of stakeholders and deepening their involvement in social innovations would support the penetration of new technology geared towards solving some of the most challenging social needs such as water supply in rural areas.

2.6 MULTI-AGENT VALUE CO-CREATION

To explain the dynamics of social innovation, Windrum *et al*. (2016) developed a multi-agent model that combines social and service innovation concepts. The public sector and social enterprises are engaged in social innovation and to a less extent for-profit enterprises. For-profit enterprises are involved in service innovation. Windrum *et al*. (2016) establish how service innovation and SI can be combined to deliver value. Research in social innovation and service is done in parallel. The same author found synergies between the two through the multi-agent value co-creation (MAVCc) concept. Where co-creation is viewed in the context of multi-agents working towards a common goal. Agents include the public and private sectors, social enterprises and

not-for-profit enterprises. Windrum *et al*. (2016) build the concept of MAVCc which enables the understanding of participant interaction to co-create and diffuse SIs where these interactions form the new co-created innovations. It also states explicitly how each actor's preferences and competencies are combined for mutual goals.

Windrum *et al*. (2016) show the application of the use of the multi-agent framework to create, diffuse and sustain SI such as the Austrian nationwide public defibrillation program where the business of portable automated external defibrillators was co-created by various agents. In their study, citizens were an important stakeholder through which SI was dissemination using multi-agent co-creation involving the private sector and enterprises (social or otherwise), public sectors and not-for-profit. Enterprises involved in multi-agent co-creation enable enterprises to distinguish their market strategy through enterprise social responsibility with obvious financial benefits. Although the theoretical framework was developed and tested with a case study, it lacks empirical grounding but can be important to tackle rural water supply with many actors involved.

Piecing together the theoretical frameworks, it is evident that social innovation and VCc, in the context of multi-agent involvement can contribute to the rural water discussion. The challenge of how the various actors interact is the only missing piece of the puzzle that Gupta *et al*. (2017) article tries to address. The same author formulates how enterprises and communities can work together to address unmet social requirements, which are currently unaddressed by institutions by looking at SI in the context of MAVCc. Social innovation can be viewed in the multi-agent context of how innovators foster trust amongst various actors and influence policy (Gupta *et al*., 2017). Gupta *et al*. (2017) describe the social and market factors that influence the emergence of social innovations to understand how to motivate them towards a common goal. Finally, the willingness to share and learn from each other is more important.

2.6.1 Actor mapping

Tadesse *et al*. (2013) identified key actors, namely: communities, social enterprises, and private and public sectors who should be active in a typical rural water supply. As one of the issues in the rural water supply is the water quality, academia (research institutions, universities) will be key to elevating the technological innovation and knowledge dimensions. All these actors need to be motivated towards contributing to

the supply of clean water in rural areas. Hence, the empirical findings on the motivation of possible actors to co-create value in the rural water supply is important for this study.

2.6.2 Actor motivation

Yin *et al*. (2020) suggested that multi-agents interact for economic, social and environmental benefits. Even though this appears clear, the nature of interaction for value co-creation and the motivation for agents to engage is still not well understood in the literature (Babu *et al*., 2020). Babu *et al*. (2020) did a study to understand what motivates multi-agents to co-create mobile phone-based financial services. Their findings were inconclusive as they showed that co-creation has to be contextualised and that not all actors are in it for monetary purposes but others are in it for social and humanitarian reasons. Using the literature on possible actors required for rural water supply, understanding the motivation of these actors is critical.

2.6.2.1 Motivation for social enterprises to co-create innovations for social purposes

To understand the motivation of a social enterprise to co-create and contribute to the rural water supply, a review of the theoretical framework by Ge *et al*. (2019) was done. A theoretical framework of how VCc affects the growth of social enterprises moderated by environmental dynamics was done using quantitative empirical research of 172 social enterprises in China. The empirical findings by Ge *et al*. (2019) clearly show that VCc effectively improves enterprise performance thereby promoting growth. Thus, customer contribution in the VCc of enterprises can efficiently advance resource integration of enterprises to be able to contribute towards solving societal challenges. Ge *et al*. (2019) also established that environment dynamics negatively moderate the relationship between VCc and social enterprise growth.

The approach has been adopted without any revisions and successfully used by Li *et al*. (2020) in the Punjab Province of Pakistan which shows that the empirical findings are generalisable. The findings by Li *et al*. (2020) can be used by enterprises to modify their business models and elevate value co-creation as it has been shown to improve both enterprise performance and contribute to societal goals. The finding by Li *et al*. (2020) demonstrated that some environment dynamic conditions (social dynamics and government policies) can affect VCc and hinder prosperity in social enterprises. Thus, in the rural water supply research environment dynamic is taken into consideration as it can impede social enterprises from fully exploring VCc.

2.6.2.2 Motivation for For-profit enterprises to co-create innovations for social purposes

Hamidi and Gharneh (2016) gave a good theoretical framework to help understand how for-profit enterprises can participate in co-creation related to societal challenges. The link between VCc, innovation capability and firm performance was studied by analysing the top 500 Iranian enterprises (Hamidi and Gharneh, 2016). The same author views VCc from the Prahalad and Ramaswamy (2004) perspective, where VCc is grounded in market competition and strategic management discourse. It also assumes that co-creation occurs in the willingness and ability paradigm from both the customer and the firm. Under this prism, customers are involved in the VCc process to learn, enhance value and in return get personalised products/services. On the other hand, firms also understand their customer better which ultimately leads to improved market share and financial value from the interaction. Hamidi and Gharneh (2016) empirically established that VCc has a positive effect on enterprise performance. Thus, VCc has a positive effect on innovation capability in alignment with finding by Tijmes (2010). Thus, relating these findings to the rural water supply context, water intermediaries and other for-profit enterprises can co-creation products/services for mutual benefits with communities.

2.6.2.3 Motivation for the public sector to co-create innovations for social purposes

The key mandates of the public sector include but are not limited to the economic and social development of its citizens. To deliver this mandate, the public sector involves the citizens through the VCc in which the citizens are active actors in generating solutions that truly address their requirements (Voorberg *et al*., 2015). Through the '*top-down*' approach, the government can create an enabling environment that can foster collective interaction for many actors to solve some of the societal challenges such as rural water supply. In such situations, the actors become effective agents of change (Halmos *et al*., 2019). Also, it is known that communities are willing to participate in activities that benefit them (Moriarty *et al*., 2013). Voorberg *et al*. (2015) highlighted that VCc is the cornerstone for social innovation for which the public sector can deliver sustainable development to its citizens. In all social innovation that the public sector does with its citizens, VCc has proved successful (Oeij *et al*., 2018).

2.6.2.4 Motivation for universities and research entities to co-create innovations for social purposes

According to Powell and Snellman (2004), scientific knowledge is the backbone of most of the technological capabilities that drive growth in human development. It is also a social good that combines individual research efforts for the benefit of the entire society. Thus, knowledge creation capability is best understood as a social capability where a combination of expertise drives innovation and creates value for humanity (Mormina, 2019).

Universities and research entities are quasi-public agents whose responsibilities should not only be about producing graduates but should engage in social and civil support. These actors exhibit advanced science, engineering and technology, which can bring a positive contribution to the rural water supply discussion. Thus, instead of only focusing on research outputs, universities and research entities can interact and collaborate with rural communities and co-design and co-create solutions (Sara and Jones, 2018). Research outputs generated through collaboration with communities are more impactful and often in alignment with government imperatives for social development. Thus, universities and research entities engaging with communities improve knowledge dissemination leading to more inventions and innovations with strong science and technology backgrounds yet more focused on societal challenges affecting rural communities.

Through the science, technology, and innovation imperative, the government seeks to expand the research system so that it aligns with the country's needs and delivers the required impact to society.

2.7 RURAL WATER SUPPLY

In general, rural water supply involves the provision of water to marginalised communities outside a typical urban environment. Sources of water include but are not limited to rainwater, groundwater, desalinized water and spring/surface water. Of these water sources, groundwater is one of the most valuable sources of water due to its relatively low susceptibility to pollution and relative abundance as compared to surface water and other sources (Sakala *et al*., 2018). Groundwater is the most practicable choice for safe water supply in rural areas as a wide range of low-cost techniques for groundwater extraction are present. In instances where groundwater is not easily extractable to meet the demand, surface water sources are used. One major

challenge of utilising surface water for rural water supply is that the water is highly susceptible to pollution and requires advanced treatment for it to be useful without health or safety concerns. To reduce health and safety fears, water purification systems are installed to clean the water to the required safe drinking standard of that country.

A review of rural water supply in the South African context is important in the understanding of the pertinent issues where technological innovation driven by multi-agents can play a role.

2.7.1 Rural water supply in South Africa

In South Africa, rural water supply is guided by policies, technical, legal and institutional frameworks such as:

- National Constitution (Act 108 of 1996),
- Water Services Act (No. 108 of 1997),
- National Water Act (No. 36 of 1998),
- Municipal Structures Act (No. 117 of 1998),
- Water Services Authorities, and
- Water Users Authorities amongst others.

All the water legislations are linked to the National Constitution (Act 108 of 1996) in particular section 27(1)(b) which states that:

> "*Everyone has the right to have access to sufficient food and water*".

In section 27(2) it states that:

> "*Government to take reasonable legislative and other measures within its available resources, to achieve the progressive realisation of each of these rights*".

With this, all the policies and regulations are meant to give effect in ensuring that every South African has access to clean water. The study focuses on water quality issues, which affect rural areas more than urban areas in South Africa. As defined by Obilonu *et al*. (2013), water quality refers to the comparison of chemical, biological and physical

features of water to a set of standards. According to the Water Services Act (No 108 of 1997), in South Africa, the standard for water quality is the SANS 241: 2015.

Rapid growth in human population, climate change and expansion of economic activities such as agriculture and industry are modifying the hydrological cycle, thereby compromising water quality (Obilonu *et al*., 2013).

2.7.2 Water quality in South Africa

In South Africa, water that is used for domestic purposes whether purified or not should be provided according to the national standard for drinking water (SANS 241: 2015) (SABS, 2015).

In rural areas, the treatment of water is either scarce or does not exist, which leads to a continuous decrease in the quality of both ground and surface water over time. Waste from livestock grazing too close to water sources is very common in most rural areas in South Africa and if not well managed adds pollution to the water bodies (Verlicchi and Grillini, 2020). A literature review study by Verlicchi and Grillini (2020) on the quality of ground and surface water in Mozambique and South Africa revealed that untreated or partially treated effluents from houses, crop production, and livestock farming are released into water bodies causing pollution. They also highlighted that water quality in rural areas keeps decreasing with time as the release of pollution into the water bodies increases. Verlicchi and Grillini (2020), did a comparison of the water quality between urban and rural areas over time, and they found that water quality deterioration is more in rural areas than in urban areas.

If water quality is below the required standard, it can affect both the health of the individual drinking it and the crops that depend on that water supply (Bwapwa, 2018). This has a bearing on food and water security. The more polluted the water is the higher the purification costs to remove undesirable substances from it. Thus, the water quality challenge in South Africa highlights the need for a combination of technological and social innovation to contribute to a clean water supply.

2.7.3 Water purification technologies

Schutte (2006) summarised the history of water purification and linked it to present-day technologies. Various water purification exists ranging from simple traditional techniques and microfiltration to nanotechnologies. The traditional techniques mostly used in rural areas are; boiling, filtration, sedimentation, solar disinfection and

chemical disinfection (Chaurasia and Tiwari, 2016). A combination of the techniques is often used to increase the effectiveness of the purification.

Water purification technologies can be deployed through a centralised or decentralised system. The most common type of decentralised water purification technology is the point-of-use type.

Venkatesha *et al*. (2020) gave a review of point-of-use water purification technologies that can be used in rural areas. The technologies are classified into four classes namely thermal/light-based, physical removal, chemical treatment, and integrated. Point-of-use water purification refers to those systems used to purify water at or near the place of use. This is often applied to areas without a centralised water distribution network in rural areas. The choice of which technology to use is dependent on the requirement for the intended use and other factors to consider include: cost implication, maintenance requirements, purification performance, easy-to-use and handle, specific needs and circumstances of the prevailing context (Venkatesha *et al*., 2020).

The point-of-use water purification system is mainly used in areas without a centralised water distribution system, often in rural areas where water is drawn from rivers, rain harvesting, ponds and wells. Nowadays, these systems are being used in public utilities (schools, clinics, etc.) regardless of whether it is supplied by a municipality or metropolitan water distribution system. This is done as a precautionary measure to curb water-borne diseases (Venkatesha *et al*., 2020).

2.8 Point-of-use water technological innovations in South Africa

From a review of ten water technological innovations (VulAmaz, AmaDrum, Safe Water Africa, Wave Energy Reverse Osmosis pump, Aquatrip, Arumloo, Biosure Process, Vitasoft Process, Eutectic freeze crystallization, Alternative RO) in South Africa from the Water Research Commission (2018) report. Only three technologies (VulAmanz, AmaDrum and Safe Water Africa) are point-of-use types. Further analysis of the three technological innovations was done and the results are presented in Table 1. As the focus of the research is to gather an in-depth understanding of who and how various actors interact to deliver clean water involving water technological innovation to rural areas. This would require that the technological innovation has been installed and tested in a rural area, for which only VulAmanz and AmaDrum technological innovations fulfil. Studying these two technologies offers the opportunity to study how

the community interacts with the technology and to gather an understanding of what value the community gained from the co-creation process.

Table 1: Selection of technological innovations based on deployment in rural areas

Technological Innovation	**Rural areas where technology was piloted**
VulAmanz	The technological innovation has been deployed in two communities in Capricorn and Mbizana Municipalities. Of these two municipalities, over 300 VulAmanz drums have been deployed in the Malatane community in the Capricorn district municipality (Vulamanz, 2022).
AmaDrum	The technological innovation has been deployed in two communities: • The Amathole District Municipality in the Eastern Cape and • Thambonkulu Community in the Nkomazi Local Municipality in the Mpumalanga Provinces. Of these two municipalities, over 350 AmaDrum were deployed at the Thambonkulu community in Mpumalanga Province (Zulu *et al*., 2015).
Safe Water Africa	No rural application for the technological innovation as it is still being prototyped at Klip River in Gauteng Province (SafeWater Africa, 2022).

2.9 CONCEPTUAL FRAMEWORK

Studying how agents interact to deliver clean water to rural areas would require a conceptual framework. Kumari *et al*. (2020) came up with a framework that outlines the process of co-creation as applied to social innovation (Figure 3). In this framework the interaction between the community and other actors occurs throughout the engagement process (Kumari *et al*., 2019) as follows:

- Prepare: Identify the societal needs, demands and challenges. In this stage, the core team is built and capacity is developed.
- Co-define: Involves mapping the stakeholders and identifying the capabilities and resources. In this stage, the challenge is collectively defined and use is made of a collaborative and open approach to understand the challenge better.

- Co-create: Involves resource integration activities leading to knowledge diffusion and mutual learning amongst the actors.
- Implement: Involves actors cooperatively using and exploiting resources and knowledge to create new solutions and to try them in practice.

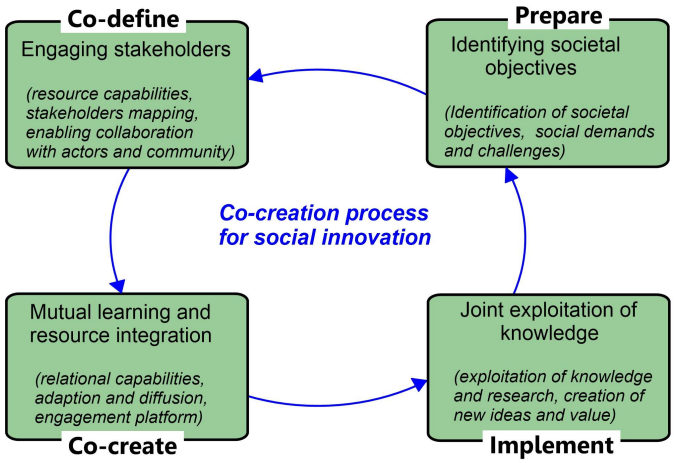

Figure 3: Value co-creation framework in social innovation (Similar to Kumari *et al*., 2019)

Other authors (Voorberg *et al*., 2015; Yang and Sung, 2016) defined social innovation as the method of VCc for the long term. Since the resources for social innovation are often very limited, co-creation becomes indispensable. Typically, in VCc, actors hinge on each other's resources for existence and since one actor cannot have all the resources, this interdependence is the one that drives exchange and resource integration (Yang and Sung, 2016).

Thus, VCc is key for the growth of social innovation as it permits actors to integrate resources and knowledge for the benefit of society in the long term (Kumari *et al*., 2019). A conceptual framework that relates technological innovation acceptance and adoption in rural areas through multi-agent value co-creation is shown in Figure 4. The framework is a combination of Kumari *et al*. (2020) framework for co-creation in a social innovation context, the innovation diffusion theory and the technology acceptance model in the rural water supply.

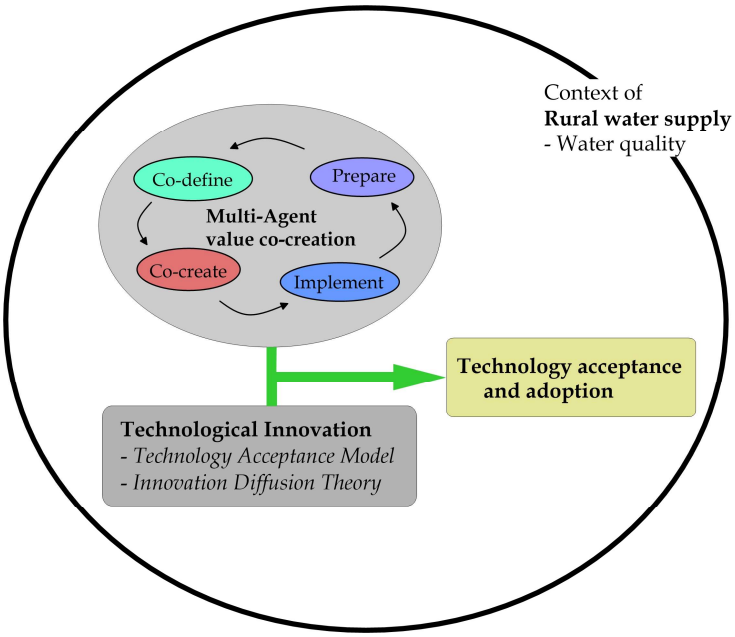

Figure 4: Conceptual framework relating multi-agent value co-creation, and technological innovation in the rural water supply (Source: Author)

Using the context, problems and literature review, the following are the research questions:

- Who are the key actors necessary for the deployment of water technological innovation in rural areas?
- What motivates actors to participate in co-creating value in the rural water supply?
- How do the actors interact in co-creating value in innovation for social purposes such as water supply in rural areas?
- What are the main factors that influence water technological innovation acceptance and adoption in rural areas?

2.10 STATEMENT OF PROPOSITIONS

The literature review suggested that actor interaction involves four processes namely preparation, co-defining, co-creation and implementation can be used to study multi-agent value co-creation in response to societal challenges. Also, knowing who the actors are, and understanding their motivations combined with mapping factors

influencing technology acceptance and adoption are instrumental to the application of technological innovation meant to address societal challenges in rural areas.

The following is the research proposition in response to the research questions as informed by the literature review conducted:

- Co-creation involving many agents and rural communities improves technology acceptance and adoption meant to address societal challenges in rural areas.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

In the previous chapter, a review of literature on technological innovation and value co-creation was done. This chapter seeks to present the research strategy and methodology by considering the research problem and the theoretical and conceptual frameworks. This chapter will follow the following logical order:

- the research strategy,
- research methodology (participants selection, process of data gathering and analysis),
- the methodology limitations,
- ethical deliberations, and
- reliability and validity considerations.

3.2 RESEARCH STRATEGY AND DESIGN

Research is the procedure involving gathering, analysing and interpreting data to understand a particular phenomenon (Williams, 2007). The same author mentions that the research process should be systematic in defining clearly the research objective, handling of data, processing, interpretation and communication of the findings within recognised frameworks and in agreement with existing guidelines. In research methods, the three approaches to conducting research are qualitative, quantitative, and mixed. A qualitative approach is adopted as the study seeks to examine in-depth the relationships among many actors in developing technological innovation in the water supply sector within the rural context (Amaratunga *et al*., 2002).

In research design, three approaches (explanatory, exploratory and descriptive) can be used (Robson, 2002). In this qualitative research, an exploratory inductive approach was adopted which involves studying rural water supplies in South Africa by looking at the contemporary descriptions of the current situation (Eisenhardt and Graebner, 2007).

As the study aims to understand the in-depth interaction of multi-agents in a rural setting with the potential to enrich the empirical description and the development of literature on this phenomenon in South Africa. The multiple case study approach was selected due to the lack of theoretical support and the context-bound nature of multi-agent VCc (Eisenhardt and Graebner, 2007) in a South African rural context. This approach would allow the generalisation of findings according to Eisenhardt and Graebner (2007). The case study approach helps to answer the '*how*' and '*why*' questions related to multi-agent co-creation and technology transfer in the rural context.

According to Yin (2003), the case study design is used if:

- the research aims to establish the '*why*' and '*how*' questions;
- the researcher cannot control the behaviour of answers of the participants in the research;
- the researcher wants to understand the contextual conditions if perceived as important to the phenomenon being researched; or
- the boundaries are not distinguished between the context and phenomenon.

The research seeks to understand '*how*' people in the rural area are interacting with technological innovations and why actors interact and how actors (for-profit and social) can interact through co-creation to deliver water to rural communities. The research calls for an in-depth contextual understanding of the prevailing conditions of how technological innovation is being accepted in rural areas in South Africa. Thus, the research satisfies two of Yin's (2003) instances, which justifies the use of the multiple-case study approach. This would also allow a more complete understanding of the rural water supply in its actual context and generates information that cannot be acquired otherwise (MacNealy, 1997). Using the Merriam approach (Merriam, 1998), case studies are carefully selected and then people are purposefully selected based on their uniqueness, convenience and applicability to the phenomenon under investigation.

A similar study was conducted looking at innovation for social purposes through the VCc lens in rural villages of India (Cornet and Barpanda, 2021). Živojinović *et al*. (2019) researched Serbia to understand the parameters that hinder or promote social

innovations in rural areas whilst at the same time identifying related institutional voids. Both researchers used semi-structural interviews and document analysis.

Lee (2003) and Vogelsang *et al*. (2013) did an extensive study on the TAM approach in acceptance research. Lee (2003) found that over 90% of publications were quantitative and use questionnaires as a data collection technique. Vogelsang *et al*. (2013) extended Lee's (2003) research and found similar findings that major publications in acceptance research are quantitative and few are qualitative. According to Vogelsang *et al*. (2013), TAM in the quantitative approach is a proven and widely accepted approach when interpretation is mainly based on statistical methods. However, the TAM in the quantitative approach, lacks descriptive power and often fails to be used in in-depth content analysis of why technological innovation is accepted or not (Vogelsang *et al*., 2013). The same authors proposed that the qualitative approach offers another lens which can solve this shortcoming associated with analysing TAM from a quantitative perspective. They also gave evidence to show that acceptance research in a qualitative approach can be used for theory building to identify constructs which can be tested quantitatively. Thus, in this study, the qualitative approach was selected to understand how humans interact with water purification technological innovation in a rural setting.

3.3 RESEARCH METHODOLOGY

The development of the research methodology which includes the selection of participants, data collection approach and data analysis are described in this section.

3.3.1 Selection of participants

The value network actor map (Figure 5) was developed to help select possible actors for interviews. The map helps to visualise how actors are related and how they interact and exchange knowledge in the value creation process (Pinho *et al*., 2014). The diagram (Figure 5) shows the initial conceptual actors groups used in this study.

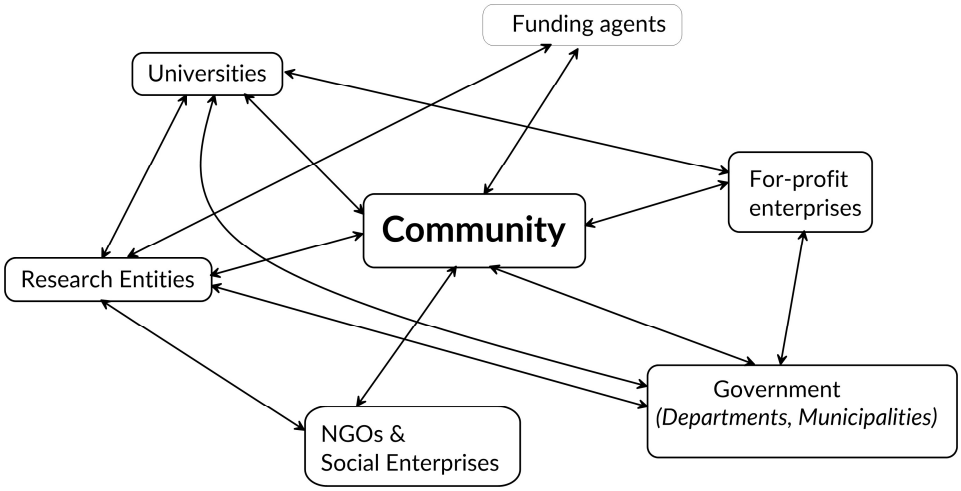

Figure 5: Value network actor map showing possible actors in a rural water supply (Source: Author)

The actors are grouped according to their possible roles as shown in Table 2.

Table 2: Roles of each actor group

Actor	**Role**
Community	Operation and to do light maintenance of infrastructure and resource management.
Funding agent	Provide funding and financial knowledge for projects (new or upgrades).
Universities	Prototyping of low-cost solutions, research and training.
Research Entities	Social and scientific research (basic, applied and advanced) for water supply.
Social Enterprises and NGOs	Funding, Social and technical support.
For-profit enterprises	Water borehole drilling, infrastructure development, services.
Government	Research management, policies, funding, regulatory.

3.3.2 Data collection and instrument

For each of the two cases (VulAmanz and AmaDrum), primary data collection was done using semi-structured qualitative interviews to avoid constraining interviewee responses (De Silva *et al*., 2020). In response to the objectives, interviews with representatives of all the actors' categories in the multi-agent interaction were done.

For the community actors, a physical (face-to-face) interview of 19 people was done. An actual community visit proved to be very critical in understanding the general way of life of the community members which has a bearing on how they respond to technological innovations. Information about the communities which would contribute to addressing the research questions was also gathered during the community visit by the author. Also, the community members were very keen to participate in the study as they deem water as a very vital topic in their lives. Trying to do the interviews on a virtual platform for rural communities would not have been comparable to the face-to-face benefits alluded to earlier.

Other actors outside the communities, were interviewed to get their perspectives regarding actor interaction and technological innovation acceptance and adoption. Virtual interviews for actors outside the communities proved to be the best approach as interviews were scheduled whenever an opening time slot occurs regardless of time or day. Only one of the actors was interviewed at his workplace. Of the 16 participants approached, 12 agreed to be interviewed and all said that the topic chosen is one of the most critical issues that the country is dealing with and another participant said that the problem of water quality issues in the water supply is crippling even to bigger metropolitans in South Africa.

The operationalisation of the research constructs to interview questions is shown in Appendix A. Each interview lasted between 30 and 60 minutes. Interviews were conducted until the point of saturation when the responses from the participants were the same and no new information could be obtained. For interviews done in rural areas, a language translator who understands the Sipedi and Swati was used in Malatane and Thambonkulu communities respectively. On completion of the interviews, the recorded audio files were transcribed (Figure 6), reviewed and revised by the interviewer to increase the research accuracy (Huber and Power, 1985). The transcribed text file was used to manually extract the themes according to the research questions.

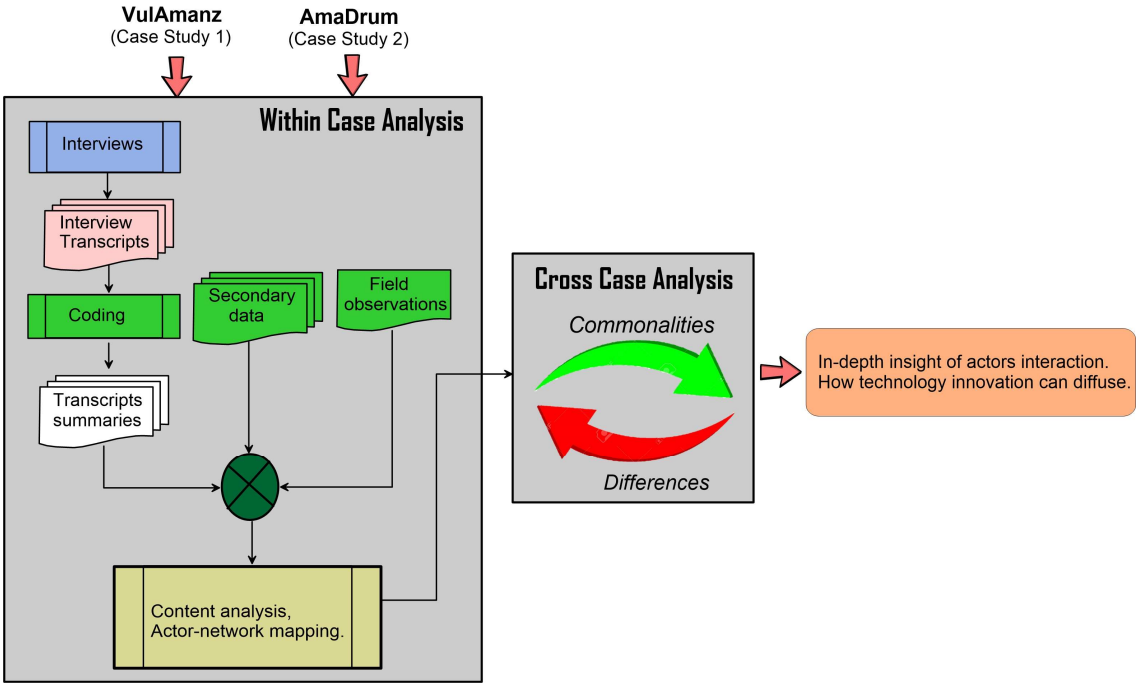

Figure 6: Summary of the steps used for data gathering and analysis in this study (Source: Author)

Data collected from secondary sources such as websites, reports, published articles and newspapers were used to provide additional information about the selected case studies. Using data collected from both primary and secondary sources enabled an in-depth understanding of the two case studies which improved the validity and reliability of the results (De Silva *et al*., 2020).

3.3.3 Data analysis

Standard approaches for qualitative data analysis as illustrated by Eisenhardt and Graebner (2007) were used. For each of the cases, content analysis and actor-network mapping were done to extract a detailed understanding of who and how multi-agents interact within each of the cases.

3.3.3.1 Content analysis

Qualitative content analysis is used to analyse data and interpret its meaning systematically and objectively in describing and quantifying a phenomenon (Elo *et al*., 2014). In this study, the inductive approach was used whereby information from interviews was coded, categories created and abstraction was done to extract the meaning of the information.

3.3.3.2 Actor-network mapping

Actor-network mapping is based on the Actor-Network Theory which provides an explanatory framework approach for understanding how actors in a network communicate to align actor interests around the development of an artefact, as in this case, rural water supply (Cater-steel and Mcbride, 2006).

For actor-network mapping, the following was considered (ENVS Resources, 2021):

- The key actors were identified for each of the case studies.
- The processes that connect these actors are briefly specified.
- Differentiate actors/processes through differentiation and code as per more/less-powerful actors, and more/less-significant processes, in the actor-network.

3.3.3.3 Within-case and Cross-case analysis

Interviews are rich in contextual details and person-specific information without which it is difficult to understand a case (Ayres *et al*., 2003). The same author also mentions that within-case analyses are not very useful in the development of generalisation alone but are useful to gather in-depth information regarding complexities within the case. Hence, multi-case is used to improve the generalisability of findings.

The unit of analysis refers to the level at which data is considered one data point during data analysis (Silverman and Solmon, 1998). In this study, the unit of analysis is an individual actor in the multi-agent group of actors. In cross-case analysis, each case study was considered as a unit of analysis.

The cross-case comparative analysis technique (Eisenhardt and Graebner, 2007) was used to understand the features of VCc in the two case studies. During the data analysis process, key themes were coded and compared with existing literature. During the data analysis process, a constant engagement with existing literature was done to establish a theoretical connection (De Silva *et al*., 2020).

3.4 LIMITATIONS OF THE STUDY METHODOLOGY

The limitations of the case study approach for this study include:

- As the study is qualitative with only two case studies, it lacks the statistical findings needed to generate empirical findings.
- A small number of experts were selected from all actor groups as a way to get diverse views about the subject. The sample size used is far too small to be generalizable to the entire rural water supply expert population.
- The community participants for interviews were purposefully selected without any randomisation, which adds some bias to the study (Stake, 2008). However, this is typical of case study approaches where limited participants exist as observed in this study.

3.5 ETHICAL CONSIDERATIONS

Ethics are standards or norms of behaviour that guide how humans interact with each other (Cooper and Schindler, 2014). The study was done ethically by first seeking clearance from the University of Witwatersrand ethical committee and then research conducted according to the laid out ethical codes and regulations. The main reason ethical consideration is done in the study is to ensure that no one is adversely affected by the research activities according to Cooper and Schindler (2014). Cooper and Schindler (2014) mention that research must be designed in a way that all participants in the study do not feel discomfort, suffer any physical harm, feel pain, lose their privacy or feel embarrassed. To defend against these, the researcher followed the guidelines as outlined by Cooper and Schindler (2014), which give the participants an explanation of the benefits of the study, explain participant rights and their protections, and finally, obtain informed consent.

A communication highlighting the purpose of the study and requesting consent from participants to be interviewed was done either through an email or verbally (Appendix B). The communication emphasizes that interviews are voluntary and that data will be secured and not be discoursed outside its intended purpose for this study.

3.6 RELIABILITY AND VALIDITY

Qualitative research must be valid, dependable, reliable, transferable, credible and confirmable. The definitions of these terms can be found in Creswell (2014).

Data was collected in a real-world environment (rural areas) using a well-established research approach and methods, where the actual water situation was gathered. Also, from the community visits, the benefits and value of technological innovation were realised first-hand which contributed to improving the validity and credibility of the findings. The methodology used in the study can easily be reproduced by following the research instrument. In the study, an identical methodology of gathering information was done in the two communities which shows the reproducibility and reliability of the methodology.

Interviews were conducted until the point of saturation was reached where no more new information was obtained as a way to improve the dependability of findings. This led to a total of 31 interviews conducted from which insights from multiple perspectives on the co-creation of technological innovation were derived. The research method used was systematic from data collection, analysis, and interpretation to deduction of insights. Thus, the research was conformable. Expert opinions were used to improve the validity of the findings from the two case studies.

As value co-creation is a complex construct that is specific to the context and often actor-centric (Rubio *et al*., 2020). The study seeks to gather an understanding of the value co-creation concept that applies to rural areas in South Africa. In the study, only two case studies were used, thus, the research findings are not intended to be transferable but the conceptual framework can be tested in other areas or fields of study.

CHAPTER 4: RESEARCH FINDINGS

4.1 OVERVIEW

In the previous chapter, the research strategy and methodology were discussed. This chapter gives details of the results of the in-case analysis of VulAmanz and AmaDrum technological innovations as deployed in Malatane and Thambonkulu communities in South Africa. In the content analysis, the actors required for the deployment of technological innovation were mapped and actor-network maps were produced. The actor interaction process was also identified including their motivation to partake in innovations for social purposes. Factors affecting technological acceptance and adoption were also identified. Results from experts interviewed are also presented as another lens to improve the understanding of water quality issues in the broader South African context.

4.1.1 Participants profile details

In this section, a description of the participants who were interviewed is provided. In total, 31 interviews were conducted with community members, researchers, community leaders, municipality officers and experts in rural water supply in South Africa. In all the interviews, consent was first sought from all the participants according to the ethical statement highlighted in Chapter 3. An interview guide in Appendix A was prepared before the participants' interviews.

4.1.1.1 Community Participants

The author visited the two communities where water purification technological innovations have been installed. More details about the selection of the communities and the technological innovation can be found in chapter two. Interviews were conducted physically (face-to-face) mostly at the interviewee's homes and some were conducted at the local tribal authority community hall. In each of the two communities, participants were selected based on the following criteria:

- participant must have used the technological innovation,
- participant must be willing to be interviewed,
- participant must be available for the interview during the community visit period,

- participant must be from the case study community, and
- participant must be over 18 years of age.

A total of 19 participants were interviewed in the two communities as shown in Table 3. Most of the participants interviewed in the two communities were female as they are mostly involved with managing water activities in rural households mainly for domestic uses (cooking, provision of drinking water, washing, etc.). Also, most of the female participants were available and willing to participate in the interviews during the community visit by the author. Participants from the technology researcher actor group attest that most of the participants in the project were women with men's involvement being to a limited extent. The following statement was said by one of the technology research actors:

> "*You know that our water managers in the home are women. Therefore, we had more women interact with our technology, but the interest in it was so much that even the men in that community came to our meetings. When we visited their homes, they also came to see, so we've got a fair number of men showing an interest in participating in the project".*

Table 3: Number and gender of participants interviewed in the two communities

Local Municipality/Community	**Gender representation**		**Total participants**
	Male	**Female**	
Nkomazi Municipality - Thambonkulu	1	8	9
Lepelle-Nkumpi Municipality - Malatane	2	8	10
Total community participants			**19**

4.1.1.2 Other actor interviews

The research involves an understanding of how various actors interact to deliver good quality water to rural areas. Thus, apart from the community actor group, five other actor groups which include researchers, government, civil society, universities and consultants were interviewed to gather their perspectives. For these actor groups, the interviews were conducted over the Zoom virtual platform. A total of 12 participants from these actor groups were interviewed using the semi-interview approach.

The criteria used in the selection of the participants were such that the:

- participant must have worked (or is an expert) in rural water supply in South Africa,
- participant must have knowledge (published papers) or have been exposed to water quality technologies as related to their actor group in South Africa, and
- participant must have worked in the case studies or similar cases in South Africa.

Table 4 shows the number and gender of participants from various actor groups excluding the community actor group.

Table 4: Distribution of participants in the various actor groups and their gender details

Actor Group	**Gender representation**		**Total participants**
	Male	**Female**	
Researchers	3	1	3 (Includes two from case studies)
Government including municipalities	2	1	3 (Includes two from case studies)
Civil society	0	2	2
Universities	1	1	2
Consultants	2	0	2
Total participants			**12**

Combining Table 3 and Table 4, a graphic representation of the demographics of the participants is presented in Figure 7. The distribution of participants is skewed more towards community participants. The reason is that the focus of the study is on understanding how people in rural areas are interacting with technological innovations and how they are co-creating solutions with other actors and the value that is brought about by such an association.

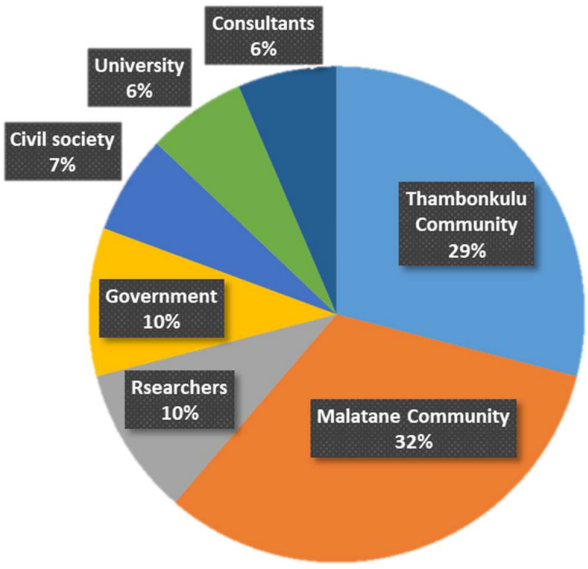

Figure 7: Demographic representative of the interviewed participant (Source: Author)

4.2 AMADRUM TECHNOLOGICAL INNOVATION CASE STUDY RESULTS

This section presents results extracted from responses from the participants in the AmaDrum case study about the water supply situation, actor mapping, actor motivation, interaction processes and technological innovation (acceptance and adoption).

4.2.1 AmaDrum technological innovation

The AmaDrum technological innovation is a South African product developed by Council for Scientific and Industrial Research (CSIR). The technological innovation was designed for unserved or underserved rural communities, looking specifically at water purification and safe storage at the household level. The technological innovation gained global prominence for its potential to solve water quality issues and associated health challenges and as a low-cost solution in African rural communities (Zulu *et al*., 2015).

The AmaDrum technological innovation is based on the chemical purification technique that combines flocculation/coagulation and disinfection. This household water treatment and storage technological innovation consist of chlorine disinfection, flocculation, sand filter and water storage. According to Zulu *et al*. (2015), water can be treated to potable drinking water standards. Water to be treated is loaded on the top, where it mixes with a chlorine-based coagulant through manual stirring until flocculants forms at the base of the top compartment (Figure 8). The water drains

slowly to the bottom via a sand filter through a suction mechanism. After passing the sand filter, the water is safely stored in the bottom storage compartment where it can be accessed via a small tap. The float is used to control the level of water in the storage compartment.

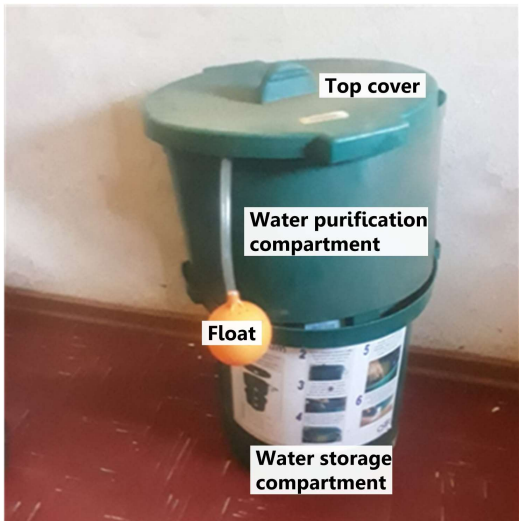

Figure 8: AmaDrum technological innovation at the Thambonkulu tribal authority hall showing the various components (Source: Author)

This technological innovation has been installed in the Thambonkulu Community which is under Mlambo Tribal authority, one of the 43 communities in the Nkomazi Local Municipality in Mpumalanga Province, South Africa. It is located about 80 km from Mbombela, the provincial capital of the Mpumalanga Province, a few kilometres from the border between Mozambique and the Kingdom of Eswatini near the World heritage site, named after the former Mozambique president, Samora Machel. The current chief of the area is Inkosi Mandla Mlambo II and the villagers mainly speak the Swati language. The language is the main spoken language in the neighbouring kingdom of Eswatini.

According to Nkuna and Ngorima (2011), approximately 3 000 people live in the Thambonkhulu community with a family size of ~ seven people per household. The same authors describe the community as an isolated and highly populated rural area characterised by a lack of basic services (clean water, clinic, etc.) and high levels of poverty. Research done by Nkuna and Ngorima (2011) revealed that community members used to collect water from unprotected well, also used by livestock. The water was consumed without any prior treatment, which led to several cholera cases in the community.

4.2.2 The water supply situation in the Thambonkulu community

The Nkomazi local municipality is mandated to supply water to all of its 43 communities including the Thambonkulu community. Rainfall is highly seasoned around the Thambonkulu community making it one of the driest regions. According to information obtained during the community visit, the community receives water from the municipality but the water supply is very erratic and rationed sometimes going for weeks without water supply. Those community members who can afford drilled boreholes to augment the water supply. When water is not available from the taps, the community gets water from the river. To illustrate the water supply challenges in the Thambonkulu community, one of the community members interviewed said:

> "*We have a problem of water not coming out of the taps which result in us going back to the river to fetch water.*"

The community uses water for domestic purposes sometimes without any form of purification, which raises issues of water quality and its associated health problems. The following are the concerns raised regarding water from the river:

> *"Domesticated animals (cattle, donkeys and goats) drink from the same water sources we drink"*
>
> *"The water point is very far from the village ~ 2 to 3 km"*
>
> *"At the river, we take turns to fetch water as the supply is slow to replenish and the river occasionally dries up"*

The following statement was uttered by one of the participants during an interview:

> "*The water fetched from the river is not safe for drinking but is the only available source and we share the same source with livestock.*"

4.2.3 Multi-agent value co-creation

To understand the interactions in the multi-agent value co-creation, first, the actors were mapped.

4.2.3.1 Actor mapping and interactions

Various participants were asked to name the various actors which are required to successfully deploy AmaDrum technological innovation in the Thambonkulu

community. Responses from the participants show that the actors include the local and district municipality; political leaders, the department of science, technology and innovation; private companies; tribal leaders and the community. Their roles are summarised in Table 5.

In response to actor mapping questions, one participant indicated that their engagement with the municipality was difficult. The following statement from one of the actors clearly illustrates this sentiment.

> "*The municipalities are a very complex stakeholder in the sense that they wanted to give people clean water, but they don't consider it done if they have not delivered tapped water.*"

As the actors and their roles have been identified, their interaction plays a role in understanding the implementation of solutions meant to solve water quality challenges in rural areas. From the participant's responses to questions about the actor interactions, an actor-network map for the Thambonkulu community was generated (Figure 9). This map shows the existence of various linkages levels (strong and weak) between the actors. The strength of connections was based on the comments by participants of words such as strong, critical, key, important, etc., to symbolise the relative strength of the relationship. Stronger reciprocal linkages were identified between the technology researcher and tribal leaders; tribal leaders and the community, and also between technology researchers and the community. The other connections were deemed weaker as the participants did not emphasise their strengths.

Table 5: Actors and roles in the AmaDrum technological innovation at the Thambonkulu community

Actor	**Actor roles in the AmaDrum case study**
Municipality (Local and District)	Mandated to provide water to the communities. They also assist in the diffusion of water-related technological innovation to the Thambonkulu community through the councillor.
Political Leaders	The political leader is mainly the local councillor who is part of the local municipality.
Department of Science, Technology and Innovation	Provide the funding for the development of the AmaDrum technological innovation.
Technology researcher - CSIR	Fulfil their mandate and core value “To conduct cutting-edge research and technological innovation to improve the quality of life of South Africans”. Lead training on how to use technological innovation.
Private company - Suppliers	Supply the drums to the CSIR which are used in the development of the AmaDrum technological innovation.
Tribal leaders	Responsible for mobilising everyone in the community and facilitating the technology transfer from the developer of the technological innovation to the community. They also mobilise the community to use the technological innovation.
Community	Consumer of clean water produced by technological innovation. The community took part in the pilot testing of the technological innovation in real-world conditions. One participant mentioned that the community was so desperate for clean water at the time the technological innovation was piloted in their community.

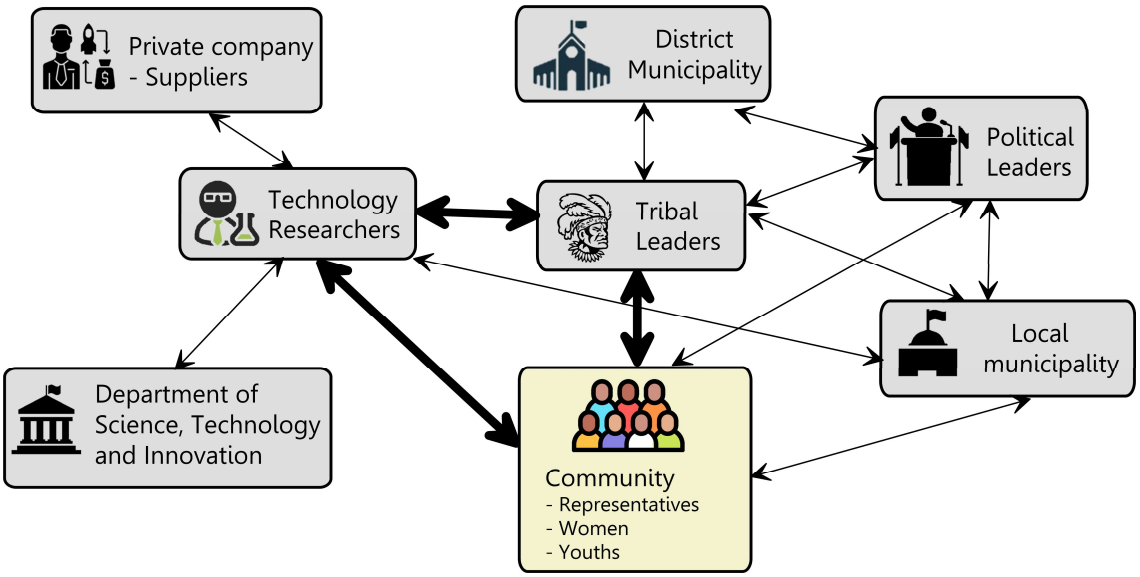

Figure 9: Actor-network map for AmaDrum technological innovation in the Thambonkulu community. The thick lines represent a stronger linkage and the thin line represent a weaker linkage (Source: Author)

By counting the number of connections (linkages) from the actor-network map, a graph (Figure 10) for the number of connections per actor group was produced. This information is critical to understanding which actors have more connections with implications to the delicacy of their influence on the water quality issues related to the rural water supply. The graph clearly shows that the local municipality, technology researchers and tribal leaders have the largest number of connections with other actors and the DSTI the least.

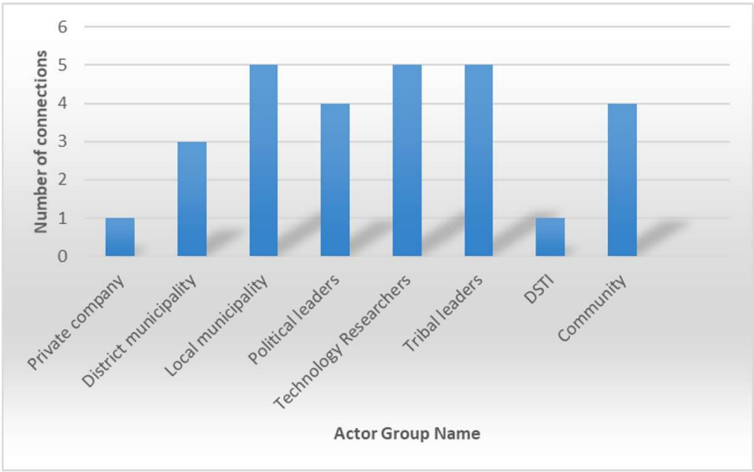

Figure 10: Number of connections per actor group graph for AmaDrum technological innovation in the Thambonkulu community (Source: Author)

As the strength in the connection between the technology researchers and tribal leaders was deemed to be stronger and both actors interact with many other actor groups. This makes this connection one of the most critical linkages to which technological innovation was deployed in the AmaDrum case study.

4.2.3.2 Actor motivation identification

Eleven participants were asked to give the motivation for actors to partake in co-creation in rural water supply, specifically looking at the Thambonkulu community where AmaDrum technological innovation was deployed. Figure 11 shows a summary of the motivations based on the responses from the participants. Broadly, the motivations can be grouped into three themes mainly target-driven, financial and social. These can be further grouped into various subgroups as outlined in Figure 11.

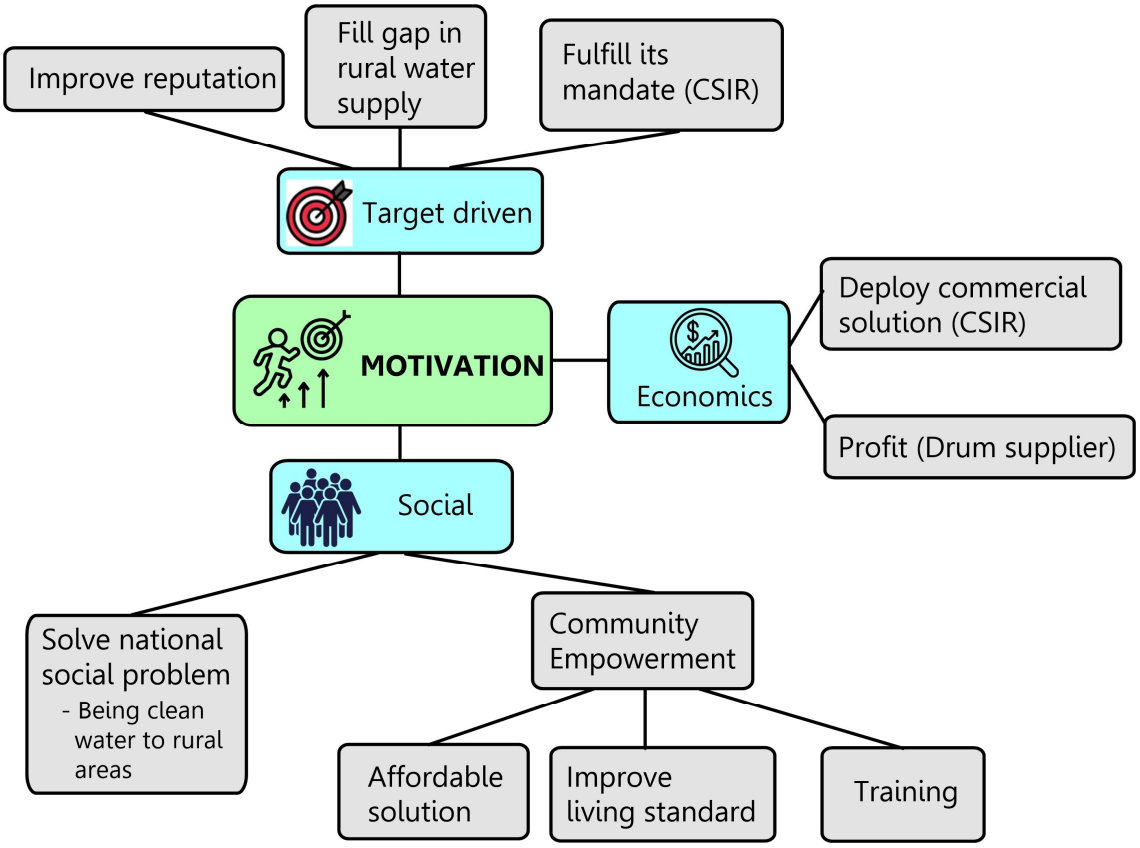

Figure 11: Motivation summary of the response from various actors in the Thambonkulu community (Source: Author)

Target Driven

There are several reasons why various actors engage in value co-creation in the rural water supply. From the technology researchers, the biggest motivator was the target-driven factor, mainly to fulfil their mandate as a research institution under the Department of Science and Innovation. The target-driven motivation can be subdivided into three subgroups (improve organisational reputation, fill gaps in rural water supply and fulfil its mandate).

Fulfil its mandate - The technology research participants indicated that the developer of the technology (CSIR) wanted to fulfil its mandate of using science, technology and innovation to improve the lives of a citizen in South Africa.

Fill gaps in rural water supply - Correspondence from the technology researcher of the AmaDrum technological innovation indicated that the other motivator was to fill the gap in rural water through the provision of a technological innovation that can be used to purify water while waiting for tap water connections. To illustrate this sentiment one technology researcher stated:

> "*There is going to be maybe five or six steps before three or two people can try to open a tap in rural areas in the home because in a rural setup, unlike in an urban setup, getting a tap to every house will cost a lot. The engineering will cost you more. So it is going to be a while before we can have every household connected to tap-water service in the rural area*".

Another technology researcher confirms the sentiment of the other researcher, stating that:

> "*In the rural area, you find that one is here and your neighbours are about maybe 500 meters away. Unlike city life where your neighbours are 15 meters away. So in such places, it is virtually impossible to have a circulation system. In most of these cases, they do not have a proper circulation system. The municipality is not even planning that because it would be too expensive to have such systems. So, the best way to do it is to find a solution to bridge the gap between access and no access*".

Improve reputation - Another motivation under the target-driven group is the potential for actors to improve their organisational reputation, as said by one of the participants.

Economics Driver

The research also found out that financial benefit is a strong motive for some actors to participate, such as profit for the local manufacturer of the drums. The water purification chemicals developed by the CSIR will also find use in the AmaDrum technological innovation. Thus, from an economic perspective, the growth of the AmaDrum technological innovations translates to the growth of the usage of this purification chemical as part of the innovation.

Social Driver

Two subgroups can be coded from the social motivation which includes solving a national social problem and community empowerment.

Solve a national social problem - Various participants stated that their main motive in participation in this co-creation is more socially oriented. They aim to contribute to the solving of a critical national social problem by bringing clean water to rural areas.

Community Empowerment - Other motivators include empowering the community through training, bringing affordable water purification solutions and generally improving the living conditions for people in rural areas.

The motivation from the community side to partake in the utilisation of the technological innovation was chiefly in the value that such a technological innovation can bring to their everyday lives. According to four participants, the community had several cases of cholera before AmaDrum technological innovation was introduced. During training, the technological innovation was demonstrated to them and they instantly wanted to try it, as it had the potential to end the effects of drinking dirty water from the rivers. The following is a list of values that the AmaDrum technological innovation brought to the community:

- Before the technological innovation was introduced, the community was drinking unsafe water from the river. Cleaning the water improved the health condition as four of the participants indicated that the cholera cases dropped after the technological innovation was introduced in the community.

- The AmaDrum technological innovation comes with a storage of purified water. No pollution such as chicken droppings can get into the drinking water.

- One participant indicated that when her grandmother visits her, she only wanted to drink water from the AmaDrum system as she says the water from the tap is not clean.

- Previously, some used to boil the water before using it for drinking, and one of the participants says it was increasing their electricity bill. The same participant said she likes the AmaDrum technological innovation as it does not require any power source to operate which lowers her electricity bill.

- One of the participants indicated that the AmaDrum technological innovation changed their lives for the better, as now they understand the effects of poor water quality which they did not know before the technological innovation was introduced to them.

- Some of the participants indicated that they previously used to buy bottled drinking water which stopped when the AmaDrum technological innovation was introduced.

Thus, the study has indicated that the key motivators are social, financial and target-driven. Since the motivation can be mapped, the next step would be to understand the processes through which actors interact to co-create solutions to water quality challenges.

4.2.3.3 Actor interaction processes

From the responses of the participants in the AmaDrum case study, information regarding the co-creation process was extracted and coded into various associated themes. Five themes were identified, namely: laboratory to the real world, creating an enabling condition, elevating technological innovation as a solution, project transfer and post-pilot (Figure 12).

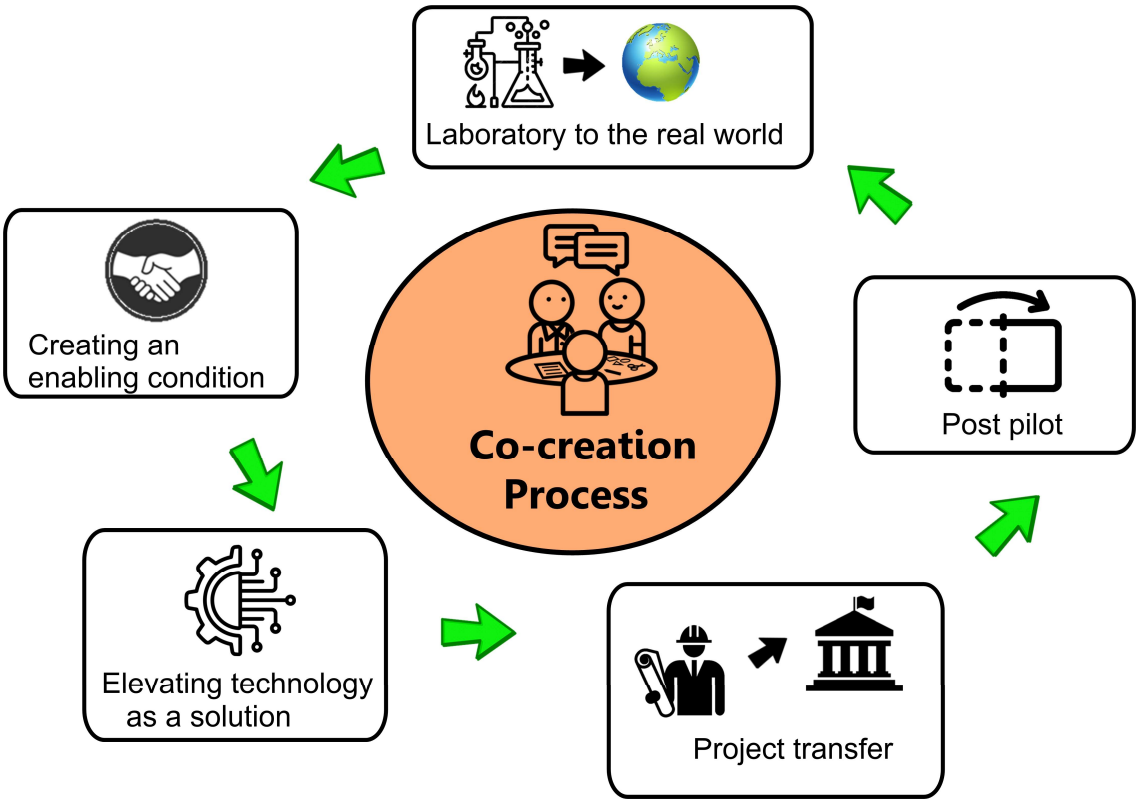

Figure 12: Value co-creation process in the Thambonkulu community case study (Source: Author)

Laboratory to the real world

The AmaDrum technological innovation was developed and tested under laboratory conditions and satisfactory results were obtained according to the technology researcher. Next, the technology researchers needed real-life conditions to test technological innovation. They selected a community with water quality challenges and where the organisation had existing relations.

The first trial was done using 30 households and later 350 units were deployed in the second phase of the project. One of the participants also extended the same sentiment by saying:

> "*They needed a community which could allow them to test the water purification technology under real-life conditions*".

According to one participant, the real-life trials done were an important step as feedback aided the improvement of the AmaDrum technological innovation.

In the Thambonkulu community, before the introduction of the AmaDrum technological innovation, people were fetching water from the nearby river where livestock were also drinking. Eight out of nine community members interviewed pointed out that the water situation was not bearable as people were often sick and cholera was prevailing in their community. Thus, any intervention to alleviate this situation was welcome by the community. This motivated the community to easily participate in the AmaDrum project.

Creating an enabling condition

From the interviews, the community was desperate for a solution to the water quality problem in the community. The technology researchers wanted to make a difference in the community. To do that, the researcher had to be part of the community to understand the situation as pointed out by one participant:

"*We become part of the community. This is not figuratively. We felt their pain*".

Consequently, the technology researchers created conditions under which it was easier to collaborate with the community. The community leadership on the other side wanted the project to succeed, hence they mobilised the community members to participate in the project and engaged them to speak out if they have concerns with technological innovation. Constant engagement between researchers and the community was done throughout the piloting stage.

Elevating technological innovation as a solution

In the rural water situation at the time, AmaDrum technological innovation was introduced to the Thambonkulu community, the technology researcher had improved the technological innovation after lessons learnt from its deployment in the Eastern Cape Province. However, they wanted a community to test the improved product. On the other hand, the Thambonkulu community with a population of over 3 000 people had a water quality challenge which required an urgent solution. Solving water quality issues such as cleaning water from a river using technological innovation that uses less or no electricity, would require some technological innovation which the CSIR had at that time. The community was open to solutions as alluded to by the community leader. Thus, CSIR offered a solution and the community benefited as a recipient of clean water including getting involved in the development of the technological innovation. The application of point-of-use technologies as a solution for water quality in the rural water supply offered an opportunity for technological innovation to diffuse

into rural areas. The CSIR also benefited from testing the product and getting feedback from the community using the product under real-world conditions, obtaining lessons which would be used in the improvement of the technological innovation. The introduction of AmaDrum technological innovation also benefited the community by introducing them to new knowledge on water quality.

Project transfer

In the Thambonkulu community, the technological innovation was implemented only for 350 people who were identified as critically in need of clean and safe water such as the terminally ill and the needy elderly. At the time of implementing the technological innovation in Thambonkulu, the water reticulation system was barely functional as community members were mostly getting water from the river. After successfully piloting the technological innovation, the project needed to be transferred to the municipality, the water service authority, but no one in the municipality was prepared to take over the project. One of the members of the technology researcher articulated that:

> *"I failed to get the local municipality to sign and take over the project because everyone was scared. It was not what was on their IDP. So all I have are records of emails and phone calls. Staff changing at the municipality, speaking to the new person, I told them I spoke to your predecessor, the other person even passed away. I spoke to the next one, but the municipality did not take over the project".*

Post Pilot

After the pilot project was completed, the CSIR continued to visit the community. One of the technology researchers said he still receives calls from the community seeking help to use the innovation. The community is still in need of the technological innovation as they say the municipality water is still rationed as they sometimes go weeks without water forcing them to get water from the river again. All the nine community members pointed out that they still need the technological innovation but the drum must be bigger than the current version.

Thus, the actors have been mapped, their motivations identified and processes by which their interaction have been established. Next, the understanding of the effect of technological innovation on social dynamics was done.

4.2.3.4 Dealing with norms, culture and traditional

According to the 11 participants interviewed in the AmaDrum case study, none indicated any effect of the technological innovation on their traditions, norms and culture. This could have been attributed to that the technological innovation is placed in the house and does not affect the water sources. A participant from the community said that:

> *"The technology only brought positive change, no effect to our water sources as it treats water at the house".*

The technology researcher pointed out that the technological innovation did not affect the traditions of the community as quoted below:

> *"The AmaDrum technology did not affect the traditions and culture of the community as we did not temper around with springs and sacred areas"*

To attest that the technological innovation did not affect the traditions of the community, one participant from the Thambonkulu community jokingly said:

> *"The technology brought so much joy to the community that even our ancestors are happy"*

The technological innovation was distributed to only 350 people in a community of over 3 000 people. Following the positive reviews by those that used them, it created tension with those that did not receive them, according to one of the community members interviewed.

4.2.4 Technology acceptance and adoption

From the AmaDrum case study, 110 statements were extracted regarding technology acceptance and adoption. The statements range from three words to paragraphs conveying the same idea. For the initial coding of the technology acceptance and adoption for the AmaDrum case study, theoretical factors (perceived usefulness, ease of use and user's intention to use) were used. For those that fell outside these theoretical codes, new codes were created. Table 6 shows the seven broad codes that can be identified from the responses to AmaDrum technological innovation deployed in the Thambonkulu community.

Table 6: Themes related to technology acceptance and adoption in the AmaDrum case study

Themes	**The number of times the theme is mentioned**
Perceived ease of use	12
Perceived usefulness	44
Intension of use	11
Training and awareness	19
Situational conditions	22
Technology features	8
Technology support	4
Total	**110**

Figure 13 shows the description of the technology acceptance and adoption parameters for the AmaDrum case study outlining the parameter connection towards use behaviour.

4.2.4.1 Perceived ease of use

The nine users interviewed in the Thambonkulu community could easily follow the steps issued on how to use the AmaDrum technological innovation. They all could recall that one needs to put two 20 litres of water in the top and add the purification chemical, stir the water and wait for ~30 minutes before drinking the water. They all understood that the sand inside is the one that removes the solid material and the chemical kills the germs which makes the water clean. They say that the researchers spend some time educating them on how to use the technological innovation. They all said that the technological innovation is very easy to use and maintain. The one barrier highlighted, was the fact that after the pilot, the chemicals were not readily available for them to continue using the technological innovation.

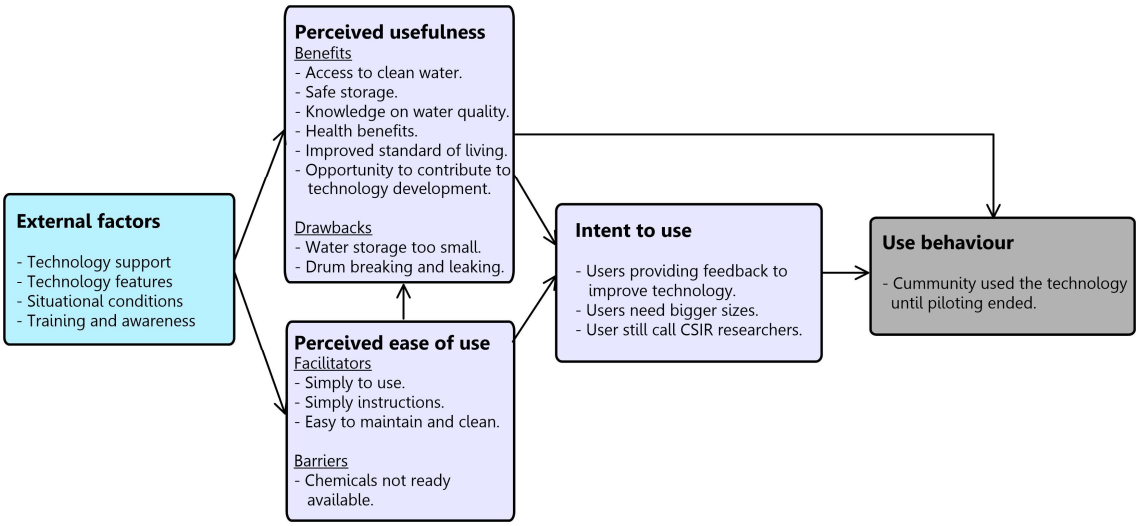

Figure 13: Descriptions of the technology acceptance and adoption for the AmaDrum case study (Source: Author)

4.2.4.2 Perceived usefulness

As mentioned in the community empowerment section of social motivation, the AmaDrum technological innovation brought more value to the community which included, health benefits, new knowledge on water resources, general improvement of the standard of living, and an opportunity to contribute to improving a technological innovation. This technology acceptance factor appears the most in the extracted text.

4.2.4.3 Training and awareness

The training given to the users of the technological innovation encouraged the community to use the technological innovation. The community was taught how to use the technological innovation and how to do general maintenance of the AmaDrum technological innovation. One participant said that the training helped them to understand the water quality effect and how to deal with it. Eight out of nine community members interviewed indicated that the training was sufficient and only one mentioned that she needs retraining. Awareness through a local radio also helped in the knowledge dissemination of the project.

4.2.4.4 Intension of use

To show the community's intention to use the technological innovation, 77% of the community members interviewed indicated that they still want the technological innovation to be re-introduced to the community. One community member indicated that a few weeks ago when the water was not available from the municipality tap, they

went to the river to fetch some water. All the community members interviewed said that the size of the drum needs to be increased and the chemicals and sand to be readily available to them.

4.2.4.5 Situational conditions

As stated in the water situation section, the water quality was not good before the innovation's introduction in the community, both from the river and municipality tap. Others were even buying bottled water or some resorted to boiling the water which both have a financial connotation for rural areas with a generally low-income level.

4.2.4.6 Technological innovation features

To understand technology acceptance and adoption it is critical to understand the technological innovation features in relationship with the community for which the solution is designed. Several questions regarding the technological innovation features which have a bearing on whether the community will use it or not were asked. Figure 14 shows the features gathered from the participants.

From the responses, the key features of the AmaDrum technological innovation can be grouped into four themes (speed, storage, simplicity and versatility). Thus, in summary, the technological innovation is fast at cleaning water, it promotes safe storage of water and is simple to use requiring less input from the users with simple instructions. They also indicated that the technological innovation works all year round.

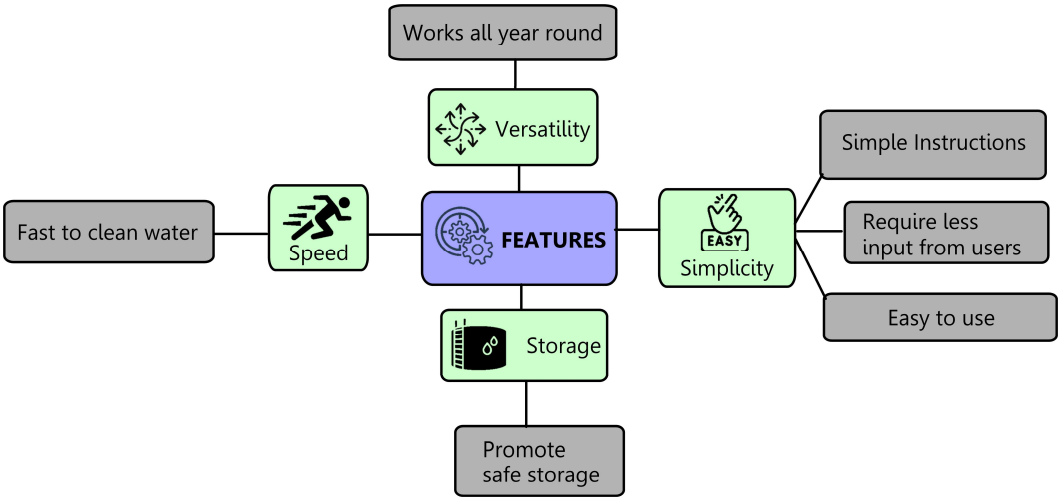

Figure 14: Features of the AmaDrum technological innovation as reflected in participant's responses linked to the Thambonkulu community case study (Source: Author)

4.2.4.7 Technological innovation support

The regular door-to-door visits by the technology researchers and the community representative were done as part of their technological innovation support. The community representative was actively involved in training and knowledge dissemination.

4.3 VULAMANZ TECHNOLOGICAL INNOVATION CASE STUDY RESULTS

Presented in this section are results extracted from responses from participants in the VulAmanz case study about water supply situation, actor mapping, interaction processes actor motivation and technological innovation (acceptance and adoption).

4.3.1 VulAmanz technological innovation

The VulAmanz technological innovation is also locally developed to address water quality challenges found in typical rural areas. The VulAmanz is an integrated water purification system which is based on the microfiltration membrane technique. It was developed by Prof Lingam Pillay and Mr Laurie Barwell from the University of Stellenbosch and Innovus Commercialisation projects respectively. The technological innovation uses a locally manufactured microfiltration material to filter pollution from the water. A disinfectant is also added to maintain the water quality during storage. The system is very portable and fits nicely inside the house (Figure 15) and does not use a form of electricity as its water is purified under gravity to produce ~ 25 L/hr of clean water (Water Research Commission, 2018).



Figure 15: VulAmamz technological innovation in the living room of one of the houses in the Malatane community (Source: Author)

Water to be treated is loaded on the top, where it mixes with a local disinfectant 'Jik' through manual stirring. The water drains slowly to the bottom via a microfiltration membrane. The water is safely stored in the bottom storage compartment where water can be drawn out using a small tap.

The technological innovation was installed in the Malatane community which has a population of ~ 2 000. Its falls under the Lepelle-Nkumpi local municipality in the Capricorn District of Limpopo Province, South Africa. The Capricorn district municipality is home to the provincial capital, Polokwane City and it lies at the centre of the Limpopo Province. The Malatane community is located ~ 80 km south of Polokwane. According to Statistics South Africa (2012), the Malatane community was founded by Seloane the first son of King Matlebjane II of Batau. The language spoken in the community is Sepedi. The climate of Malatane can be described as humid subtropical with hot and humid summers and mild to chilly winters (Mpandeli *et al*., 2019). The maximum rainfall is observed in summer and the minimum is in winter. The community receive their bulk pipeline water from Olifantspoort Dam.

According to the policy brief (Sinyolo *et al*., 2018), water quality is one of the major challenges that the Malatane community is facing. In a study conducted in the Malatane community, it was established that before the introduction of the point-of-use water purification technology, the community had access to untreated water from the Olifants River which is gravity fed into communal taps. This water was making them vulnerable to waterborne diseases such as cholera and they were unhappy with the water quality (Sinyolo *et al*., 2018).

4.3.2 The water supply situation in the Malatane community

According to the Water Services Act, the Capricorn district municipality is the water services authority which should ensure that everyone in the district has access to water services. The Lepelle-Nkumpi local municipality which is the second-largest municipality in the district is mandated to supply water to all its 30 wards including the Malatane community.

According to information obtained during the community visit, the community used to get water from the Olifants River and the children were always getting sick from drinking the water. Now that the municipality supplies water, six people interviewed indicated that the water is not very clean. To illustrate the water quality challenges in the Malatane community, the following was said by the community members:

"*The water from the tap is not clean, one has to open the tap for a while to clear it before drinking it*"

"The water situation of the water was very bad before VulAmanz technological innovation came to our community. The water was very dirty and salty"

"Our kids were getting sick with bilharzia from drinking water from the river. We devised a solution of boiling the water before drinking it"

These statements illustrate that the water quality issues are still prevailing in the Malatane community even though they have piped water. During the community visit, the author observed that all the interviewed participants are still using the VulAmanz technological innovation to even clean the water from the municipality tap.

4.3.3 Multi-agent value co-creation

To understand the interactions in the multi-agent value co-creation, first, the actors were mapped.

4.3.3.1 Actor mapping and interaction

Similarly, as in the AmaDrum case study, various participants in the Malatane community were asked to name the various actors in the deployment of the VulAmanz technological innovation in the Malatane community. From the responses, Table 7 shows that the actors identified include the district municipality; political leaders, water research commission, technology researcher (Stellenbosch University), tribal leaders and the community (including community representatives and high school students). The roles of the actors are also presented in Table 7.

From the participant's responses to questions about the actor interactions, an actor-network map for the Malatane community was generated (Figure 16). Strong reciprocal linkages were identified between the following: technology researcher to the community; district municipality to the community, and technology researcher to district municipality.

Table 7: Actors and their role in the VulAmanz technological innovation case study

Actor	Role
District Municipality	In Malatane, the district municipality acted as a water committee and interacted with the community on water-related issues.
Political Leaders (Councillor)	The Councillor acts as the interface between the community and the local municipality. This is the person who knows the area and knows who wants the services according to one participant from the municipality.
Water Research Commission	Provide the funding for the research.
Technology Researchers – Stellenbosch university	Brings the technical perspective, designs the solution and leads training on how to use the technological innovation.
Tribal leaders	Responsible for getting the community on board with the project.
Community	Consumer of clean water produced by technological innovation. The community took part in the initial development of the VulAmanz technological innovation.
Community representative	Attend to all the users and link them to the municipality and the VulAmanz company.
Local high school students	Their role was to do the field surveys as they know the area very well, train people and help users to solve simple problems of the technological innovation.

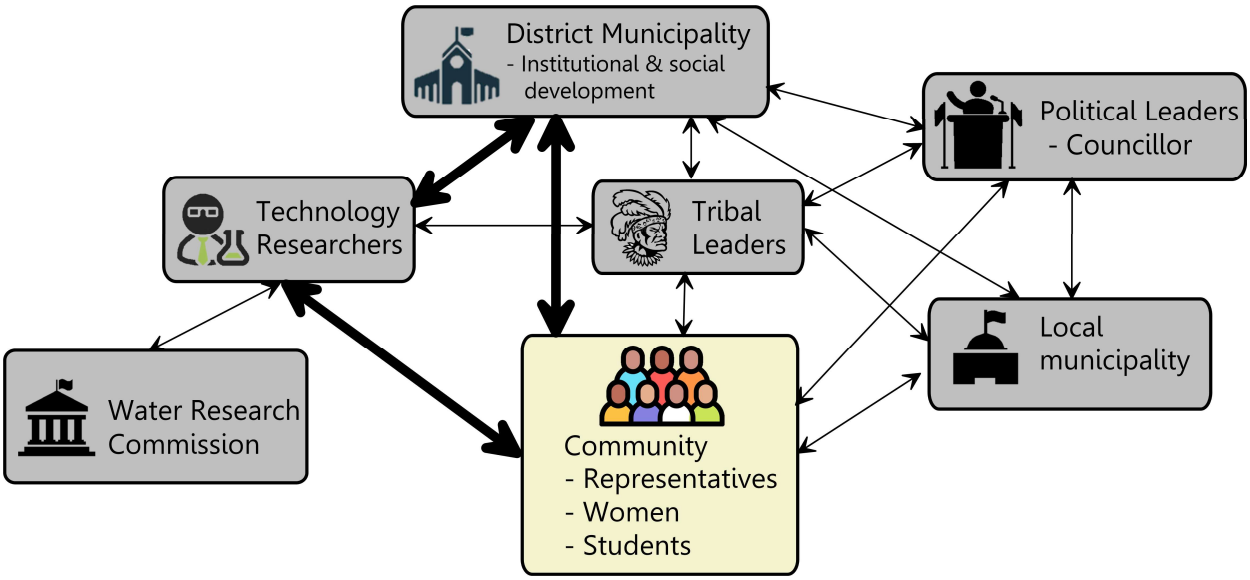

Figure 16: Actor-network map for VulAmanz technological innovation in the Malatane community (Source: Author)

The following are some key interactions as related by the participants in the VulAmanz technological innovation:

- The technology researcher involved the community from the initial phase of the development of the VulAmanz technological innovation. The inventor said:
    - "*Actually went to a village that one of my students came from and we spoke to the traditional leaders and spoke to the people on the ground to find out what they would really like and redesigned our system from that perspective now, to talk about sustainability, these units that I mentioned to you were implemented between 2015 and 2017.*"
- The interaction between the technology researcher and the leadership of the community was such that the researcher first spoke to the traditional leaders and then spoke to the councillor separately and then met them together. The technology researcher said the following regarding their interaction with the community leadership of Malatane:
    - *"Our interaction was, initially there were individual meetings with the hierarchy, the traditional leaders, separate from the councillor, then a meeting together with them."*
- After the first interaction, the leaders then convened a meeting with the community and elected a representative committee that will be the interface between the community members, and the researchers and report back to the community leadership. One researcher said the following to emphasize the representative committee:
    - *"Basically, a committee is set up and then future interactions go between the committee that exists at the village level and the researchers".*
- All the participants from the Malatane community indicated that they communicate with their representative who is a local teacher on all issues regarding the technological innovation. They either use the phone or even visit her house to report an issue, get cleaning chemicals or seek advice on a challenge of the technological innovation. One of the community members mentioned that the community representative is very active as she visits the users to check if they are having any issues using the technological innovation.

By counting the number of connections to each actor group, a graph (Figure 17) for the number of connections per actor group was produced for the Malatane community. In the case study, the district municipality, political, technology researchers and tribal leaders and the community actor groups have the largest number of connections. The WRC has the least number of connections.

As the strength in the connection between the technology researchers and the district, the municipality was deemed to be stronger and both actors interact with many other actor groups. This makes this connection one of the most critical linkages to which technological innovation was deployed in the VulAmanz case study.

Since the actors were mapped in the VulAmanz case study, their motivations to co-create innovations for social purposes are presented in the next section.

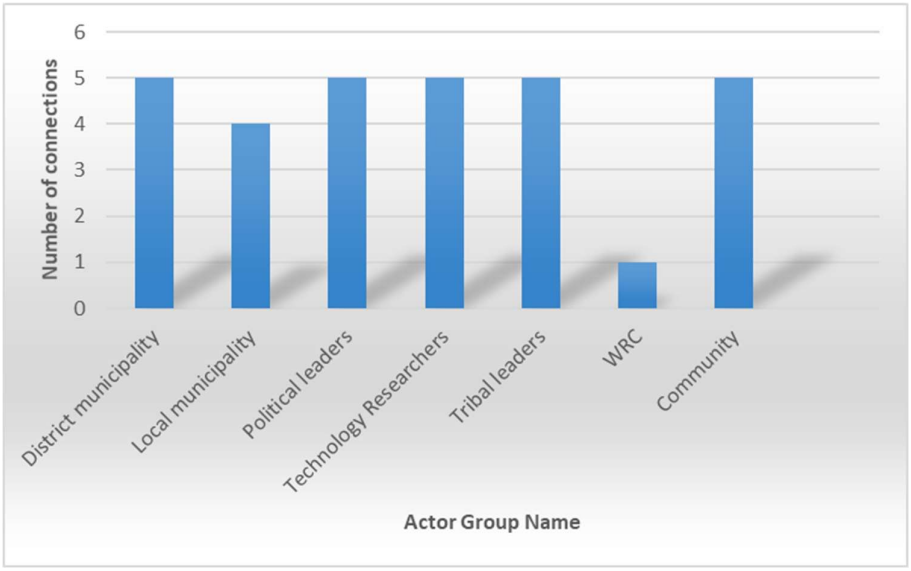

Figure 17: Number of connections per actor group graph for VulAmanz technological innovation in the Malatane community (Source: Author)

4.3.3.2 Actor motivation

Twelve participants were asked what motivates actors to partake in co-creation in rural water supply looking specifically at the VulAmanz technological innovation. Figure 18 shows a summary of the motivations based on the responses from the participants. Broadly, the motivations can be grouped into four groups mainly personal technical competency, perceived benefits, financial and social. These can be further grouped into various subgroups as outlined in Figure 18.

Personal Driver

One of the motivations for providing a solution to water quality issues was the personal technical competency of the inventor of the technological innovation.

> *"We were working on membrane technology for bioreactors which are used for wastewater treatment. I think it was a person from the water research commission who suggested looking at a bigger problem in terms of the supply of water to rural areas".*

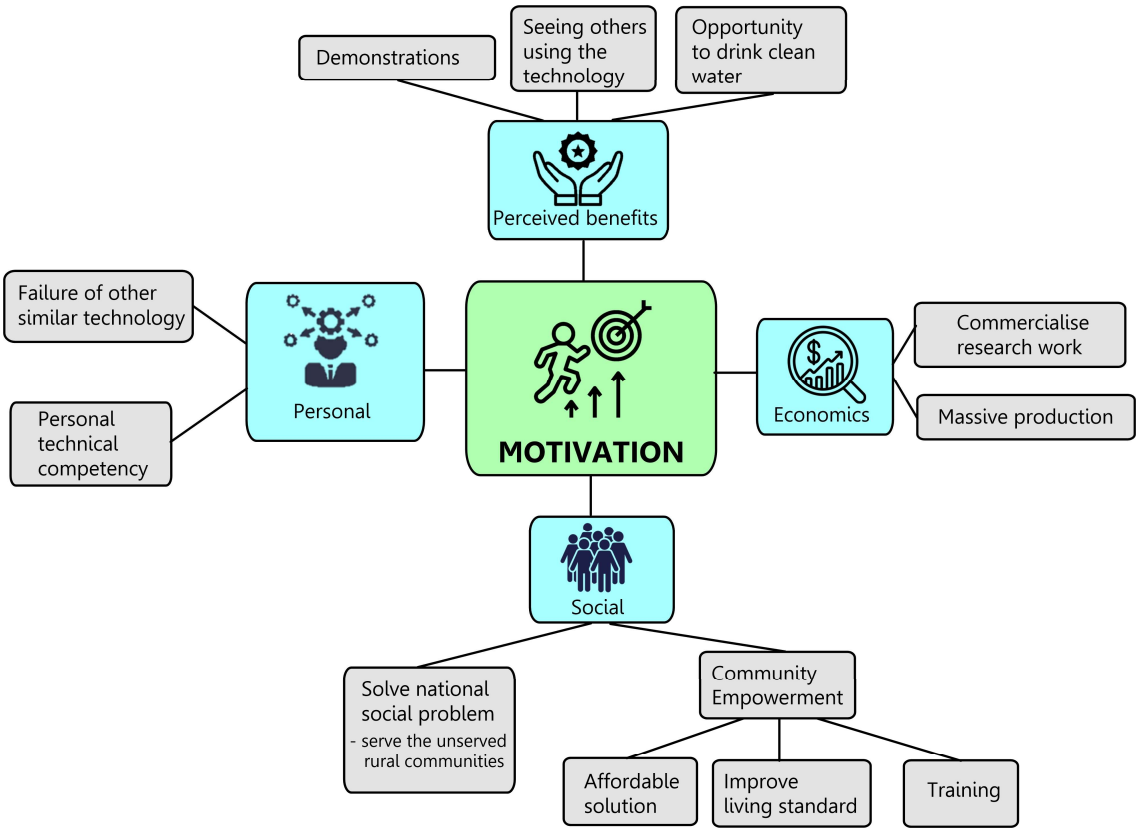

Figure 18: Summary of motivations in Malatane community case study (Source: Author)

Failure of other similar technology and the need to combine expertise in membrane technology motivated the inventor to start the development of the technological innovation. The inventor said the following regarding the motivation for the development of VulAmanz technological innovation:

"The CSIR has had various projects, department of science and technology and various technologies predominant from overseas have been tried out. And none of them to date have been successful. Generally, after two to four months people stopped using them for various reasons. Hence, we started developing this."

Perceived benefit driver

From the responses, perceived benefits were identified as a motivator for the community to participate in the development of the technological innovation. These perceived benefits can be grouped into three subgroups namely: Demonstrations, Seeing others using the technological innovation and the opportunity to drink clean water.

Demonstrations - When the technological innovation was first demonstrated in the community, one technology researcher put soil in the water and put the dirty water in the VulAmanz technological innovation, then he drank the water from the technological innovation while the community watched. This had a significant impact on proving to the community that the technological innovation works and that the technology researchers believed in their technology. Of the ten participants interviewed from the Malatane community, four people indicated that the demonstration was what motivated them to start using the technological innovation. One participant said the following regarding the demonstrations:

"We were called to a community meeting and a representative of VulAmanz put soil in water and pour it on the top of the VulAmnaz drum. He added 'Jik' and waited for a few minutes, then opened the tap and drink the water while we watch".

The community representative shared the same sentiment with other community members regarding the technological innovation demonstration:

"When they showed us how the filter works. It was impressive".

Seeing others using the technology - The first people who received the technological innovation spoke well about it and the benefits that the technological innovation brought to their lives. This triggered others to want to try it. During the community visit, one member of the community approached the author and asked if he can also get the technological innovation as everyone that he knows is talking well about it.

Opportunity to drink clean water - As the community had challenges with water quality, the introduction of technological innovation that could potentially solve the challenge was welcome. Thus, according to one participant, the opportunity to drink clean water was his biggest motivation to use it. He said, *"Prevention is better than cure"* to illustrate his motivation for using it. Fifty per cent of the participants interviewed in the Malatane community were motivated by the opportunity to drink clean water.

Economics driver

The technological innovation was developed using public funds through the Water Research Commission. The opportunity for commercial research work and massive production was identified as a strong financial motive in the VulAmanz case study.

Commercialise research work – Most research work done by universities ends up pilled on shelves, so why not commercialise it? The inventor of the technological innovation was challenged by this and pushed towards developing the VulAmanz technological innovation into a commercialised product.

Massive production - Critical to financial motivation for products meant for rural areas, the products must be of low cost. Massive production has the potential to lower the cost of the product. The inventor said the following regarding massive production:

> *"After the project was over and we had technology that works, a significant investment would be required to take this into commercial production. We were fairly lucky and we got a significant capital input to set up mass production for the technology. The project started at the beginning of last year and the first units will be coming out of that production facility in May 2022."*

Social driver

Social aspects were also a motivator towards the development of solutions for rural areas. These can be subdivided into two broader groups. One involves contributing to solving a national social problem and the other involves community empowerment similar to the Thambonkulu community case study.

Solve a national social problem - Two participants stated that one of the critical motivators for co-creation is socially oriented and were contributing to solving a national social problem by serving the unserved rural communities in the country.

Community Empowerment - Other motivators include empowering the community through training, bringing affordable water purification solutions and generally improving the living conditions for people in rural areas.

The motivation from the community side to partake in the utilisation of the technological innovation was chiefly in the value it can bring to them. According to most participants, the community believes the water from the tap is not clean and is still relying on the VulAmanz technological innovation for drinking water. When the innovation was demonstrated to them, they instantly wanted to try it, as it had the potential to end the effects of drinking dirty water. The following is a list of values that the technological innovation brought to the community as said by the community participants during the interviews:

- One other concern in rural areas is the safe storage of water. Often they use a large container to store water which can be a risk as children can fall into it. One participant said that the innovation is very helpful, as the children cannot fall into the storage container. The other participant concurs that the VulAmanz drum is closed on the top and is safe for their children to get drinking water.

- According to one community member, their children like drinking water from the innovation as they say the water tastes better than the one from the municipality tap. The other community member mentioned that *"Even our visitors from towns are satisfied with the quality of water from the technology"* illustrating the perceived quality of water from the technological innovation. One participant from the community said that:

    - "*The neighbours who do not have the technology even come to drink water from the drum."*

- The technological innovation brought several health benefits to the community. As pointed out by over 90% of the community members interviewed. Some indicated that after the introduction of the innovation in the community, no '*running stomachs*' were observed and they attributed it to the cleanliness of water they now drink from the technology. Thus, from the community's perspective, technology is the one that is protecting them from sickness and is a solution that prevents them from drinking dirty water.

The research has indicated that the key motivators in the VulAmanz case study are social, economic, personal and perceived benefits. Since the motivation can be mapped, the next step would be to understand how the actors interact (processes) to co-create a solution to water quality challenges.

4.3.3.3 Actor interaction processes

From the responses of the participants in the VulAmanz case study, information regarding the co-creation process was extracted and coded into various associated themes. All information regarding interacting processes was also extracted and coded. In the VulAmanz case study, five themes were obtained namely; first community contact, leadership involvement, scaling up and training, outreach and technology support (Figure 19).

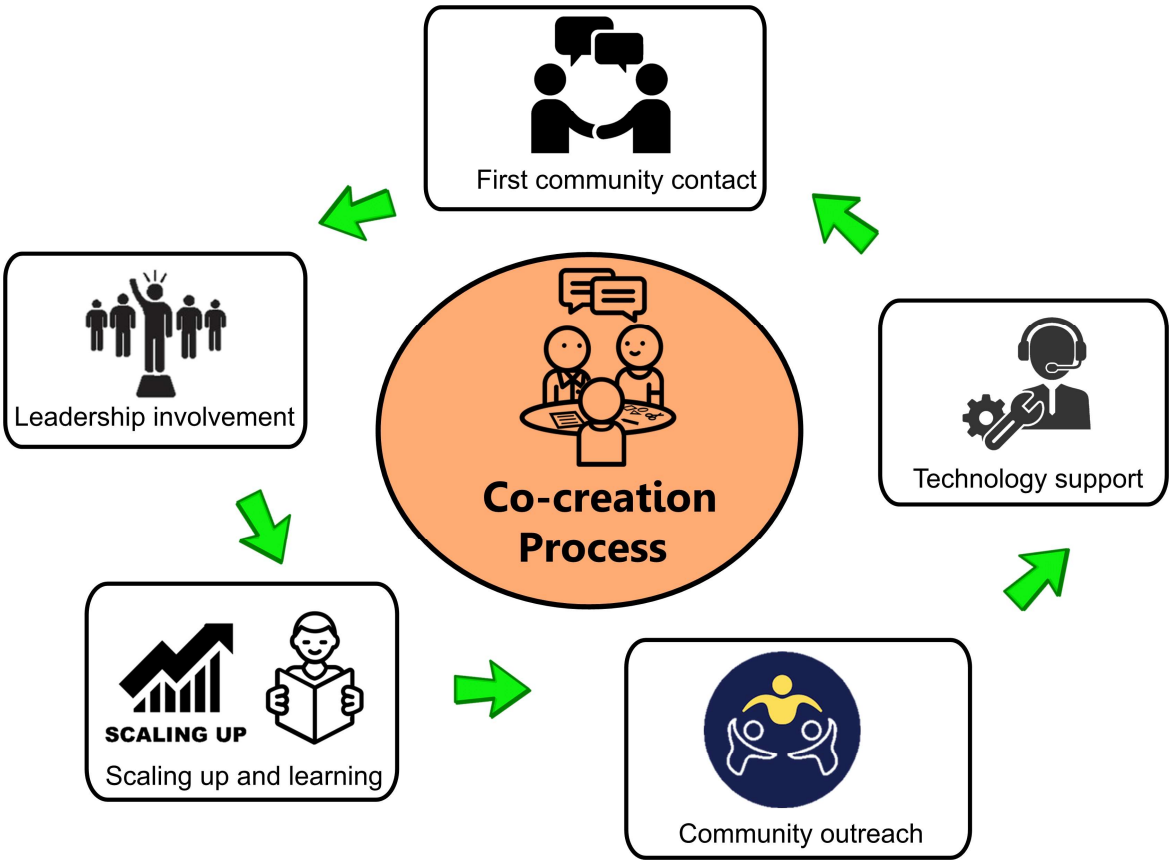

Figure 19: Value co-creation process in the Malatane community case study (Source: Author)

First community contact

The inventor mentioned that when he first started the development of technological innovation, he went to the community where one of his students came from. He spoke to the traditional leaders and the people on the ground to find out what they would like, then they redesigned the system using that perspective. The final product was completely different from the one they conceptualised as described in the following statement:

> *"In fact, the final design ended up quite, quite a bit different from what I initially envisaged. For example, I initially thought that one would have a very large system next to a river and that people would go there, use it and fill it up for the next person. The feedback suggested that this was not going to work too well because someone was going to steal parts and everything will be gone. And then people said they would prefer if there was something that they could be in charge of at their actual households".*

After redesigning the technological innovation, it needed deployment. As a flagship project of the DSI, the technological innovation was presented to all municipalities and 27 district municipalities wanted to try the technological innovation but the DSI selected Capricorn for implementation. To this effect the inventor gives an account of the selection process:

> *"Essentially, various technologies were showcased to all the district municipalities. The district municipalities indicated which ones they would like to participate in. From the feedback, 27 district municipalities said they would like to try this, but DSI selected Capricorn district municipality for implementation".*

In the Malatane community, before the introduction of the VulAmanz technological innovation, the piped water from the municipality was of poor quality. All the ten community members interviewed pointed out that the water situation was very bad before the VulAmanz technological innovation was introduced to the community. Thus, the VulAmanz intervention alleviated the water quality issues.

Leadership involvement

The researcher approached the traditional and the political leaders and explained what they were trying to do. Once they were convinced, they then mobilised the community

to partake in the project. Thus, according to one researcher, the successful deployment of the VulAmanz technological innovation in the Malatane community, was because the community leadership understood that the project was bringing some value to the community and that it was more of a collaborative effort meant to improve their lives. This engagement approach ensured that the technological innovation was piloted in the Malatane community without any resistance.

According to the inventor, normally the community elects a water committee which would be the bridge between the community and the researchers, but in the Malatane case study, the Capricorn district municipality acted as the water committee. The following statement illustrates this sentiment:

> *"And the water committee interacted with the rest of the community in Capricorn, very similar to areas rural water supply projects, except that there wasn't a water committee formed there. The Capricorn district municipality water personnel themselves were the ones that went into the field."*

The local municipality as the water service provider was also involved in the project launch as echoed by one participant:

> *"The local municipality is ultimately responsible, for water supply and it was involved in the project from the beginning."*

Scaling up and learning

In the rural water situation at the time VulAmanz technological innovation was introduced to the Malatane community, the technology researchers had a prototype which needed more testing and a large-scale proof of concept before commercialisation. On the other hand, the Malatane community had a water quality challenge which required an urgent solution. Thus, mutual benefits could be realised from the two actors' interactions.

When testing the technological innovation on a large scale, the technology researchers benefited from testing the product in the Malatane community and obtained feedback and lessons which were used in its improvement. The following statement from the inventor emphasizes what they learned from the project:

> *"What it enabled us to do was to realise how to go about doing things in rural areas. We were very fortunate in that."*

Community outreach

As part of the outreach program, the community was trained to use the innovation and to do basic maintenance such as cleaning the filtration membrane. The training offered to the community proved useful as all the ten participants knew very well how to use the technological innovation and all could rely on the steps required to successfully get clean water it.

The community representative was constantly engaged in ensuring that all the users are well supported and that all the units are working optimally. Sixty per cent of the participants indicated that they are always in contact with their community representative.

In the Malatane case study, during the implementation of the project the researchers used students from a local high school to do surveys, train people and solve some basic issues about the innovation.

> *"We also found it very useful to involve students from the local high school in the Capricorn project. The students were involved in field surveys, training people on how to use the units and helping users to overcome problems that they might have while using the technology."*

Technology support

The technology researchers are still in contact with the community representative and the municipality still visits the community to check on the progress of the large-scale testing of the technology. According to the inventor, over one thousand units are in use in the country. Most of the current users of the technology indicate that they intend to continue using it when the project ends.

4.3.3.4 Dealing with norms, culture and traditions

As pointed out early, rural actors are very suspicious if a foreign individual/ company comes to their community for a project. To deal with this challenge, the researchers had to prove the value of the technological innovation to the Queen first. Therefore, they left her one unit and taught her how to use it as illustrated in the quotation below:

> *"Apparently, the queen was very, very suspicious at initiation as reflected in questions she asked:*

"I want to know why these people are coming all the way from Stellenbosch over here to do this? Is there something that they want or something?"

"So eventually the Capricorn district municipality official left one unit with the Queen. And told her to, you know, use it and get back to them and let them know if she'd like the project to go ahead. A week later she contacted him and said, well, this works well".

Another critical aspect mentioned by the researcher was that getting the confidence of the people who will try the product was a major milestone, which allowed them to obtain honest feedback in the development stage. Avoiding false expectations, the technology researchers declared upfront that the project was still at the development stage and wanted the community to give them the truth as they interact with the technological innovation. The following were extracted from one of the researchers:

"To get the confidence of local people is very, very important…….you need to get the complete trust of people……...and don't build up false expectations…….learned that interaction with the locals is critical in terms of gaining trust, gaining confidence and success of the project."

According to all the 12 participants interviewed in the VulAmanz case study, none indicated any effects on their traditions, norms and cultural beliefs. Similar to the AmaDrum and VulAmanz innovations is also placed in the house and does not affect the water sources.

One technology researcher interviewed mentioned that for the successful deployment of technological innovation in a socially complex environment such as a rural area, the first contact with the community plays a critical role, especially in language. Thus, in Malatane, the technology researcher used one of their student who understands the traditions and language of the community to which the technological innovation was to be deployed. The statement below illustrates this sentiment:

"One of my ex-students speaks various languages very well and is one of these guys that people find very easy to get on with. Therefore, he was one of our front people because he would; you know, talk and translate to eventually develop some degree of confidence. What we did realize is first, people that live in rural areas are very, very conservative and very suspicious of outsiders".

Another illustration also echoes the same sentiment:

> *"We're fortunate in that, my first student was working on this project in Durban. He came from that area. So, most of my students were in fact from rural areas. So, they brought us up to speed with the traditional practices".*

To attest that the technological innovation did not affect the traditions of the community, three participants from the Malatane community said that:

> *"The technology did not affect our beliefs and traditions. It only brought positive and good to the community"*

4.3.4 Technology acceptance and adoption

From the VulAmanz case study, 114 statements were extracted that talk about technological innovation acceptance and adoption. The statements range from three words to paragraphs conveying a similar idea. For the initial coding of the technology acceptance, theoretical factors (perceived usefulness, ease of use and user's intention to use) were also used. For those that fall outside the theoretical codes, new codes were created. Table 8 shows the eight broad codes that can be identified from the responses in VulAmanz technological innovation deployed in the Malatane community. Figure 20 shows the description of the codes and how they are related in response to how technological innovation is accepted and diffused in rural areas.

Table 8: Themes related to technology acceptance in the VulAmanz case study

Themes	**The number of times the theme is mentioned**
Perceived ease of use	17
Perceived usefulness	19
Intension of use	20
Training	15
Situational conditions	18
Technology features	9
Technology support	10
Technology Demonstration	6
Total	**114**

4.3.4.1 *Perceived ease of use*

The technological innovation is relatively easy and simple to use as it is a modification of the traditional bucket way of storing water except that filtration technology has been added to the bucket and a tap for safe extraction of water. All the ten participants interviewed in the Malatane community could rely on all the steps followed in using the VulAmanz technological innovation. They all could recall that one needs to put 20l water on the top and adds two drops of the purification chemical, stir the water and wait for a few minutes before drinking the water. They say that the training offered educated them on how to use the technological innovation, which helped them to understand the functionality of the technological innovation. The system is also easy to use and easy to clean the filter. It is user-friendly that children can operate the technological innovation at ease as mentioned by one participant. Despite this ease of use, manual loading of water to the drum was highlighted as a potential barrier to technology acceptance and adoption.

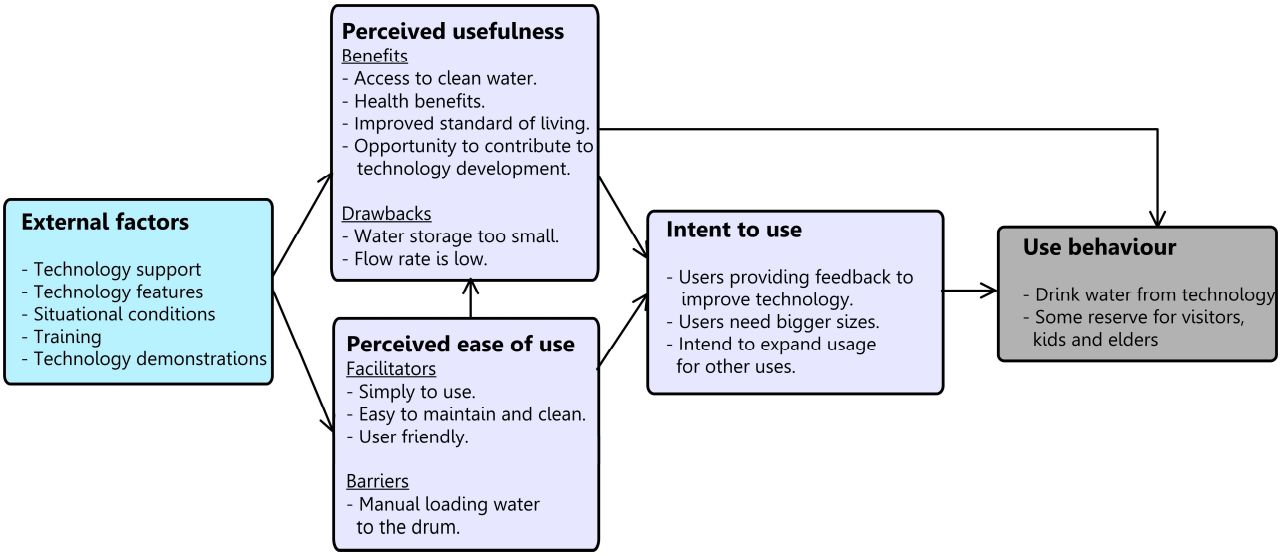

Figure 20: Descriptions of the technology acceptance model for the VulAmanz case study (Source: Author)

4.3.4.2 *Perceived usefulness*

This theme is the one that appears mostly in the statements extracted for analysing technology acceptance and adoption of VulAmanz technological innovation. As mentioned in the community empowerment section of social motivation, the VulAmanz technological innovation brought more benefits to the Malatane community which include: access to clean water, several health benefits, general improvement of the

standard of living, and is a co-creator of the VulAmanz technological innovation. However, the participants also indicated that the storage was too small and that the flow rate was low during times when the water demand is high. One participant said:

> *"We would like the VulAmanz water storage to be bigger so that we have enough water during summertime when it's hot and we have many people at home".*

4.3.4.3 Intension of use

To show that the technology acceptance and adoption were relatively high, 90% of the community members interviewed indicated that they would continue to use the technological innovation. According to the VulAmanz technological innovation researcher, 95% of the units they have developed to date are still operational:

> *"There was a survey done and about 95% of the units were still in use at that point. So that indicates a very high level of user uptake and sustainability, and that is what is critical in terms of implementation of systems in developing economies".*

4.3.4.4 Training

Training is one of the external features that affect technology acceptance. The training that was given to the user of the technological innovation also contributed to the community making use of the technological innovation. The training included the supply of information on how to do general maintenance of the technological innovation. All ten community members interviewed indicated that the training was sufficient and simplified how to operate the technological innovation.

4.3.4.5 Situational conditions

Situational conditions are another external factor which determines how the social issues about water quality have a bearing on technology acceptance. In the VulAmanz case study, the water quality was not portable before the technological innovation was introduced in the community which created a situation where the community was desperate for a solution. As alluded to earlier on, the water was fetched from the river and the community also claims that the piped water is not clean. Bringing a water quality solution during a state of need could be one of the critical factors in technology acceptance and adoption.

4.3.4.6 *Technology features*

Several questions regarding the features of the technological innovation which have a bearing on whether the community will use it or not were asked. Figure 21 shows the features of the VulAmanz technological innovation as mentioned by the participants in the VulAmanz case study.

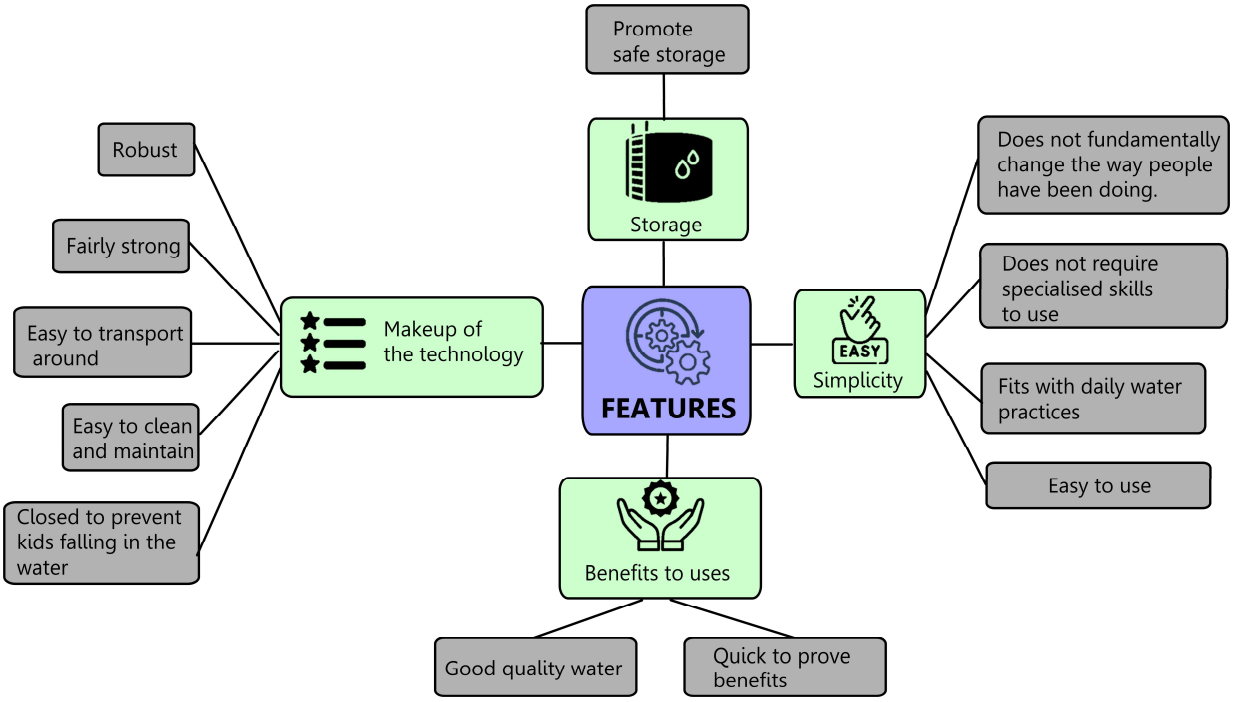

Figure 21: Features of the VulAmanz technological innovation (Source: Author)

Simplicity

In the VulAmanz technological innovation applied in the Malatane community, the simplicity of the technological innovation could have been one of the attributing factors to its success. From the responses, four themes about the simplicity of the innovation can be gathered, mainly:

- easy to use,
- does not require specialised skills to use,
- technological innovation does not fundamentally change the way people have been living, and
- fits with daily water practices.

Rural areas are often attributed to low levels of literacy, thus for a technological innovation to be easily accepted it has to be simple and should not require too many specialised skills to use. Above all, it should not fundamentally change the way people have been living, for them to easily use the innovation according to the inventor of the VulAmanz technological innovation.

The makeup of the technological innovation

The design of the technological innovation does play a pivotal role in the acceptance and adoption of the technology by the community. In the VulAmanz technological innovation case study, several features of the technology which make it more adaptable to rural areas were identified as:

- The technological innovation is robust. As illustrated by one participant, she has been using the technological innovation for the past six years. Thus, it is fairly durable.

- From the responses of the users of the technological innovation in the Malatane community, it was evident that the system is fairly easy to clean and maintain. Only the brush is used to wipe off the dirt from the membrane surface after several uses.

- One other feature mentioned was that the VulAmanz drum is closed at the top, which makes it safe for children to use.

- As a small drum, the system is easy to transport.

Benefits to users

Regarding benefits to the users, the technological innovation offered a solution to alleviate the water quality issues at the point of inception. All ten participants interviewed indicated that it produces good quality water and emphasized that they will continue to use it.

One researcher gave an account of a success story brought about by the technological innovation deployment in the Malatane community:

> *"Firstly, we have some phenomenal, positive feedback. An example is a granny at Malatane village, she used to take her grandson to the clinic every week to get drips for treating diarrhoea. About a month after she started using this water*

treatment unit, the clinic contacted her to find out why she no longer brought the child and wondered if maybe the child had passed on. She then invited them to her house and showed them how bright and active the kid was. So then the people from the clinic sat and then she starts to purify water for them as well."

Storage

One other aspect of the technological innovation is that it safely stores water at the household level which is one important feature that most of the participants alluded to. One participant mentioned the following in response to the question on what she likes about the technological innovation:

"The technology offers a storage of water and no going outside to fetch water at night".

4.3.4.7 Technology support

The regular door-to-door visits by the community representative supported the end-user in the use of the technological innovation.

4.3.4.8 Demonstration

The demonstration done by immersing soil into the water and purifying the water whilst the community watched stood out on its own as a possible drive that boosted the way the community viewed the technological innovation.

4.4 RURAL WATER EXPERT PERSPECTIVE

Eight experts from key actor groups (university, civil society, consultants, government, and the private sector) were asked questions regarding water supply issues, particularly water quality, as their views offer invaluable insight that contributes to improving the generalisation of the research finding in South Africa.

4.4.1 Actors Mapping

Experts identified the following actors (Table 9) as generic for dealing with water quality issues in the rural water supply.

4.4.2 Actor Interaction processes

According to the experts interviewed, interaction for co-creation between the various actors is one of the most crucial elements to improving technological innovation uptake

by communities. The key factors highlighted include community empowerment, communication, formalities, problem definition and improved agent interaction.

Table 9: Actors and roles mentioned by experts in rural water supply

Actor	**Roles**
Community	As an equal partner in the interaction and an end-user of clean water.
Government	National (Legislator), District and Local (Water service providers).
Tribal leader	Point of first contact that helps to mobilise the community so that the technological innovation can be deployed without resistance.
Consultants	Brings the technical perspective to technological innovation. Often it is driven by financial gains.
Investor	Provides the funding for the projects. The investor can be government or a private entity. When the government invests in water quality technological innovation in rural areas it is motivated by the desire to improve the standard of living.
Civil society	According to one participant civil society is a more neural actor which can resolve disputes between various actors in rural areas.

For effective interaction between various actors, the societal challenge needs to be well-defined and understood by all. That is, a mutual understanding of challenges to be addressed and the need to be co-defined by all actors. Activities and roles need to be well defined and everyone assumes their roles.

4.4.2.1 Community Involvement

As the deployment of the technological innovation is in rural areas, community empowerment is so critical that it can either accelerate progress or deter the community from engaging in the project even though the project aims to benefit them. From the interviews, the expert suggested the following form of empowerment:

- Consider the wishes, aspirations and expectations of the community including getting their opinion on the possible solutions that can solve their water quality challenges. The solution should incorporate their general habits.

- Empower the community through training, knowledge sharing and engagement in projects through employment and supporting their initiatives.
- Involve the community from design and implementation to post-implementation. This would enable the community to own the solution at the end of the pilot phase.
- Community is a key factor which should be treated as an equal partner not as a simple end-user.
- Follow the hierarchy channel of engagement such as from district, local, and tribal to the community.
- Involve the tribal authority to seek their consent and make them aware of the project. This should be done at all stages of the project.

Therefore, community inclusiveness is key to getting the community's buy-in. Also, there should be a constant adjustment to the process of engaging with the community to ensure that mistakes, errors or omissions are minimised.

4.4.2.2 Communication

Communication between various actors cannot be over-emphasised in multi-agent value co-creation. The following are the views of the experts regarding communication in multi-agent interactions:

- use various methods of communication, such as meetings, technologies such as WhatsApp groups, emails, and phone calls;
- Inform the community how the technological innovation would improve their lives and how they can contribute to its development;
- communicate ways of knowledge sharing;
- visit the community and promote engagement days, and;
- communication should be open and good.

4.4.2.3 Formalities

All engagements need to be formalised to ensure that all rules of engagement are documented in the event of intellectual property (IP) lodgement or commercialisation of products being born from the interaction to avoid misunderstanding and lawsuits. This would safely guard against failure of future engagement due to previous unsuccessful encounters. This can be done through contracts, a Memorandum of understanding (MOU), a Memorandum of Agreement (or is it of Association) (MOA) or other appropriate forms of formalities.

4.4.2.4 Agent interaction

In formulating the interactions, all key agents should be involved. Activities should be aligned with agents. Since we will be dealing with many actors, each actor has his / her epistemological background. Hence, these differences must be understood to find common ground to promote unity for co-creation to happen. In areas which are critical but are outside the competencies and ability of the actors, collaboration with external entities can be used to close the gap. It all goes by the saying that in all interactions, trust and respect will ensure that dialogue between actors remains organic and open.

4.4.3 Actor motivations

Seven themes were extracted that show motivators for actors to co-create in rural areas, namely: economics, community empowerment, solving a national problem, serving the bottom of the pyramid, target driven, personal and environmental.

4.4.3.1 Economics

Under economics motivation, over 70% of the experts indicated that financial motivation is the biggest motivator for actors to co-create. Other participants indicated that actors mostly in the private sector want to provide a service to rural areas as part of their expansion or as a business goal to service the unserved consumers in rural areas.

4.4.3.2 Social

This theme can be further broken down into, community empowerment, solving a national problem and the bottom of the pyramid.

Community empowerment

Another social motivation for actors to be involved in co-creation is to empower the community through education, protecting them from illness, access to clean water and general improvement of the standard of living.

Solving national problem

Issues relating to water quality are a national challenge that requires solutions. It is interesting to note that the experts mentioned that some actors engage in multi-agent interactions, particularly in rural areas as part of their contribution to lessening the impacts such as outbreaks and solving water-related health issues. Others mentioned that motivation can be humanitarian such as wanting to make a better living for someone, caring for others and broadly contributing to humanity.

Bottom of pyramid

Serving the previously unserved consumers such as people in rural areas was mentioned as another reason for the development of solutions to serve this segment of the population. One participant said,

> *"One other possible drive to coming up with technologies for rural areas is to serve what is now called the bottom of the pyramid by looking for solutions which can serve this market segment."*

4.4.3.3 Target driven

As some of the experts interviewed are from public and private sectors, a strong mention of their motivation was towards meeting their set target which ranges from organisational, regional and national levels. Also, other motivators in the target-driven theme included targets on improving the reputation of their brand.

4.4.3.4 Personal

One expert spoke about him being motivated by wanting to see his scientific work changing the lives of people in rural areas. Another mentions that satisfaction with being able to solve a national water quality problem is his biggest motivation.

4.4.3.5 Environmental

One expert mentioned that management of the environment and water on its own is a motivator for getting involved in interactions with other actors towards addressing water quality issues in rural areas.

4.4.4 Dealing with norms, culture, traditions and values of communities

To deal with community social dynamics enabling or impeding technology diffusion or its acceptance, the community leadership and its representatives need to be involved. Another approach outlined by 50% of the experts, was to involve an expert in social science or at least a person who understands the language, culture, values and traditions of the community in which the project will be implemented. This person should understand the protocols showing respect for the traditions which would make it easy to interface with the community leaders.

Another view regarding dealing with social dynamics (norms, values, beliefs, traditions and culture) aspect of rural areas is that the technological innovation should take into account these existing social dynamics. This can be done through a feasibility study to know what is allowed or not. This should include community engagement efforts. Another expert emphasised that prior consultation to understand the social dynamics should be considered in the design of the solution from the start.

One other challenge that was mentioned is the issue of community affordability of the solution, which can deter the community from accepting them. Thus, solutions should align with community affordability and should be sustainable as elaborated by one of the experts with a social science background.

Above all, supporting mechanisms through government support would allow the community to familiarise themselves with technological innovation before fully implementing a solution in case the community reject solutions that would address the societal challenges.

4.4.5 Technology acceptance and adoption

Using information gathered from interviews with experts in technologies related to rural water supply, training, and technology, certain aspects were extracted.

4.4.5.1 Training

Three out of eight participants pointed out that training has the potential to improve the acceptance of technology in rural areas. One of the participants said

> *"Training the community to be able to operate the technology and fix simple problems would make them understand the technology and be willing to try using it".*

4.4.5.2 Technology aspects

To improve technology acceptance, the technology aspect that makes the community adopt it is critical. The participants mention several aspects of the technology. These included the following:

- The technological innovation needs to be demonstrated to show the community how it functions.
- The technological innovation should produce water which is within the required standards.
- The technological innovation should connect community needs to what it can deliver.
- Technological innovation support should be an integrated part of the project.

CHAPTER 5: DISCUSSION OF THE RESEARCH FINDINGS

5.1 INTRODUCTION

In the previous chapter, the research results were presented for the two case studies (AmaDrum and VulAmanz technological innovations) and expert opinions on the rural water supply. In this chapter, a discussion of the results is done to generate new insights and knowledge into the provision of clean water in rural areas.

5.2 BACKGROUND

In the succeeding sections, research findings will be discussed as follows:

- The cross-case analysis offers a foundation for the discussion.
- Mapping of the key actors necessary for the deployment of water technological innovation in rural areas.
- Establishing what motivates actors to participate in co-creating value in the rural water supply.
- Understanding the interaction processes for co-creating value in water supply in rural areas.
- Identifying the main factors that influence water technological innovation acceptance and adoption in rural areas.

5.3 CROSS-CASE ANALYSIS

Considering that each technological innovation deployed in rural areas can be viewed as a unit of analysis, the two cases can be compared to extract relevant commonalities and differences. The results are summarised in Table 10 and Table 11 for commonalities and differences respectively.

Table 10: Commonalities between the two case studies

Criteria	**Commonalities between the two cases**
Actor mapping and interaction	• The government, municipalities, tribal leaders, communities, researchers and private companies played a critical role. No social enterprises were involved in the two cases. • Women are actively involved in the use of technological innovation. • The technological innovation researchers and tribal leaders interact with many actors as compared to other actors.
Actor motivation	• The introduction of the technologies improved the living conditions of the communities for the better. • The community even purify water from the municipality's piped water system, as they still believe the water is not clean enough when compared to water from the two technologies. • People now understand the value that technological innovation brings in addressing societal challenges in their communities. • The need to contribute to solving the water quality issues in rural areas was one of the key motivators • Two broad subgroups (social and economic) of motivation were identified across the two cases.
Technology features adaptability to rural areas	• Developed locally and mostly use locally available material. • Offer safe storage of the water which can be drawn using a tap at the base of the drum. • Easy to use and had good technology adoption. • The technological innovation deployment did not affect the norms, traditions and cultures of the community where they were deployed.
Technology acceptance	• The members intend to continue using the technologies. For both technologies, the community still feel that the storage space needs to be increased so that refill is not as often as is with the current versions. • The training offered was sufficient as most of the participants interviewed knew all the steps required to operate the technological innovation.

Table 11: Differences between the two case studies

Criteria	**AmaDrum innovation in the Thambonkulu community**	**VulAmanz innovation in the Malatane community**
Actor mapping and interaction	• The traditional leaders were actively involved as a link between the community and the technology researchers.	• The district municipality was more actively involved as a link between the community and the technology researchers.
Actor motivation	• The AmaDrum motivation from the inventor's perspective was to deliver the mandate and get a chance to deploy their existing chemical treatment solution. • Training triggered the use of AmaDrum innovation.	• The personal technical competency of the inventor was identified as one of the critical motivators for the development of the VulAmanz technology. • The demonstration triggered the use of VulAmanz innovation.
Interaction of multi-agent	• Researchers brought an already developed product to the Thambonkulu community.	• The researchers co-designed the technological innovation with Malatane community members.
Technology acceptance	• The technological innovation has since been disconnected as the municipality did not take over the project after the pilot trials were over.	• The technological innovation is still working six years after it was first deployed in the community.

5.4 MULTI-AGENT VALUE CO-CREATION

This section gives a discussion on actor mapping and interaction; actor motivation and actor interaction processes.

5.4.1 Actor mapping and interaction

From the content analysis of the two case studies, the actors that are deemed to be critical for the successful deployment of water purification technological innovations in rural areas in South Africa are government, municipalities, tribal leaders, communities, researchers and private companies as presented in Figure 22. These can be reclassified into communities, private and public sector actors, which is consistence with the actors mapped by Tadesse *et al*. (2013) except for the social enterprise actor group that was missing in the case studies.

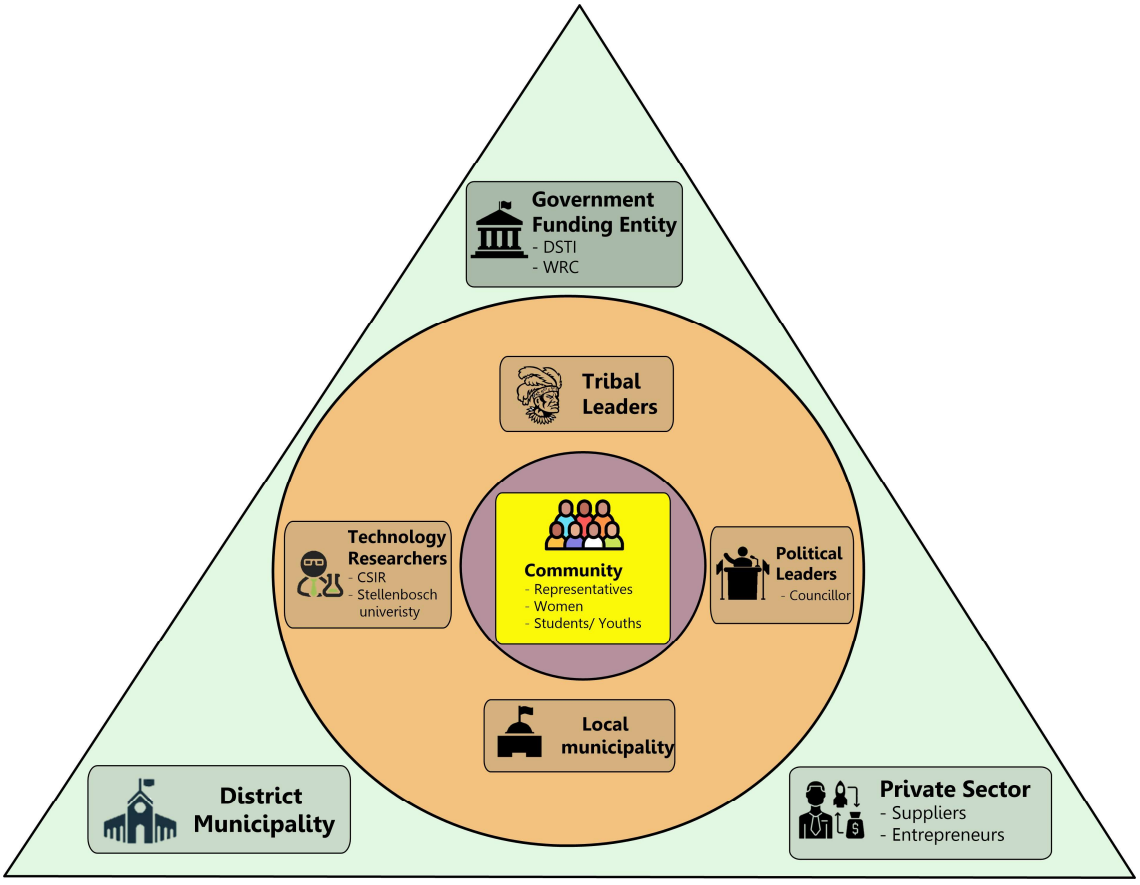

Figure 22: Actors mapped in the research for successful deployment of water purification in rural areas (Source: Author)

A comparison between the actors mapped in the two case studies and the experts interviewed generally shows an agreement on most of the actors except for the social enterprise actor group which is missing from the two case studies. Looking at the reasons given by the experts, the social enterprises are only involved if there are disputes which need to be resolved and they come to the community with solutions through the "*Adjacent-down*" approach highlighted in chapter one. The possible reason why this actor group is missing could be that in the two case studies, no disputes between various actors were identified. From this, one can postulate that social enterprises are responsive only during the time of need.

In the study, the government was instrumental in providing the resources for piloting technological innovations to address water quality challenges in rural areas. This contradicts Bock (2016) who was of the view that innovation for social purposes is a means by which governments shift responsibilities of rural development to civil societies and communities through the co-creation with citizens. It is seen from the study that the government through the research councils and universities did not shift responsibilities but worked with communities in solving their societal challenges.

The government did not only provide funding as suggested by Martens *et al*. (2021) but also provided an enabling environment that fosters knowledge and technology transfer to people living in rural areas in support of Jing and Gong (2012). Despite the conditions for success prevailing, in the AmaDrum case study, a problem only arose at the end of the pilot stage, when it was supposed to be handed over to the municipality to implement a full deployment of the technological innovation to the community. Unfortunately, the municipality failed to take ownership of the project as such technologies were not in their integrated development plans (IDP). The IDP report (Nkomazi local Municipality, 2019) for Nkomazi municipality for the financial year 2011-2021 is rigid towards the provision of piped water inside dwellings and does not mention how they deal with water quality issues or at least create opportunities for other interim measures while waiting for piped water installation. That means that until the municipality gets enough financial resources to provide all households with piped water, the unserved communities will still be without access to clean water. Thus, this municipality's performance indicators need revision. Considering the benefits of the point-of-use technological innovations identified in this study, these could be added to the municipality IDP as an interim/bridging solution to areas without piped water inside dwellings. This would ensure that people living in rural areas have access to clean drinking water in fulfilment of section 27 of the National Constitution (Act 108 of 1996).

Critically also, the research work done by universities, and technology researchers should be done with a consultancy with municipalities, this calls for an alignment between technology aspirations, and policies in entities with municipalities IDPs.

The study established two distinct approaches (municipality-led and tribal-leaders-led) on how enterprises can engage the rural communities. The municipality-led approach involves a strong linkage between the municipality and the community (Figure 23a) while the tribal-leaders-led approach involves a stronger linkage between the tribal leaders and the community (Figure 23b). The tribal-community-led approach which does not fully engage the municipality early in the process has proven to create challenges in transferring the project ownership to the municipality after successfully testing the technological innovation. From this, it would be best if the municipality as the water service authority is involved from the initial stages of the co-creation process to avoid the challenges associated with transferring over the project after completing the testing stage as was the case in the AmaDrum technological innovation case study.

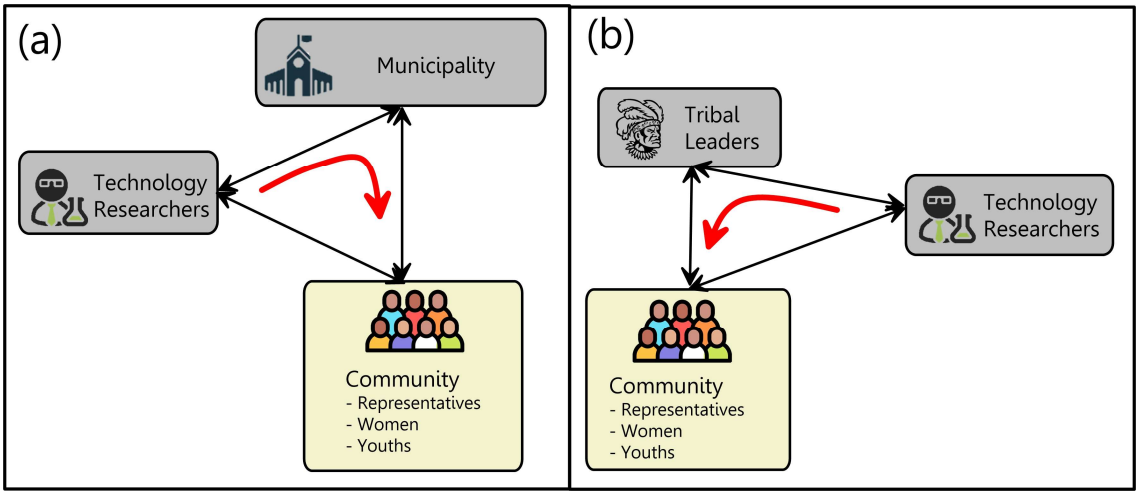

Figure 23: (a) Municipality-led and (b) tribal-leaders-led approaches to multi-agent value co-creation in rural water supply (Source: Author)

5.4.2 Actor motivation

Yin *et al*. (2020) postulated that actors interact for economic, social and environmental issues purposes. By examining the actor interaction in the two case studies, the study identified that actors interacted for economic and social purposes (Figure 24) but the environmental aspect was not pronounced explicitly. One possible explanation could be that the point-of-use water purification technologies are designed around cost

reduction and simplicity with little mention of the environmental benefits associated with them. Even though the environmental aspects are not explicitly stated, this type of technological innovation is environmentally friendly in that they do not use electricity, and thus has a low energy footprint. In the case of VulAmanz technological innovation, the filtration material is made from a local woven fabric made from plant material, which again considers the environmental issues about biodegradable material upon disposal of the material.

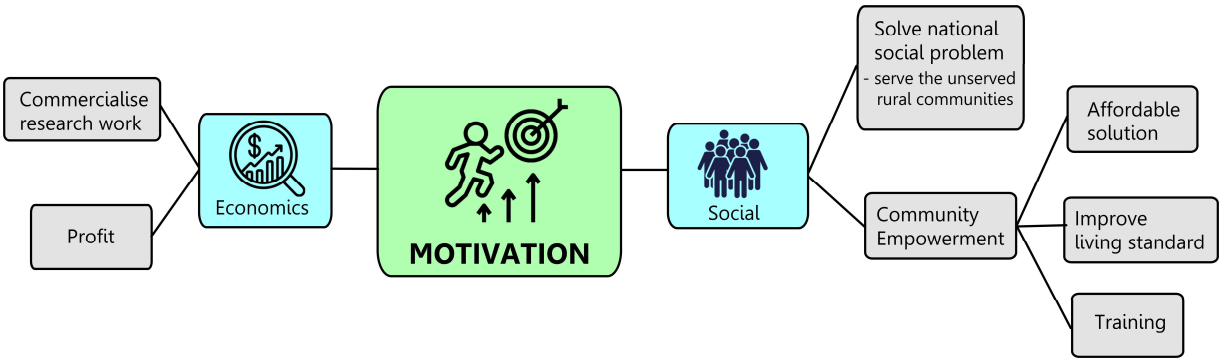

Figure 24: Summary of key motivations for actors in the successful deployment of water purification in rural areas (Source: Author)

The VulAmanz technological innovation is a spin-off of research work done at the university and is one of the success stories where research work is patented, commercialised and is in response to addressing critical societal challenges through co-creation with rural communities. This is in agreement with Sara and Jones (2018) who suggested that universities should not focus on research outputs but should also be motivated to interact and collaborate with rural communities to co-design and co-create solutions that address some of the societal challenges. This case study shows that the government not only regulate but also creates innovations from public-funded research geared towards addressing societal challenges and also commercialisation the research for the benefit of the society at large.

Despite the community being motivated by the benefits brought by the technological innovation, the communities were also instrumental in the testing of the technological innovation which is one of the critical stages of product development (Pessoa and Trabasso, 2017). Their willingness to partake in co-creation backs the findings of Moriarty *et al*. (2013) and Voorberg *et al*. (2015) in that regard. This greatly assisted the technologies in refining them using the feedback received. Thus, the product

generated through this process is bound to respond well in the market as the products have been tested in real-world conditions.

In the AmaDrum case study, the water purification innovation which is a new product was developed utilising an existing commercialised product (the chemical used in the purification process) developed by the same institute (CSIR). This is in alignment with Windrum *et al*. (2016) who postulated that enterprises are motivated to partake in multi-agent value co-creation to distinguish their market strategy through enterprise social responsibility with financial benefits. Thus, this technological innovation can be viewed as part of the marketing strategy for the chemical product already on the market.

5.4.3 Actor interaction processes

The study identified the processes used in both case studies for actor interaction and compared them with Kumari *et al*. (2020) framework. The processes include preparation, co-defining, co-creation, implementation and post-pilot support (Figure 25).

In the preparation process, the societal needs, demands and challenges are identified. In the case studies, the '*laboratory to the real world'* and '*first community contact*' stages involved the technology researcher identifying water quality challenges and obtaining the views of the people in the community is consistent with the preparation stage of the co-creation interaction processes by Kumari *et al*. (2019).

The 'co-defining' process corresponds to enabling collaboration between the actors and the community through engagements between them. In both cases, all critical actors were engaged including community leaders and the enabling environment for collaboration was present which is consistent with Kumari *et al*. (2019).

According to the Kumari *et al*. (2019) model, the 'co-creation' process involves mutual learning and resource integration which leads to improving acceptance and adoption of innovations. The technology researchers had the technology and knowledge to contribute to the provision of clean water. On the other hand, the communities have the numbers required for large-scale testing of such technologies and needed clean water. Thus, co-creation, in this case, can be viewed from the willingness and ability paradigm (Prahalad and Ramaswamy, 2004).

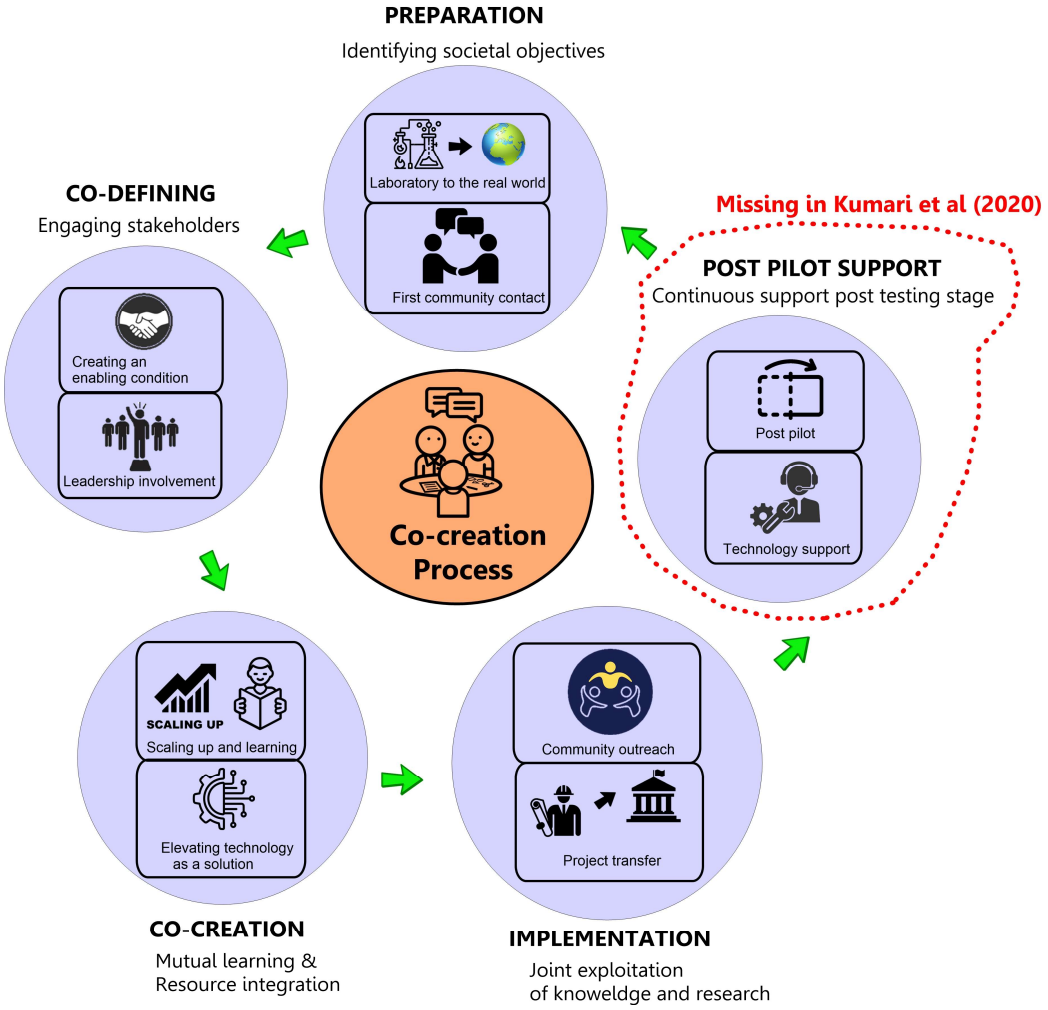

Figure 25: Summary of actor interaction processes mapped against Kumari *et al*. (2020) framework (Source: Author)

The 'Implementation' process value is generated, and knowledge and research joint exploited according to Kumari *et al*. (2019). In the study, the individual household-centred water purification system which is now a fully commercialised product innovation was born partially from the exploitation of knowledge gained from rural areas. The request for the technological innovation by municipalities, schools and clinics around the country and abroad is increasing, which shows an increase in the market share of the technological innovation, which also supports the empirical findings by Hamidi and Gharneh (2016) that VCc has a positive effect on enterprise performance.

The Kumari *et al*. (2020) framework does not include post-implementation. It appears that this framework is designed for an ongoing project where knowledge and creating

value are constantly being exploited. The co-creation processes of actor interaction of the conceptual framework were compared with the mapped processes from the two case studies. The results show the alignment of all four processes (Table 12). The only difference is that the post-implementation stages are missing from the conceptual framework but were identified in the two case studies.

Table 12: Comparision of VulAmanz and AmaDrum co-creation processes with the conceptual framework

Process	**VulAmanz**	**AmaDrum**
Prepare	First community contact	Laboratory to real world
Co-define	Leadership involvement	Creating an enabling conditions
Co-create	Scaling up and training	Elevating technological innovation as a solution
Implement	Outreach	Project transfer
post-pilot support	Technological innovation support	Post pilot

Thus, the study identifies another stage (post-pilot support) which is the need to sustain a technological innovation once it has successfully been piloted. Thus, this finding extends the value co-creation framework beyond the piloting stage of technological innovation in rural areas.

5.5 TECHNOLOGY INNOVATION

The study has shown that if technological innovations are introduced in a rural area from a social perspective involving multi-agents, their acceptance and adoption are greatly improved. These findings are in agreement with Ragauskaitė and Žukovskis (2019) and Živojinović *et al*. (2019) who proposed that when dealing with rural areas approaches from a social perspective are required in navigating through the unique social challenges found in rural areas.

5.5.1 Technological innovation drivers

The content analysis identifies four of seven key drivers (Achilladelis and Antonakis, 2001) for the technological innovation in the two case studies:

1. The availability of local material (the woven fabric in VulAmanz and local sand in AmaDrum), which can be used in pollution removal;

2. Existing competencies (scientific and technology) can be pooled together towards generating solutions to societal challenges such as rural water supply.

3. Market demand for research emanating from publicly-funded entities i.e. the CSIR chemical for purification of water and the commercialisation of the VulAmanz microfiltration technology, and

4. The need to fulfil the societal need for clean water in rural areas.

From the study, the integration (the orange region in Figure 26) of the first three technological innovation drivers (availability of local material, existence of technical competencies and market demand) could contribute to the promotion of the application of technological innovation in addressing societal challenges such as access to clean water.

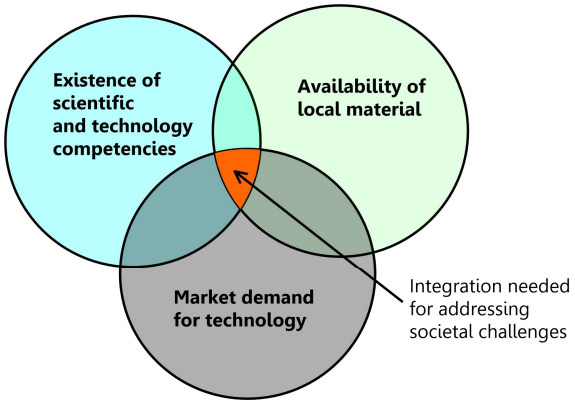

Figure 26: Integration of technological innovation drivers need for addressing societal challenges in rural areas (Source: Author)

5.5.2 Technological innovation acceptance and adoption

In this study, the technology acceptance model and the innovation diffusion theory were combined and analysed qualitatively as a lens through which technological innovation for social purposes can be assessed in rural areas. This approach provides critical information to understand how point-of-use water purification technological innovations are being accepted and adopted in rural areas in South Africa. The study identifies that: the perceived ease of use; perceived usefulness and the external conditions (water situation, technological innovation features, support, training, demonstration) (Figure 27), affect the acceptance and adoption of this type of technological innovation.

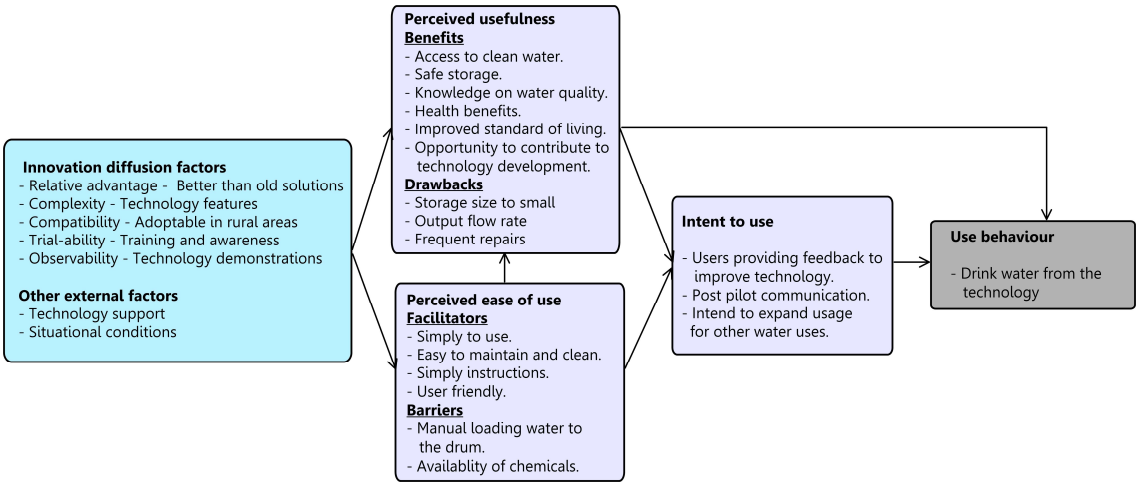

Figure 27: Summary of factors affecting technological innovation acceptable and adoption (Source: Author)

In the two case studies, all the four factors (perceived usefulness, perceived ease of use, intent to use and user behaviour) can be used to understand technology acceptance as outlined by Portz *et al*. (2019). Benefits and drawbacks were identified which are instrumental in how technological innovation is perceived to be useful (Figure 27). Health topped the benefits list as the most sought after by the community. Thus, the issue of water quality can be viewed also in the context of sanitation. Following this, the inclusion of sanitation could improve the research findings.

Factors that do not fall within the theoretical TAM such as support, technological innovation features, situational conditions, training and awareness can be related to the factors of Roger's innovation diffusion theory (Figure 27) as:

- Relative advantage – The introduced innovations replaced the boiling method with a better alternative solution that does not require electricity or a heating source, therefore cutting costs for heating and associated dangers. The water storage feature offers a relative advantage in hygiene, health and safety over the previously used open drums. The two technologies are simple to use and maintain (i.e. cleaning of the filtration system), with few steps to get clean water which makes it less complex for application in rural areas that have low literacy levels (Živojinović *et al*., 2019).

- Compatibility - The water purification innovations are drum-like with a filtration mechanism inside, similar to the drum water storage that the community uses for

storing water. The innovations also did not alter traditions, customs, values and beliefs but fit very well with their daily lives.

- Trial-ability - The community members had a chance to test and interact with the technological innovation during training which helped in the adoption of the technological innovation.

- Observability – The live demonstration and training fostered trust in what the innovation can do which supports Gupta *et al*. (2017) that trust is a critical factor in interaction for co-creation.

Other external factors - Other factors, such as situational conditions and technology support, can be considered as external factors which emanate outside the user's control but are critical in understanding technology acceptance. For example, the situational condition such as the water quality challenges before the technologies was very unbearable for the community members with no other options available from which to make choices. It cannot be established how the communities could have reacted if they had other options to choose from. Thus, the situational condition is not a good indicator of technology acceptance for cases where only one solution exists with no other options to compare with. The technology support factor aims at the transfer of technology from the inventor to the community as described by the users during the interviews was also important. This is one critical factor which needs consideration as without it the sustainability of the technological innovation post-piloting is compromised.

5.5.3 Dealing with norms, values, traditions and culture

In the study, it was recognised that the technology researchers used an individual who understood the local language and traditions of the communities. This had a huge impact on getting the community to accept the innovations. This approach used is consistent with the findings by Lee *et al*. (2014), who used a similar approach to access the migrants and refugees in Western Australia. The issue of rural communities being very suspicious of outsiders in the VulAmanz case study is not new. Quandt *et al*. (1999) reported the same barrier to researchers accessing rural areas. They proposed an approach they termed *'gaining entrée*', in which they used a person who understands the culture and language which improved the interaction with rural actors and overcame this barrier.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

Lack of access to clean water in rural areas is a widespread challenge that affects millions of people in South Africa. Some communities are accessing water from unprotected sources or, if they have access to a municipal piped water connection, the quality of the water is still a concern. Many enterprises/agents are developing solutions to address these challenges, but engaging the affected communities is intricate and requires unique approaches owing to the complex social dynamics in rural areas.

This study will offer invaluable insights into how enterprises/agents can co-create value in response to societal challenges in rural areas, specifically by harnessing technological innovation in response to social needs.

The study highlights the nature of interactions and the motivations of various agents to take part in co-creating solutions to contribute to closing the gaps in this regard. The study contributes towards resolving some conflicting views in the literature regarding the concept of innovation for social purposes in rural areas.

6.1 MAJOR FINDINGS

The major findings of the study are summarised in Table 13, where answers to the research questions are given.

There are different ideas regarding the involvement of government in co-creation. The study found that the government was instrumental in providing the resources to test technological innovations in response to societal challenges. This finding, in fact, runs counter to the notion in the literature that governments shift the responsibilities of rural development to civil society and communities through co-creation.

The availability of local materials, the existence of local technical competencies and market demand play a role as drivers of technological innovation geared towards addressing societal challenges in rural areas.

Table 13: Summary of answers to research questions

Research question	**Summary of answers**
Who are the key actors necessary for the deployment of water technological innovation in rural areas?	The study has established that the successful deployment of technological innovation in rural areas requires a coordinated approach involving the national government, municipalities, tribal leaders, communities and private enterprises. The various actors integrate resources to address societal challenges by building trust, mutual benefits, and learning, taking into account existing social dynamics and motivations within the realm of the willingness-ability paradigm. The study also highlighted that women and youths in rural areas interacted more with the technological innovation and contributed to its development.
What motivates actors to participate in co-creating value in the rural water supply?	Actors engage with one another for economic and social purposes (mainly to empower communities) with little mention of environmental aspects. It was established that universities and technology researchers were driven by the need to make an impact on rural communities through the co-creation of technological innovations.
How do the actors interact in co-creating value in innovation for social purposes such as water supply in rural areas?	The four processes through which actors engage with one another are through namely preparation, co-definition, co-creation and implementation. This finding is confirmed by previous researchers. The study further extends the co-creation processes beyond the implementation stage by adding a “post-pilot support” process, where technological innovation is continuously being supported and exploited post-implementation. Involving a person who understands the local culture and language improved interaction with rural communities.
What are the main factors that influence water technological innovation acceptance and adoption in rural areas?	Through a qualitative analysis of combined technology acceptance model and innovation diffusion theory, the study has identified that perceived ease of use, perceived usefulness and external conditions (water situation, technology features, support, training, and demonstration) are the main factors that influence water technological innovation acceptance and adoption in rural areas.

6.2 KEY CONCLUSIONS

The study suggests an initial conceptualisation of the processes which enterprises/agents adopt to contribute towards sustainable development goals. These processes are particularly those related to the inclusion of rural communities and enhancing partnerships for development. Thus, co-creating technological innovations with rural actors as active participants enhances technology and knowledge transfer to rural communities which, in turn, contributes to improved standards of living in rural areas. From a business perspective, product development is enhanced which, in turn, improves technology acceptance and adoption in rural settings. Furthermore, the growth of enterprise attributed to co-creation of technological innovation with rural communities was also identified.

There are two distinct approaches that agents/enterprises can adopt in engaging with rural communities on water solutions. One involves establishing a strong linkage with the municipality (municipality led) and the other entails involving tribal leaders (tribal leaders led), where the 'municipality led' approach avoids the challenges of ownership transferring after piloting is complete.

The current rigid approach used by municipalities in addressing rural water supply needs changes to accommodate co-creation and technological innovation. The municipalities' integrated development plan for water supply are designed bearing in mind the provision of piped water to dwellings with low flexibility for the inclusion of contributions that can be brought about by technological innovation. As an example, the introduction of point-of-use technologies as an interim/bridging solution in areas without piped water inside dwellings or where there are concerns about water quality arises will improve access to clean water.

6.3 RECOMMENDATIONS

The following recommendations are considerations for researchers, agents, and enterprises wanting to improve the acceptance and adoption of technologically innovative solutions in rural areas.

- To avoid challenges arising from transferring project ownership to a project beneficiary (municipality or community) at the end of the pilot phase of product development, beneficiary expectations, requirements and concerns should be incorporated in the design and implementation stages of the project with constant engagement with stakeholders throughout the project life.

- Universities should not focus on research outputs but should also be motivated to interact and collaborate with rural communities to co-create innovations that address some of the societal challenges in rural areas.

- The successful deployment of technological innovation in rural areas requires a coordinated approach that involves the national government, municipalities, tribal leaders, communities and private enterprises. For example, a water sectoral innovation system can be established where actors can share and exploit knowledge for economic and social purposes.

- It is recommended that municipalities reconsider integrated development plans to accommodate co-creation and technological innovations as an interim measure towards addressing water quality issues in rural areas.

- The chosen technological innovation should be aligned with community affordability and maintenance requirements ensure that long-term benefits are reaped from it.

- The technological innovation should incorporate features to improve ease of use, simplicity and usefulness to the communities.

- Incentives enterprises that contribute to development in rural areas through co-creation of solutions with them.

6.4 SUGGESTIONS FOR FUTURE RESEARCH

Research can be conducted whereby other types of innovation which apply to rural areas such as grassroots, the base of the pyramid and frugal innovation can be combined with the approach devised in this study. As an example, the filtration containers or other small low-technical components (taps, cleaning tools) can be co-manufactured in rural areas thereby creating jobs and industries in these communities.

Water quality issues do not only affect people living in rural areas as other areas such as informal settlements, high-density areas and farming regions also have similar challenges for which the proposed framework can be tested.

Other aspects of the rural water supply such as water quantity and sanitation emerged as issues that could be researched through a similar prism.

The qualitative assessment of the combination of the technology acceptance model with the innovation diffusion theory yield factors that affect the acceptance of innovations and adoption. A quantitative approach to building empirical relationships between these factors can be done for theory building.

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APPENDIX A: INTERVIEW PROTOCOL

Participant No.:_____ Age group: <30, 30-40, 40-50, 50+ Gender:__Male / Female____

Used the Tech (YES/NO), willing (YES/NO), available (YES/NO), +18 (YES/NO)

Interview Protocol: Community members

Thank you for agreeing to a meeting on such short notice. The purpose of the interview is to answer research questions on the topic "*Multi-agent value co-creation and technological innovation in rural water supply in South Africa*". I am delighted for your community to feature in this research.

Introductory Questions

1. Can you tell me about the water situation in your community before the water purification technology?
2. Who do you talk to about water issues in general?

Addressing key Research Questions

3. How is the community involved in the water purification project? What is your role in the project?
4. From your perspective, how does the water purification technology work?
5. What do you like about water purification technology? What don't you like or feel can be improved on the water purification technology?
6. On the water purification project, list the group of people you communicate with and how do you communicate with them?
7. What motivated you to use the water purification technology?
8. What good did the water purification project bring to the community in general? Examples
9. Besides getting clean water from the technology, what other activities was the community involved in within the water purification project?
10. Did the technology affect the traditions, cultural values and way of life of the community?

Closure

11. What other information about the water purification technology do you what to share which can help with the research?

Thank you for your time and input, and for granting this interview at short notice.

Interview Protocol: External agents (Researchers, local water authority, for-profit and social enterprises)

Thank you for agreeing to a meeting on such short notice. The purpose of the interview is to answer research questions on the topic "*Multi-agent value co-creation and technological innovation in rural water supply in South Africa*". I am delighted for your company to feature in this research.

Introductory Questions

1. In your perspective, briefly describe the water purification technology and its successes to date? Please mention, any key features that make it adaptable for rural areas?

Addressing key Research Questions

2. At community X, how was the water quality issue identified?
3. Looking at community X, what motivated your company to provide a solution to the water quality problem?
4. At community X, which stakeholders were (are) involved in this project, and please state their roles?
5. How would you describe your interaction with other agents and the community in the project?
6. How is collaborating with other agents aiding in technology transfer to communities and how has it contributed to your company?
7. What is the community involvement in this project and what feedback did you get from them?
8. Since we are dealing with a rural area, how have the customs, values, and traditions affected the implementation of the new technology?
9. What are the perspective, views, or concerns of the community regarding the project? How has that affected the deployment of the technology?

Closure

10. What are your closing comments? Could you kindly suggest any other persons who might have different perspectives, to possibly interview?

Thank you for your time and input, and for granting this interview at short notice.

Interview Protocol: Experts in the field of rural water supply using technological innovations

Thank you for agreeing to a meeting on such short notice. The purpose of the interview is to answer research questions on the topic "*Multi-agent value co-creation and technological innovation in rural water supply in South Africa*". I am delighted for you to feature in this research.

Introductory Questions

1. From your perspective, what is the general state of rural water supply in South Africa looking specifically at water quality? In your answer, include any stories of successes and failures?

Addressing key Research Questions

2. For successful deployment of a water quality solution in rural areas, which stakeholders should be involved, and please state their roles?
3. What could motivate a company to provide a solution to the water quality problem in rural areas?
4. In your opinion, how should stakeholders interact with each other and the community in solving water quality issues in the rural water supply?
5. How should stakeholders collaborate in aiding water quality solutions for communities?
6. How should the community be involved in water quality solutions?
7. Since we are dealing with a rural area with strong customs and traditional values. Could you please give me your opinion on the best way to ensure success in the implementation of the water quality solutions?

Closure

8. What are your closing comments? Could you kindly suggest any other persons who might have different perspectives, to possibly interview?

Thank you for your participation and attendance of the interview at short notice.

APPENDIX B: INTERVIEW REQUEST LETTER

Good Day,

I hope I find you well and safe. My name is Emmanuel Sakala and I am a master's in Innovation Studies student at the Wits business school in South Africa. As part of my master's program, I am doing research on the topic "*Multi-agent value co-creation, technological innovation in rural water supply in South Africa*", under the supervision of Prof Thembela Hillie.

The study seeks to generate insights into who and how various actors interact to deliver clean and sustainable water to rural areas in South Africa. It also intends to establish how technological innovation diffuses in rural areas despite the complex social dynamics by looking at it from an innovation perspective. As an expert in rural innovation, I would like to invite you for an interview (virtual / or one-one) together with information to help with the research. The interviews will take ~ 30 - 40 minutes of your time. Anonymous and confidentiality will be observed during the interviews. Data generated from the interviews will be kept securely and in a computer with password protection. If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. The information collected during the study will be used to write a research report which can be accessed from the university library website after completion of the studies. If the data is required to be used by other researchers, permission with be sought from you first.

For any concerns or complaints that might arise related to ethical procedures, please contact the University Human Research Ethics Committee (Non-Medical), by telephone at +27(0) 11 717 1408, email hrec-medical.researchoffice@wits.ac.za

Please find attached the ethics certificate from the university. Looking for your response.

Yours sincerely,

Researcher: Dr Emmanuel Sakala, 2517476@students.wits.ac.za

Supervisor: Prof Thembela Hillie, thembela.hillie@wits.ac.za