



# **Out-Of-The Box**

## **2018 Conference Proceedings**

24-25 October 2018

CSIR, Pretoria, South Africa

Out-Of-The Box 2018 Conference Proceedings

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ISBN 978-0-7988-5639-3

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## **Foreword by the Department of Science and Technology**

The primary goal of the Out-Of-The Box Conference was to underscore the importance of technology and innovation in achieving sustainable human settlements. The conference provided a platform for greater interaction amongst key stakeholders championing innovation and technology, particularly in the research community.

The conference also provided space to engage and reflect on enablers and barriers for innovation uptake in the human settlements sector.

The event generated views and opinions informing the sector transition process towards smart communities and green settlements.

It is our firm belief that science, technology and innovation has an immense role and contribution in helping communities to become sustainable, carbon neutral, resilient and energy efficient.

However, this requires a partnership approach, dedicate innovation programmes and interventions in the sector.

*Mr Tshepang Mosiea*

*Director for Science and Technology for Sustainable Human Settlements  
Department of Science and Technology*

## **The STI 4 SHS Roadmap**

Human habitats continuously evolve. Our understanding and approach to shaping them shifts over time. Since the birth of its democracy, South Africa has, on the one hand, allowed free markets to satisfy a portion of the needs for housing and neighbourhoods whilst establishing a formidable range of institutions and instruments - a veritable machine - to provide access to housing for [previously] marginalised households. However, a good look at the status quo reveals that business-as-usual is not producing satisfactory results to the extent needed.

The Property Sector Charter Council measured the size of the property market in South Africa at R5, 8 trillion in 2016. The formal residential property accounts for nearly three-quarters of property owned in South Africa, and grew from an estimated R3 trillion at the end of 2010 to current estimated R3.9 trillion. The total economic contribution to GDP of the residential property sector was R103, 7 billion, while it contributed R20, 1 billion to the fiscus through various forms of tax in 2012. A telling part of this research, is that, whilst informal residential property is quantified by the number of households provided by the Department of Human Settlements, it has been assigned no value.

With a Gini coefficient of 0.63 in 2015, South Africa is one of the most unequal societies in the world. A World Bank report in 2018 indicated that the top 1% of South Africans own 70.9% of the country's wealth while the bottom 60% controls 7% of the country's assets. Africa Check estimated that in 2015, 30 million people, or 55% of the population of South Africa, lived on less than R1000 per month.

Indications are that housing backlogs in South Africa are increasing. In 1994, backlogs were estimated to be 1.5 million, in 2011, 1.9 million and by 2017, 2.3 million. The cost of addressing housing backlogs by 2020 is estimated to be R800 billion, while the annual budget for 2018/19 for human settlements, including electrification and water programmes, was R56, 5 billion. Scaling up programmes to construct housing within budgeted timeframes can also be problematic and, in 2018, R600 million made available for new housing went unspent because of delays.

The Department of Water and Sanitation's Water Reconciliation All Town Study indicates that water resources in 30% of South Africa's towns are already in deficit. It suggests that water shortages are expected in at least another 15% of South Africa's towns in the next five years, with an addition 12% of towns also suffering shortages in the five years following this.

Existing spatial patterns and poor housing reinforce poverty levels by requiring poorer households to spend a large proportion of their household incomes on travel and basic services. On average, low-income households spend 20% of their incomes on transport and 34% on food. Occupants of low-cost housing can also spend as much as 20% of their income on heating in winter and inappropriate heating methods can lead to suspended particulates being well over World Health Organisation guidelines leading to a significant health problems.

In South Africa, human settlements are associated with significant carbon emissions and residential buildings consume 13% of South Africa's energy and generate 25 million tons of carbon dioxide emissions per year. The manufacture of building materials and components, much of it used in new housing, consumes another 5% of South Africa's energy.

Against the backdrop of the current status quo described above, is a trajectory which is likely to see continuing rapid urbanisation, locally as globally, with growing city populations, infrastructure strain, hollowing rural areas and deepening vulnerabilities. Climate change and resource scarcity render our goals and commitments (NDPs, SDGs and others) an imperative to build resilience in face of emerging threats to water and food security.

Science, technology and innovation may have a crucial contribution to make in transforming and shaping our future human habitats, to avert and cope with the challenges which lay ahead, and to realise the potential of South Africa's human settlements to provide for a decent standard of living; safe, resilient and sustainable households and neighbourhoods. Yet, that science, technology and innovation plays such a role is not inevitable, nor is it immediately evident, what its best contribution would look like or how such a course would be chartered.

At the 2017 National Department of Human Settlements Development Summit, the opportunity was identified to respond to these challenges by means of upscaling the use of innovation and transformative technologies as a means to support new human settlements required by accelerated urbanisation, as well as for the upkeep and renewal of existing settlements. The assigned summit commission resolved to adopt a defined agenda and plan - that is the STI 4 SHS Roadmap - for the up-scaling of innovation and implementation of alternative

technology solutions for smart cities with a community approach. In 2018 the Department of Science and Technology initiated a two year roadmap definition process to define a flexible, yet robust framework, to respond to and support emerging innovative technologies, in a systematic and evidence-based manner, so that appropriate technologies can be identified and mainstreamed.

This STI 4 SHS Roadmap for the adoption of science, innovation and technology for sustainable human settlements will be crafted between April 2018 and March 2020, and implemented over the following ten years. An extensive consultation process with role-players and key stakeholders, as well as intensive research is to be employed in the development of the STI 4 SHS roadmap.

The 2018 Out-of-the-Box Human Settlement Conference was conceived as a platform for academic thought leaders to make a first contribution to the conversation from the academic community's perspective. These proceedings, flowing from the constructive two day conference and parallel engagements, cover a broad range of themes and communicate some very important key lessons to be taken forward in the Roadmap.

*Ms Peta de Jager and Dr Jeremy Gibberd.*

This text is substantially based on the *STI 4 SHS Draft Status Quo Report*.

## **The Academic Session**

### **Introduction**

As part of the Out-of-the-Box Human Settlements Conference, an Academic Panel was scheduled to enable selected academics to provide their insights on the conference themes. Proceedings of the panel session were recorded and are outlined below.

### **Members of the Academic Panel**

Dr Jeffrey Mahachi, University of Johannesburg

Dr Sithembiso Myeni, University of Kwa Zulu Natal

Prof Sijekula Mbang, Nelson Mandela University

Prof Soyez, University of Potsdam (Germany)

Dr Philip Stott, Central University of Technology Bloemfontein

Dr Darlington Onojaefe, Cape Peninsula University of Technology

Prof Amira Osman, Tshwane University of technology

Prof Mark Napier, CSIR

Dr Jeremy Gibberd, CSIR (Chair)

### **Panel Session Format**

The panel session provided an opportunity for Academics to discuss key issues at the conference. The questions below were emailed to the panel in advance of the conference and were used to structure the discussion. Proceedings were recorded and the session lasted about two hours.

### **Key Questions**

- A. **Needs:** What are the 2-3 key/pressing needs in South African human settlements that could be addressed through science, technology and innovation?
- B. **Science, technology and innovation:** What 2-3 science, technology and innovation interventions do you think could make the most significant difference to people living in South African human settlements, particular in underserved areas?
- C. **Implementation:** How can the interventions you have identified be implemented? Who should do this? How should implementation be funded? Are there particular prerequisites, models and partnerships required? If so, what do these look like?

### **Distilled Themes from Panel Discussion**

The themes outlined below were drafted by the Panel Chair, Jeremy Gibberd. Views within the panel were diverse and sometimes divergent so the themes below do not represent a shared, consensus view but rather a distillation by the Chair of some of the concepts and ideas that were shared.

1. **Partnerships:** There was a view that better working partnerships were required to improve housing delivery and the integration of valuable technologies into existing and new human settlements. Current delivery of low-cost housing is isolated to one or two government departments and this arrangement limits the potential for innovation and the scaling up delivery. It

was therefore recommended that opportunities for collaboration and the co-production of human settlements and technologies should be taken.

2. **'The poor'**: There was a view that many housing and technology solutions claimed to address 'the poor'. This is problematic for a number of reasons. Firstly, designers who developed solutions for 'other people' may not have made the effort to understand the issues sufficiently and sometimes inappropriate solutions were developed. Secondly, this approach does not empower users who are regarded as passive recipients. Thirdly, this approach tended to result in a 'poor' and a 'normal' solution which lead the perception that some solutions were inferior. Instead a more universal approach may be appropriate. Thus, for instance, in a very water-scarce area, the same water-saving sanitation could be used in wealthy suburbs as well as in poorer areas. This would avoid the perception that 'second-class' technologies were being provided to poor people.
3. **Neighbourhood**: The concept of the neighbourhood was considered to be undervalued and it was thought that human settlement development in South Africa should promote this idea more strongly. It was argued that beneficial aspects of neighbourhoods such as local schools, parks and recycling schemes, local economies and social interaction and organisations, such as neighbourhood groups, should be promoted. These aspects, it was argued, could greatly enhance the quality of life of inhabitants as well as having a range of sustainability benefits.
4. **Codes and Competencies**: The quality of low-cost housing in many new developments in South Africa was considered problematic. Problems include inadequate foundations, inferior materials, poor workmanship and non-compliant construction techniques. This has led to the requirement for rectification programmes which are a waste of resources and disrupt the lives of occupants. Defining quality standards and processes may help address this situation. This could include ensuring that quality standards are defined and properly adhered to. This can be supported by effective contracting and appointment documentation, explicit quality assurance procedures and enhanced technical capacity within the client, contractors and professional teams.
5. **Specialisation**: Levels of technical expertise to address current and emerging issues in human settlements were considered insufficient. Climate change, the upgrading of informal settlements and renewable energy systems, for instance, need to be addressed and are not catered for in current built environment professional team capabilities and training. Specialist courses and focussed modules in built environment professional curricula to address these emerging issues are recommended.
6. **Innovation**: It was argued that innovation in South African human settlements should be made more exciting and be mainstreamed by marketing this better. Lessons could be learnt from France where innovation is regarded as desirable and is promoted very effectively.
7. **Community Practices**: There was a view that we do not learn enough from current practices. For instance, communities and households have processes of developing dwellings and settlements that can be used and refined to create more responsive human settlements. An example of this is the 'flat-pack' timber and corrugated iron house sometimes found on roads into townships that can be bought, transported in a pick-up truck and erected in about an hour.
8. **Vision**: There was a view that we need to develop and test ideas about what sustainable human settlements are. In particular, researchers and academics needed to work with local government to pilot new approaches that show potential for improving the sustainability of new settlements and learn from this process.
9. **Criteria**: Improving the efficiency, effectiveness and sustainability of human settlement construction and products requires explicit and quantifiable objectives, criteria, targets and measurement protocols. It was therefore argued that these should be developed and rigorously applied to benchmark existing processes and test alternatives that could lead to better performance.

## **The Peer Review Process**

A full double blind peer-review process was followed for the Out-of-the Box Conference. This included a double-blind peer review process for all abstracts. A double-blind peer review of all full papers was also undertaken.

Reviews were undertaken by the Review Committee under leadership of the Scientific Committee. The committees were established through peer recommendation and consists of highly experienced senior academics and built environment professionals.

A full list of members of the Scientific and Review Committees is below.

Full papers also received final editing and quality checks before being included in the proceedings.

### **Scientific Committee**

Dr Jeremy Gibberd, CSIR, South Africa

Dr Dirk Conradie, CSIR, South Africa

Mr Llewellyn van Wyk, CSIR, South Africa

Ms Peta de Jager, CSIR, South Africa

Ms Lorato Motsatsi, CSIR, South Africa

Dr Jeffrey Mahachi, University of Johannesburg, South Africa

Dr Sithembiso Myeni, University of Kwa Zulu Natal, South Africa

Prof Sijekula Mbanga, Nelson Mandela University, South Africa

Prof Babatunde Agbola, Mangosuthu University of Technology (MUT), South Africa

Dr Jennifer Mirembe, South Africa, National Department of Human Settlements

### **Reviewers**

Dr Jeremy Gibberd, CSIR, South Africa

Dr Dirk Conradie, CSIR, South Africa

Mr Llewellyn van Wyk, CSIR, South Africa

Mr Steve Szewczuk, Private, South Africa

Ms Naamlamkai Ampofo-Anti, Private, South Africa

Dr Jeffrey Mahachi, University of Johannesburg, South Africa

Dr Sithembiso Myeni, University of Kwa Zulu Natal, South Africa

Prof Sijekula Mbanga, Nelson Mandela University, South Africa

Prof Babatunde Agbola, Mangosuthu University of Technology (MUT), South Africa

Ms Taahira Goga, University of Witwatersrand, South Africa

Dr Jennifer Mirembe, South Africa, Department of Human Settlements

Prof Gerhard Bosman, University of Free State, South Africa

Prof Amira Osman, Tshwane University of technology, South Africa

Prof Fidelis Emuze, Central University of Technology, South Africa

Dr Darlington Onojaefe, Cape Peninsula University of Technology, South Africa

Prof Brian Wasserman, South Africa, State University of Minnesota, USA

Prof Miklas Scholz, Lund University, Sweden

Prof Silke Flassnoecker, HS-Wismar University of Applied Sciences, Germany

## Neighbourhood 4.0: A response to urban futures

AK Cooper<sup>1,2</sup>, N Sebake<sup>1</sup>

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<sup>2</sup> Centre for Geoinformation Science, University of Pretoria

### ABSTRACT

South Africa's commitment to meeting the Sustainable Development Goal (SDG) 11, "*Make cities and human settlements inclusive, safe, resilient and sustainable*", requires the country to have an understanding of the range of possible, likely and preferred urban futures. With concepts such as digital cities, smart cities, smart infrastructure, smart places and urban resilience, it is evident that there has been some consideration of cities and infrastructure of the future. However, little is known about urban futures at a neighbourhood level. Therefore, the idea of investigating possible urban futures provides an opportunity for exploring the implications of the global forces of change and urban issues that are shaping not only cities, but neighbourhoods as well.

The "*Fourth Industrial Revolution*" and "Industry 4.0" are labels being applied now to the era of cyber-physical systems that go beyond mere automation, with industries and systems that are decentralized but integrated and transparent, self-optimizing, self-configuring and self-diagnosing. It encompasses concepts such as smart factories, the Internet of things, and highly-flexible mass customization. Broadly, the Third Industrial Revolution was then driven by computers, the Second by electricity and the First by steam power.

Whether hyperbole or a fad or a black swan or the natural evolution of automation or a paradigm shift or even a new opportunity for developing countries to leapfrog past the developed world, what are the implications of the Fourth Industrial Revolution for human settlements? What is needed by cities, towns, neighbourhoods and dwellings to benefit from Industry 4.0? Will Industry 4.0 benefit only human settlements that are well resourced and populated by the rich and well-educated, or can Industry 4.0 actually benefit impoverished communities?

This paper considers the neighbourhood of the future, or Neighbourhood 4.0. Our research aims at identifying and understanding the neighbourhoods of the future, because they are unlikely to face the same challenges neighbourhoods face now.

Keywords: Industry 4.0, Neighbourhood 4.0, Urban Futures, Sustainable Development Goals, Urbanization

## 1 INTRODUCTION

### 1.1 URBANISATION AND MEGACITIES

Globally, the proportion of people living in urban areas is expected to grow from 47% in 2000 to 50% in 2014, 60% by 2025 and 67% (or 6.6 billion people) by 2050. Most of this growth is expected in developing countries, as people move from rural areas (Cooper & Du Plessis, 2008; United Nations, 2017). Although urbanisation is not new, its speed, scale and scope in the past decades has been unprecedented in world history, with more people living in urban areas than in rural areas. This has an impact on the future (Karuri-Sebina *et al.*, 2016).

This phenomenon is resulting in an increase in the megacities phenomenon, including for instance, Lagos (Nigeria), Dhaka (Bangladesh), Mumbai (India) and New York (USA) (Karuri-Sebina *et al.*, 2016). Megacities house over 10 million people (Cooper & Du Plessis, 2008), and typically have extremely high population density levels, ranging from 20,000 to 30,000 people per square kilometre (Karuri-Sebina *et al.*, 2016). These higher densities are resulting in the formation of new, unique settlement patterns and urban forms.

Although, South Africa does not yet technically have megacities, the combination of the three metropolitan municipalities in Gauteng (Johannesburg, Tshwane, and Ekurhuleni) reflects all the characteristics of a megacity. Together they cover some 5,765 km<sup>2</sup>, and their combined population rose from some 7,7 million in 2001 to as much as 10,5 million in 2011 (Cooper & Du Plessis, 2008; StatsSA, 2018). Given the predominance of a low-density housing model, South Africa's urban environments are among the most inefficient and wasteful

globally (Du Plessis & Landman 2002). Still primarily based on a low-density housing model, this has resulted in the formation of settlements that sprawl over large areas, making it expensive for to deliver housing and basic services to furthest (often poorest) households (Cooper & Du Plessis, 2008; National Planning Commission, 2011).

In addition to unique urban forms, this rapid urban growth makes it difficult for cities to manage their already pressurised resource base (Zimmerman, 2014; Karuri-Sebina *et al.*, 2016).

## 1.2 RATIONALE

Urbanisation is inevitable, and the trend of rapid urban growth is likely to continue well into the future (Chakraborty, *et al.*, 2015). To meet the needs associated with an increasing urban population, cities must be more innovative in their approaches to improve the efficiency of their operation (Guzmán Araña, 2014).

It is therefore important that this phenomenon is studied, not only to understand how megacities function, but also how their ecology may be managed (Cooper & Du Plessis, 2008). With concepts such as digital cities, smart cities, smart infrastructure, smart places and urban resilience becoming prominent in both research and implementation, there is evidence that there has been some consideration of cities and infrastructure of the future.

There is relatively little known about urban futures at a neighbourhood level. Despite this, there are a number of ways that communities are responding to urban futures and the need for housing and services at a neighbourhood level, a level at which urban dwellers are most affected. Current trends in neighbourhoods include gentrification, ethnic enclaves, redlining, formation of informal settlements, backyard shacks, gated communities, rent control, high-rise public housing, slum clearance, sprawl and shared space (no segregation between pedestrians and vehicles), all of which can be considered undesirable and have unexpected consequences, depending on the circumstances.

Gibberd (2013) argues that built environment development strategies need to be developed at a neighbourhood level to make the day-to-day living patterns of the community more sustainable over time. Glaser *et al* (2012) concur, adding that planning of “the city at eye level” (which they term street plinths) is better, particularly so that pedestrians feel safe and comfortable and are captivated by what they see, smell and hear.

## 1.3 THE OUTLINE OF THE PAPER

In this paper we begin by describing the neighbourhood, we then provide some background on the Industrial and other revolutions, prior to outlining the international imperative and national policy and legislative framework on urban futures. Thereafter, we consider the impact of the Sustainable Development Goals and the apparent new paradigm of the Fourth Industrial Revolution on Neighbourhood 4.0. Lastly, we present some emerging characteristics of Neighbourhood 4.0 before concluding.

## 2 THE NATURE OF A NEIGHBOURHOOD

A neighbourhood is defined as “*a district or community within a town or city*” (OUP, 2018). It consists of a collection of buildings (e.g. private dwellings, commercial and government buildings), internal streets and/or paths and perhaps designated (and even controlled) entrances and exits, and public open spaces.

A neighbourhood can be delineated by a barrier (i.e. a mountain, river, railroad or highway), a change in land use (i.e. an industrial area adjacent to a residential neighbourhood), legal requirements (i.e. zoning) or by social convention. Alternatively, a neighbourhood could be determined by its core (such as the neighbourhood shops), by its homogeneity (i.e. building styles or sizes, demographics, etc.), by some arbiter of taste (e.g. delineating an historic district), by a developer (e.g. Jonathan Liebmann’s creation of the Maboneng Precinct in Johannesburg (GTA, 2018)), or some arbitrary characteristics. Consequently, a neighbourhood can straddle administrative or cadastral boundaries, i.e. across suburbs or original farms (in South Africa). Neighbourhood boundaries can be fixed or fuzzy. They can change as the environment changes, particularly due to new construction, i.e. a new highway splitting up an old neighbourhood. Neighbourhoods can be isolated by their boundaries through barriers or buffer strips, sometimes done deliberately, for instance under Apartheid in

South Africa (Landman, 2000), as peace lines in Northern Ireland (Department of Justice, 2017) and ghettos throughout history, most notoriously those of Nazi Germany (Yad Vashem, 2018).

Residents themselves can also isolate themselves intentionally in enclosed neighbourhoods with controlled access, with the aim of improving their safety and quality of life (Landman, 2000). The *Guidelines for Human Settlement Planning and Design*, commonly known as the Red Book, supports this notion stating that, “residents of South African cities should be encouraged to again assume ownership of their neighbourhoods. This is essentially a case of territoriality... [which is] a sense of ownership of one’s living or working environments” (CSIR, 2000).

The success of a neighbourhood is generally determined by, and determines, the community’s social cohesion. This is largely independent of the skills and the resources of the individual community members, because the actions required need just time and effort, e.g. keeping the streets and properties clean, looking out for one’s neighbours, looking after and socialising children, conducting patrols and supporting local events. It also needs inhabitants interested in face-to-face social interactions and a balance between the self-interests of the individuals and the interests of the community within a neighbourhood (Glaser *et al*, 2001; Wikipedia, 2018b). Typically, a neighbourhood provides some services to the community and has some sort of a core, whether obvious (such as a square or a cluster of shops) or implied. Indeed, the absence of an obvious core might imperil the potential success of the community. Successful neighbourhoods are then more liveable, more enjoyable and safer.

### 3 INDUSTRIAL AND OTHER REVOLUTIONS

#### 3.1 OVERVIEW

The Fourth Industrial Revolution and Industry 4.0 are labels that are being applied now to the era of cyber-physical systems that go beyond mere automation, with industries and systems that are decentralized but integrated and transparent, self-optimizing, self-configuring and self-diagnosing. It encompasses concepts such as smart factories, the Internet of things, and highly-flexible mass customization, and was introduced by the Industry 4.0 Work Group of the Federal Ministry of Education and Research in Germany (BMBF, 2017). Broadly, the Third Industrial Revolution was then driven by computers, the Second by electricity and the First by steam power. Toynbee (1884) first popularised the term *industrial revolution* (in English, at least), though Engels (1845) wrote “*Diese Erfindungen gaben bekanntlich den Anstoß zu einer industriellen Revolution*” (but was only translated into English in 1892), and the term was used loosely in French before that (Griffin, 2013), such as by Briavoinne (1837), “*C’est dans ce moment que la révolution industrielle commence*”.

#### 3.2 EARLY REVOLUTIONS

Before the Industrial Age though, there were a number of periods of technological innovation and development that could have been considered to be industrial revolutions (and hence the first), though they are generally considered to be agricultural rather than industrial revolutions (Britannica 2018, Wikipedia 2018a, 2018c-2018n). These include:

- The Neolithic or First Agricultural Revolution, introducing the likes of farming, towns, pottery and proto-writing;
- The Bronze Age, introducing bronze, brass, glass, writing systems, navigation and long-distance trade); the Iron Age (cast and wrought iron, and carbon steel);
- The Romans introducing the mechanical reaper, wheeled plough, screw press for pressing olives, greenhouse, foot-powered loom, glassblowing, aqueduct and weatherproof roads;
- The Medieval Renaissances, specifically the Renaissance of the 12th century, which introduced gunpowder (to Europe), vertical windmills, spectacles, mechanical clocks, Gothic architecture, three-field crop rotation and universities (the Carolingian and the Ottonian Renaissances, from about 770 to 1000, were primarily within the courts and dependent on royal patronage, but did standardise Medieval Latin, calligraphy and currency);
- The Scientific Revolution, from the Renaissance to the Enlightenment (mid 16th to late 18th centuries), introduced the scientific method, printing press, heliocentric solar system, gravity, anatomy, modern chemistry, optics, electricity, calculus, refracting and reflecting telescopes, vacuum pump, mercury barometer and microscope; and

- The British Agricultural Revolution, from the mid-17th Century to, and overlapping with, the First Industrial Revolution, introduced the four-field crop rotation; single national market free of tariffs, tolls and customs barriers; selective breeding of livestock; and canals.

As summarised above, these agricultural and industrial revolutions were primarily supply driven, but some consider them to have been facilitated by surpluses (that can be spent on developing and implementing the new technologies) and the enabling political environment, and to have been preceded by increasing demand.

### 3.3 INDUSTRIAL REVOLUTIONS

The First Industrial Revolution was the transition from manual and animal power to steam power, from agrarian and rural societies to industrial and urban ones, and from cottage industries to the factory system; canals and railroads; textiles, iron and chemicals; the development of standard components and machine tools; capitalism, organised labour and increasing literacy, social reform and mass political participation. It began in Great Britain in the mid-1700s in textile manufacturing and spread rapidly to Europe and North America. It coincided with The Enlightenment, which emphasised the scientific method, reductionism (understanding the characteristics of the parts of a system and of the system itself) and questioning of orthodoxy, which obviously can help spur the thinking needed for a paradigm shift such as an industrial revolution.

The Second Industrial Revolution (or *Technological Revolution*) was driven by electricity, steel, oil, railways, telecommunications, industrial chemistry and metallurgy; and introduced production lines, mass production, control theory, accounting, scientific management, all-weather roads, bicycles, automobiles, aircraft, plastics, radio and universal time; allowed much greater construction works and more powerful engines; and globalization. It was first recognised by Geddes (1915), "... a new economic order a Second Industrial Revolution is once more arising, requiring corresponding changes in economic theories, corresponding expression in its turn". It began around 1870, after the American Civil War (1861-5) and the Meiji Restoration in Japan (1868), and with the unification of Germany after the Franco-Prussian War (1870-1). It started in Western Europe, North America and Japan, and is considered to have been ended by the First World War in 1914. Obviously, industrial development continued during the War and while primarily focused on military technologies and processes (e.g. tanks, tracer bullets and aircraft carriers), it did yield spin-offs for civilian use, such as modern plastic surgery, sanitary napkins, mobile X-ray machines and daylight saving time, and due to the high numbers of women working for the war effort in factories and so on, helped to accelerate the granting of voting rights for women around the world. After World War One, significant industrial developments included liquid-fuelled rockets, television, the electric razor, frozen food and purified insulin.

The Third Industrial Revolution (or *Digital Revolution*) has been driven primarily by transistors, semiconductors, computers, communication technology, software and digital data storage. It began in the 1950s, primarily in North America and Great Britain, leveraging off the technologies they developed and used during the Second World War for cryptography, ballistics, the atomic bomb and so on. Hilton (1964) referred to the scientific-social-technological-economic-cultural revolution and the cybercultural revolution. It is not clear when the terms Third Industrial Revolution and Digital Revolution were first used, but by 1982 the International Conference on Communication had as its theme, The Digital Revolution (Schoppe, 1982). We are still in this era, with personal computers, smartphones, the Internet, the World Wide Web, digital social networks, electronic commerce – and information overload, digital surveillance, spam and fake news!

At the same time, but not really connected, the Green Revolution (or Third Agricultural Revolution) took place between 1950 and 1970, delivering high-yielding varieties of cereals and increased use of chemical fertilizers, agro-chemicals, irrigation and mechanization. It is alleged that the Green Revolution saved 1 billion people from starvation by 1970.

The industrial revolutions do not have rigid boundaries, can overlap, occurred at different rates in different parts of the world and are not necessarily linear. For example, a subsistence farmer could plough with an animal-drawn plough (pre-Industrial Age) drawing a standard plough (First Industrial Revolution), and deliver their surplus food to market by truck (Second Industrial Revolution), having used an app on their smartphone to select the best market.

Neighbourhoods began with the Neolithic Revolution and the introduction of towns, as inhabitants needed to band together to survive and thrive. Figure illustrates how the various ages discussed in this section have contributed to the development of neighbourhoods.

### 3.4 FOURTH INDUSTRIAL REVOLUTION

Some are sceptical that there actually is a Fourth Industrial Revolution now, because innovation is continuous and non-linear and exponential growth occurs at any time, not just when any industrial revolution might start (Garbee, 2016). Hence, one could consider it to be Industry 3.1. Further, the 4th Industrial Revolution was proclaimed in 1940 for modern communications, in 1948 for atomic energy, in 1955 for electronics, in the 1970s for computers, in 1984 for information, and then for nanotechnology (Garbee, 2016).

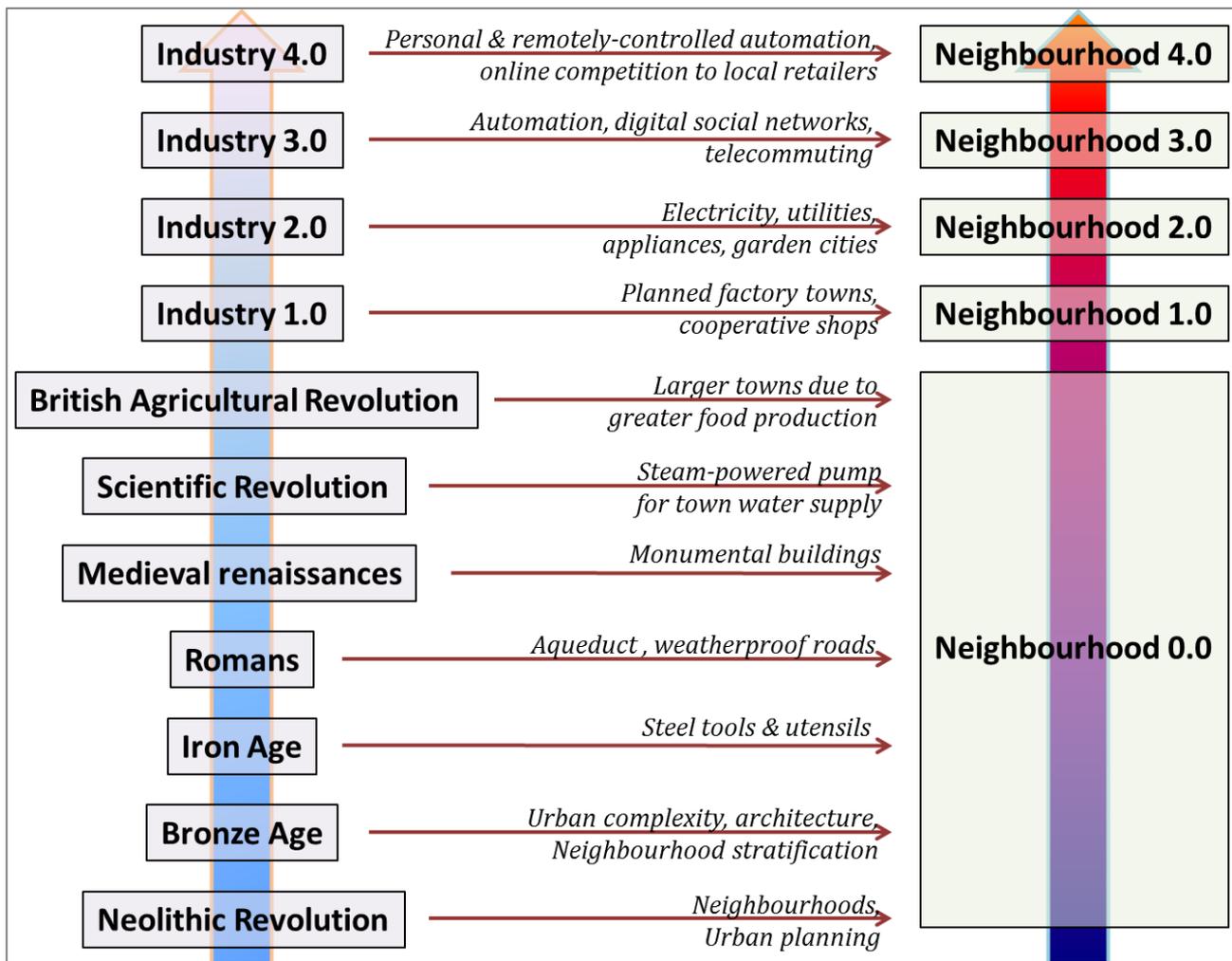


Figure 1 The industrial ages and neighbourhoods

In her speech on 17 May 2018 introducing the Budget Vote for the Department of Higher Education and Training, Minister Naledi Pandor identified three features of society that she regards as a challenge to action for higher education: protests around #feesmustfall; the need to produce skilled human resources; and the Fourth Industrial Revolution. For this third challenge, she intends “to create a multi-stakeholder task team to advise us on how we should take up opportunities of the 4th Industrial Revolution” (Pandor, 2018).

Of great concern in South Africa, though, are the high levels of poverty, the lack of skilled labour, the poor condition of the education system and de-industrialization. These really need to be addressed before South Africa can make a significant impact on Industry 4.0 – though individuals and companies might become world leaders in Industry 4.0 in their own right.

Whether hyperbole or a fad or a black swan or the natural evolution of automation or a paradigm shift or even a new opportunity for developing countries to leapfrog past the developed world, what are the implications of the Fourth Industrial Revolution for human settlements? What is needed by cities, towns, neighbourhoods and dwellings to benefit from Industry 4.0? Will Industry 4.0 benefit only human settlements that are well resourced and populated by the rich and well-educated, or can Industry 4.0 actually benefit impoverished communities?

## 4 INTERNATIONAL IMPERATIVE AND NATIONAL POLICY AND LEGISLATIVE FRAMEWORK ON URBAN FUTURES

### 4.1 INTERNATIONAL IMPERATIVE

#### 4.1.1 Sustainable Development Goals (SDGs)

The seventeen Sustainable Development Goals (SDGs) were adopted through a resolution of the United Nations on 25 September 2015 (United Nations, 2015b). These SDGs are wide ranging, having 169 targets and 304 indicators. The SDGs succeeded the eight Millennium Development Goals (MDGs), which ran from 2000 to 2015 (United Nations, 2015a). Both the MDGs and SDGs have aimed at addressing critical existing problems, with the MDGs even being beyond the reach of some countries. It should be noted however, that the MDGs and SDGs were never intended to be visionary statements of the future with stretching targets for all countries, rather they were meant set measurable and realistic goals for improving lives and the environment globally. For example, the word 'future' is mentioned only once amongst the goals, targets and indicators, in Target 14.c, and then only in referencing the document "*The future we want*" (United Nations, 2015b). Hence, the SDGs will be easy for some countries to achieve, but difficult for others. Regardless of this, the SDGs provide a baseline for any decent neighbourhood of the future. The 17 SDGs are:

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10. Reduce inequality within and among countries
- Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts\*
- Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development
- Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development (United Nations, 2015b).

None of the goals, targets and indicators explicitly mentions the words '*smart*', '*digital*', '*neighbourhood*' or '*suburb*'. The word 'automation' is mentioned only once in terms of the penetration of automated teller machines (ATMs) for Indicator 8.10.1.

Of particular relevance for any consideration of neighbourhoods is obviously Goal 11, Make cities and human settlements inclusive, safe, resilient and sustainable, as discussed below. However, even though the targets and indicators are generally at a high level for the country as a whole (e.g. Indicator 1.1.1, *Proportion of population below the international poverty line*), there are specific targets and indicators from the other Goals that are relevant for neighbourhoods, as discussed below in Table 1.

Table 1 SDG 11 targets and indicators (United Nations, 2015b & 2018)

| Target                                                                                                                                                                                                                                                                                                                                                                                                    | Indicator                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Neighbourhood relevance                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11.1 By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums                                                                                                                                                                                                                                                                                         | 11.1.1 Proportion of urban population living in slums, informal settlements or inadequate housing                                                                                                                                                                                                                                                                                                                                                           | This addresses the character of neighbourhoods directly.                                                                                                                                                                                                                               |
| 11.2 By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons                                                                                                 | 11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities                                                                                                                                                                                                                                                                                                                                   | While primarily about transport, this reflects on the accessibility of public transport from within neighbourhoods, though it is not clear how 'convenient' is to be measured.                                                                                                         |
| 11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries                                                                                                                                                                                                                         | 11.3.1 Ratio of land consumption rate to population growth rate                                                                                                                                                                                                                                                                                                                                                                                             | This is measured nationally, but the neighbourhoods of the future will determine if their consumption of land is appropriate.                                                                                                                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                           | 11.3.2 Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically                                                                                                                                                                                                                                                                                               | Not about neighbourhoods specifically.                                                                                                                                                                                                                                                 |
| 11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage                                                                                                                                                                                                                                                                                                                | 11.4.1 Total expenditure (public and private) per capita spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and World Heritage Centre designation), level of government (national, regional and local/municipal), type of expenditure (operating expenditure/investment) and type of private funding (donations in kind, private non-profit sector and sponsorship) | This is relevant for each and every neighbourhood, where their cultural and natural heritage needs to be identified first, and then neighbourhood value determined, before being preserved, protected and conserved appropriately. Unfortunately, expenditure is a poor measure alone. |
| 11.5 By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations                                                                                 | 11.5.1 Number of deaths, missing persons and persons affected by disaster per 100,000 people                                                                                                                                                                                                                                                                                                                                                                | Resilience to disasters applies also at the neighbourhood level. The actual indicators will be determined by the <i>Sendai Framework for Disaster Risk Reduction 2015 – 2030</i> (United Nations 2015c).                                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                                           | 11.5.2 Direct disaster economic loss in relation to global GDP, including disaster damage to critical infrastructure and disruption of basic services                                                                                                                                                                                                                                                                                                       | As above.                                                                                                                                                                                                                                                                              |
| 11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management                                                                                                                                                                                                                                 | 11.6.1 Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities                                                                                                                                                                                                                                                                                                            | Relevant to neighbourhoods, particularly as zero waste, or as local production and consumption.                                                                                                                                                                                        |
|                                                                                                                                                                                                                                                                                                                                                                                                           | 11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)                                                                                                                                                                                                                                                                                                                                                  | Relevant to neighbourhoods, particularly those dependent on burning fuel in the home for heating and cooking.                                                                                                                                                                          |
| 11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities                                                                                                                                                                                                                      | 11.7.1 Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities                                                                                                                                                                                                                                                                                                                    | Open spaces need to be at the neighbourhood level, otherwise they are not accessible to many. Further, the community will then take ownership of their open spaces.                                                                                                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                           | 11.7.2 Proportion of persons victim of physical or sexual harassment, by sex, age, disability status and place of occurrence, in the previous 12 months                                                                                                                                                                                                                                                                                                     | Interventions need to be at the neighbourhood level, but accessing the statistics is currently a problem in South Africa.                                                                                                                                                              |
| 11.a Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning                                                                                                                                                                                                                                      | 11.a.1 Proportion of population living in cities that implement urban and regional development plans integrating population projections and resource needs, by size of city                                                                                                                                                                                                                                                                                 | Hopefully, such planning will consider neighbourhoods explicitly.                                                                                                                                                                                                                      |
| 11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels | 11.b.1 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015-2030                                                                                                                                                                                                                                                                            | Risk reduction strategies apply also at the neighbourhood level. The actual indicators will be determined by the <i>Sendai Framework for Disaster Risk Reduction 2015 – 2030</i> (United Nations 2015c).                                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                                           | 11.b.2 Number of countries with national and local disaster risk reduction strategies                                                                                                                                                                                                                                                                                                                                                                       | A national measure.                                                                                                                                                                                                                                                                    |
| 11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials                                                                                                                                                                                                                                   | 11.c.1 Proportion of financial support to the least developed countries that is allocated to the construction and retrofitting of sustainable, resilient and resource-efficient buildings utilizing local materials                                                                                                                                                                                                                                         | While a national measure, it is about localization and sustainable, resilient and resource-efficient buildings at the neighbourhood level.                                                                                                                                             |

South Africa's commitment to meeting the Sustainable Development Goal (SDG) 11 requires the country to have an understanding of the range of possible, likely and preferred urban futures. With concepts such as digital cities, smart cities, smart infrastructure, smart places and urban resilience, it is evident that there has been some consideration of cities and infrastructure of the future. However, little is known about urban futures at a neighbourhood level. Further, the 10 Targets and 15 Indicators for SDG 11 do not mention 'future', 'innovation', 'smart', 'digital', 'automation', 'neighbourhood' or 'suburb' explicitly. Therefore, the idea of investigating possible urban futures provides an opportunity for exploring the implications of the global forces of change and urban issues that are shaping not only cities, but neighbourhoods as well.

The relevance for neighbourhoods of the targets and indicators for SDG 11 are explored in Table . Table 2 discusses relevant targets and indicators from the other SDGs. The first two columns present the targets and indicators verbatim, with the third column providing an assessment of the relevance of the targets and indicators to neighbourhoods. It becomes clear that there are more indicators that need to be developed for some targets and even those indicators measured at a national level can be relevant to neighbourhoods directly. It may be argued, therefore, that a country needs successful and resilient neighbourhoods to achieve all the SDGs.

#### 4.2 RELEVANT TARGETS AND INDICATORS IN THE OTHER SDGS

Examples of targets and indicators from the other 16 SDGs that are relevant for neighbourhoods are discussed Table .

Table 2 Selected SDG targets and indicators (United Nations, 2015 & 2018)

| SDG | Target                                                                                                                                                                                                                                                                                                                                       | Indicator                                                                                                                                                                         | Neighbourhood relevance                                                                                                                                                                    |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | 1.4, By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance | 1.4.1 Proportion of population living in households with access to basic services                                                                                                 | <i>While a national measure, it concerns service delivery to each and every neighbourhood. There should also be indicators for property ownership and the other aspects of Target 1.4.</i> |
| 6   | 6.b Support and strengthen the participation of local communities in improving water and sanitation management                                                                                                                                                                                                                               | 6.b.1 Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management | <i>This is explicitly about neighbourhoods and direct community participation.</i>                                                                                                         |

#### 4.3 (URBAN) FUTURES LEGISLATIVE AND POLICY FRAMEWORK

There are a number of ways policy currently responds to possible urban futures, though much of this and of urban future studies focus on the higher, regional or city level, or on dwelling units and other buildings. Recent South African legislation and policy emphasise the importance of the future. The National Development Plan 2030 (NDP) contains a lengthy vision statement, which calls for "a national discussion on the future of towns, cities and rural settlements" (National Planning Commission, 2013). The Overview of the NDP also hopes that: "Our homes, neighbourhoods, villages, towns, and cities are safe and filled with laughter". Declarations about the future are made in both the Local Government: Municipal Systems Act (MSA) and the Spatial Planning and Land Use Management Act (SPLUMA) (South Africa, 2000 & 2013). To this end, both these Acts require municipalities to formulate vision statements concerning development.

Section 12(1) of SPLUMA determines that "the national and provincial spheres of government and each municipality must prepare spatial development frameworks that-(b) are informed by a long-term spatial development vision statement and plan" and section 21 says that "a municipal spatial development framework must – (c) include a longer term spatial development vision statement for the municipal area which indicate desired spatial growth and development patterns for the next 10 to 20 years". Section 26 (5) further instructs that "a municipality may, after public consultation, amend its land use scheme if the amendment is – (c) in order to further the vision and development goals of the municipality."

Section 26 of the MSA lists the core components of an Integrated Development Plan (IDP) including "(a) The municipal council's vision for the long term development of the municipality with special emphasis on the municipality's most critical development and internal transformation needs" (South Africa, 2000).

Nominally, planning is about the future, though there are concerns that planning is actually reactive (i.e. responding to legislation and policy) and that planners neglect the future. In South Africa, the key problems inhibiting long-term planning include the lack of funds in many municipalities, the limitations of the five-year cycle of the Integrated Development Plans (IDPs), the need to address backlogs and the focus on short-term projects for immediate political gains (Petzer, 2016).

## **5 EMERGING CHARACTERISTICS OF NEIGHBOURHOOD 4.0**

Based on the above discussion, a number of characteristics emerge about the neighbourhood of the future, ones that meet the Sustainable Development Goals, whilst exploiting any offerings from Industry 4.0. For instance, a neighbourhood of the future could:

- Be walkable, with a radius of 400m generally being considered to be walkable (CSIR, 2000, Phaphana *et al.*, 2014). For example, using 400m buffers around stops and ranks in Johannesburg, Mokgukulushi *et al.* (2018) found that the Metrobus service covers 18.2% of the City's area and 28.8% of its population, while the minibus taxis cover 10.1% of the City's area and 48.4% of its population.
- Have good penetration by public transport, cycle paths, green spaces and viable neighbourhood shops and other services, which will probably require densification.
- Have a healthy food environment; it would not be a food desert. This would be achieved by ensuring that residents have ready access to nutritious food (Phaphana *et al.*, 2014; Cooper *et al.*, 2017). A neighbourhood should also provide a healthy environment with low levels of pollution, noise and offensive smells.

Further research is needed to build on this list. In doing so, we must consider the neighbourhood itself:

- How does the neighbourhood of the future affect the dwelling, dwelling density and erven (plot size) of the future given increasing security measures being installed, and dwellings becoming smaller?
- Should a neighbourhood of the future be intentional or organic? For example, should this be determined by public transport routes (e.g. as planned by Johannesburg's corridors), by job opportunities, by topography, by socio-cultural differences, by the natural environment, etc.?
- Should a neighbourhood of the future be focused on a particular demographic (e.g. a nappy valley or a retirement home), or should it encourage mixed demographics (e.g. aged parents living close to their grandchildren)?
- Should a neighbourhood of the future have an obvious neighbourhood centre?
- Is the neighbourhood level good, bad or indifferent?

At the same time, we must consider the impact of Industry 4.0 on Neighbourhood 4.0. In so doing, we need to consider whether or not:

- Industry 4.0 will balkanize households and neighbourhoods and increase social isolation, possibly due to the greater dependence on an online life, rather than in the physical world
- Industry 4.0 can make Neighbourhood 4.0 more democratic. This could be done by increasing access to decision makers, information and alternative viewpoints. It could also be achieved by allowing residents to present their own narratives, as well as, challenging the status quo with regard to urban planning.

## **6 CONCLUSION**

This paper has identified possible characteristics of the neighbourhood of the future, or Neighbourhood 4.0. The research in this paper has been prospective or speculative; this still needs to be tested through field work and case studies. The challenges neighbourhoods face now and emerging characteristics of the neighbourhood of the future will be instrumental in helping us understand how to improve the development of neighbourhoods in the future.

## ACKNOWLEDGEMENTS

This research was funded by the CSIR project, B1JP400, Understanding urban futures: Shaping a neighbourhood level response (2018/19). We would like to acknowledge and thank our colleagues for their inputs into preparing this paper, specifically Tinus Kruger, Engela Petzer, Mark Napier, Thuli Ndlovu and Beth Crankshaw. We would also like to thank the anonymous referees for their insightful comments.

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## Innovations for improving service delivery: A case study of the innovation partnership for rural development programme

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### ABSTRACT

Technology innovation plays a critical role in the socio-economic development of countries around the world. This is more so in the context of a globalised world where technological innovation has become the primary driver of socio-economic development. In acknowledging this reality, the South African Government has noted that technological innovation is invaluable to the country's global competitiveness and the provision of services to its citizenry. Against this backdrop, this article uses a case study approach to understand the benefits/barriers of using innovations to improve service delivery in rural municipalities. Underpinned by the interpretivist paradigm comprising primary (individual interviews and focus group discussions) and secondary qualitative data from desktop research, the study noted that improving basic service delivery using innovation requires a systems approach and a coordinated policy framework. However, the lack of policy coordination and coherence remains a key barrier to technology innovation and adoption in South Africa.

Keywords: Technology Adoption, Technological Innovation, Policy, Innovation for Service Delivery, Technology Diffusion, Strategic Partnerships, Capacity Building, Community Participation

### 1 INTRODUCTION

According to a report by the National Treasury (2011), providing basic services (e.g. roads, water, electricity, housing, health and education) innovatively can substantially reduce poverty and unemployment and can strengthen social capital. It can also be a factor in reviving agriculture, tourism and other rural enterprises. Innovation plays a critical role in improving the efficiency and effectiveness of service delivery. The concept "innovation" suggests alternative methodologies of production, characterised by efficiency, effectiveness, and better quality products and services. According to the diagnostic report of the National Planning Commission, challenges that impede development in South Africa related to efficiency, effectiveness, and quality of products and basic services (National Planning Commission, 2011).

The Department of Science and Technology (DST) has been instrumental in promoting policy shifts towards innovation for inclusive development. Key policies include the recent draft White Paper on Science and Technology (2018), and the Innovation for Local Economic Development Strategy (2016). Innovation in the public sector is embedded in the National System of Innovation (NSI), driven by the DST and its strategic partners (Draft Science, Technology and Innovation White Paper, 2018). One related project, supported by the DST, is the Innovation Partnership for Rural Development Programme (IPRDP). The IPRDP focuses on innovation to enhance basic service delivery in distressed municipalities (Hart *et al.*, 2018).

Around the world, social innovation in public service delivery has become an inherent prerequisite for local government. This is an outcome of the devolution of responsibilities to local government (Dirie, n.d). In recent years, innovation in the public sector has been characterised by rapid growth; and has become a critical component for improving basic service delivery, and addressing some pressing socio-economic challenges. The value of innovation in the public service is particularly relevant to the global South, where resource constraints (both human and fiscal) are key contributing factors to poor service delivery.

Using the IPRDP case study, we assess how innovations can improve basic service delivery in rural municipal contexts. We argue that improving basic service delivery using innovation requires a systems approach and a coordinated policy framework. We further argue that stakeholder coordination is a prerequisite for the creation of an atmosphere for the effective uptake of innovations.

This article first examines the definition and the concept of "innovation" in the context of basic service delivery. Secondly, we examine the enablers and barriers of the uptake of innovation for service delivery in

municipalities, as examined in the IPRDP programme. Lastly, we reflect on the perspectives of different stakeholders in respect of policy tools required to support innovation uptake to improve the delivery of basic services. The paper concludes with recommendations that could enhance the deployment of innovation for effective and efficient service delivery.

### 1.1 DEFINING THE CONCEPT OF INNOVATION IN THE CONTEXT OF SERVICE DELIVERY

Literature reveals that there is a general lack of understanding of what public innovation is (Bloch and Bugge, 2013; Matei and Bujac, 2016; Biljohn 2017; Vickers *et al.* 2017). Bourbon (2010) lays these difficulties at the door of conventional public administration and governance theories, which were not designed for the complexities of public service delivery in the 21st century. Conventional public administration and governance theories fail to emphasise the prominent roles of citizens in public service delivery in general and in the social innovation process in local government in particular (Biljohn, 2017). Biljohn further argues that the inclusion of citizens is imperative in improving local government service delivery since citizens have the first-hand experience of the problems that affect them and are, therefore, better positioned to propose valuable solutions.

Biljohn (2017) defines citizen participation in co-creating new services as “*social innovation*”. Grimm *et al.* (2013, 450) argue that depending on the research field or policy area, the concept of social innovation has assumed a variety of distinct but related meanings, which can be both a strength and a weakness of social innovation. In addition, the fact that social innovation comprises a variety of activities may also be considered either a strength or a weakness in its conceptualization.

Grimm *et al.* (2013) argue that the challenges in conceptualizing social innovation (about which there appears to be at least some form of consensus, namely that it can be both a process and an end in itself) are the result of the fact that social innovation is under-theorized. In the South African context, public administration and governance policies do not provide an appropriate policy framework for the implementation of social innovation to improve public services (Biljohn, 2017). However, this does not prevent national, provincial and local governments from using social innovation to improve service delivery.

In the South African context, the concept of social innovation is associated with poverty alleviation interventions (DST, 2014). The use of innovation for development refers to social innovation as a means to an end and to it being process-oriented. This means that social innovation should have a social purpose and should involve social actors such as the poor, civil society, as well as the public and private sectors (Hart *et al.* 2014). Hart *et al.* (2014) suggest that for the concept of social innovation to be understood and for it to have an impact in South African communities, certain policy actions should be considered.

According to Biljohn (2017), three schools of thought can be identified in terms of how social innovation is utilised to improve public service delivery. In the first school of thought, social innovation is goal-oriented and is used to address societal problems (OECD, 2015; Mulgan, 2014; Pol and Ville, 2009; Hart *et al.* 2014). When social innovation is used in this way, it results in the delivery of public services to address specific societal problems (Grimm *et al.*, 2013:438). In the second school of thought, social innovation is used as a process to address societal problems (Mumford, 2002; Chalmers, 2012; Hart *et al.* 2014). In this context, it results in collaborations, relations, self-organization among actors and social relations, all with the goal of addressing societal problems. These relations result in social innovation being process-oriented, which might alter the flow of authority and resources in a social system. In the third school of thought, social innovation is used both as a goal and as a process to address societal problems (Bouchard 2012; Grimm *et al.*, 2013). When social innovation is used in this way, it serves a dual purpose which not only involves finding solutions but also building relationships to find such solutions. Though this dual purpose is considered as separate by the first two schools of thought, it can be concluded that the goal of the dual purpose is to address societal problems, regardless of whether the use of social innovation results in the use of services or in a process that entails relations and collaborations to find solutions to these problems.

### 1.2 INNOVATION IN THE PUBLIC SECTOR INSTITUTIONS

The terms capacity and capabilities are used interchangeably in the literature. The OECD (2012) defines public sector capacity as the ability of individuals and organisations to “...*perform functions, solve problems and achieve objectives...*” *keeping in mind how they “...understand and deal with their development in a broader context and in a sustainable manner*”. Similarly, Lewis and Richard (2014) define capabilities as an asset of skills, resource and functional competencies individuals and organisations accumulate over time to perform certain duties. A critical ingredient to develop capacity is learning (Lundvall & Lema, 2015). Through learning, public sector organisations and officials could advance their capacity to deliver public services effectively.

There are at least three main factors that affect public sectors' capacity to learn. These factors are important indicators of innovative capacity. First, is the governance structure, which is the environment in which municipalities operate. Political and administrative context, legal culture of the public sector, state and government traditions are all possible variables that can affect the level of innovation capacity of public sector organisations and their officials (Lewis & Richard, 2014). Capacity and capabilities in public sector organisations are sometimes seen in a negative light, as they are often associated with the routinisation and path dependency (Garud & Karnøe, 2001). Indeed, most local municipalities are known for routine work, which could hinder the application of innovative strategies in their daily routines. In this instance, learning usually does not take place. However, the capabilities of the public sector are not always perceived as un-innovative. As long as the routines and processes established promote the acquisition, assimilation, transformation and exploitation of knowledge, public sector institutions and individuals can be innovative and engage in learning. The ability to break through this chain to recognise the value of innovation is an important step required to turn public organisations into innovative engines.

Lewis and Richard (2014) explain that innovation capacity is not only affected by the formal structures within which public sector organisations operate; but also informal structures such as social networks and relationships amongst organisations and public sector officials. In fact, informal structures are important channels for information sharing and diffusion of innovation activities and practices (Lewis & Richard, 2014). Within the scope of social networks, factors such as hierarchical seniority, social capital, and trust are acknowledged.

A third crucial factor is leadership. Leadership plays a critical role in the capacity of public organisations and officials to innovate. The presence of innovation leadership is an important factor for the innovation capacity of public sector organisations and officials.

The lack of (or insufficient) indicators to measure innovative technology uptake to improve service delivery is a barrier to innovation uptake in public service delivery (Lewis & Triantafillou, 2012; Lonti and Gregory, 2007; Micheli and Neely, 2010; Lewis & Triantafillou, 2012). According to Kattel *et al.* (2013), it is difficult to measure innovation in the public sector as it is difficult to clearly see the benefits of activities that are attributable to innovation interventions in the public sector. There are also limitations to citizen involvement in the co-design, co-production and co-governance of public services through innovative models (Biljohn, 2017).

Oyelaran-Oyeyinka (2014), in reviewing state and innovation policies in Africa, recognizes that its attainment is not particularly easy. Lundvall and Lema (2015) have identified that a way in which the public sector can advance their ability to deliver public services efficiently and effectively is through learning. Osborne *et al.* (2012) contend that innovation in the public sector requires multiple actors of inter-organisational nature involved in the delivery of basic services acting through an inclusive approach to adopt innovation to solve societal problems.

The slow pace of the adoption of innovations, the capacity to learn and absorb knowledge is a barrier for uptake (Koch *et al.*, 2006). The South African Public Sector Innovation Manifesto by the Centre for Public Service Innovation (CPSI) already commands that learning be embraced by public servants to adopt the behaviour of a creative calibre (CPSI, 2009).

For the public sector to increase innovation and achieve an improved status of basic services, it is imperative that the public sector increases its innovation capacity and capability by; sharpening the government structures that support innovation, strengthening leadership and smoothening relationships with local citizens. Further, they ought to acknowledge the uniqueness of each beneficiary Municipality services, open themselves up to learning and adopt new innovative models, discontinue outdated policies and approaches and ensure that the culture of routinization and path dependency is terminated.

## **2 THE CONTEXT OF SERVICE DELIVERY IN SOUTH AFRICA**

The Constitution of the Republic of South Africa of 1996 (Chapter 10, Section 195) provides that basic services must be provided to all South Africans. The Constitution empowers and obliges municipalities to structure and manage their administration to deliver basic services and develop the communities they serve. According to the Constitution, local governments must also promote social and economic development; facilitate a safe and healthy environment; and foster local participation in local government (Department of Cooperative Governance and Traditional Affairs (COGTA), 2016). The Integrated Urban Development Framework (a national urban policy managed by COGTA through multi stakeholder collaboration) advocate for an integrated

spatial planning and land use management in a manner that ensures spatial redress in terms of access to services through inclusion, sustainability, efficiency and transformation.

To achieve this transformation, the National Development Plan (NDP) advocates a developmental state through improved functioning of local government systems in a way that enables officials to utilise technology and innovation in the delivery of basic services. The NDP stresses the importance of Science, Technology and Innovation (STI) in the achievement of good public services and administration (National Planning Commission, 2012). Despite this ambition, municipalities continue to face institutional capacity and financial challenges that affect their abilities to innovate (Hart *et al.*, 2018).

Recently, several public institutions and municipal entities have been piloting different innovations and policy instruments to support the adoption and uptake of innovations for service delivery in the public sector. These experiments range from business process innovations, infrastructure, water, sanitation, energy, innovative buildings and construction methods, as well as the use of various decision support tools and frameworks to improve efficient management and delivery of services. Key institutions that are experimenting with innovations for the delivery of services include the South African Local Government Association (SALGA); the DST; Technology Innovation Agency (TIA); the National Housing Building Regulatory Council (NHBRC); the National Treasury; the Centre for Public Service Innovation; and the Department of Public Works. Despite these experiments, access to basic services continues to be a challenge in rural areas.

### **3 RESEARCH DESIGN AND METHODOLOGY**

The study adopted a qualitative approach to collect primary and secondary qualitative data to understand how innovation could improve service delivery. We reviewed project documents and literature as secondary data to extract insights on policy implications for the demonstrated technology. Primary data were collected through Focus Group Discussions (FGDs) and key informant interviews. Four FGDs in the form of learning forums were held across three provinces namely; KwaZulu-Natal, Mpumalanga and Gauteng with each focus group comprising between 8-15 participants. Participants in the FGDs were selected purposively from among project managers and infrastructure managers in 27 municipalities where the IPRDP was implemented. In addition to the FGDs, 10 key informants selected purposively based on their role in the project were interviewed. These were drawn from the Department of Water and Sanitation (DWS), the Water Research Commission (WRC), and the Council for Scientific and Industrial Research (CSIR). The analysis of data was conducted through thematic, content and contextual analysis.

### **4 BACKGROUND OF THE IPRDP**

According to the IPRDP business plan (DST, 2014), the strategic objective of the IPRDP programme was to encourage the adoption of technologies to improve access to quality basic services in a manner that creates economic development opportunities. A key informant from the DST noted that the IPRDP was introduced as a programme geared towards improving service delivery, through the demonstration of innovative technologies that can improve the quality of life in rural communities.

The IPRDP was designed to build capacity through a set of technology-based pilots and demonstration initiatives that respond to social and economic infrastructure needs in 27 priority district municipalities. Sectors targeted for technology demonstrations included water (with a focus on both access to water and water quality); sanitation (off-grid sanitation technologies); access to electricity through renewable energy solutions; Information and Communication Technology (ICT) services; and ecological or green infrastructure. In addition, the IPRDP delivered ICT platforms to improve the capacity of municipalities to manage water incidents, while empowering the community and small medium micro enterprises.

### **5 FINDINGS AND DISCUSSION**

#### **5.1 BENEFITS OF INNOVATION UPTAKE**

The study revealed that household beneficiaries impacted by the programme were mostly female-headed rural households largely dependent on government social grants with high unemployment and low-income levels

(below the poverty line in certain areas) with limited access to quality drinking water, poor sanitation, limited access to electricity, and are mainly located in remote rural areas.

Some participants in the key informant interviews reported that the programme has enabled rural households to have access to ICT tools such as the Corrective Action Request and Reporting System (CARRS) to report water incidents where communal water standpipes existed. In areas where communities did not have access to piped water, the key informant interviews revealed that households who received the point-of-use water filtration devices used these units and benefited from the technology in terms of accessing clean and quality drinking water. The filters were found useful in municipalities that are water stressed and where councils are struggling to provide clean piped drinking water to households and where households collected water from rivers. The project manager in one of the beneficiary district municipalities reported that “*after technology demonstrations, most households who received low pour flush sanitation technology widely accepted this technology*”.

The FGDs further indicate that municipalities regarded these technologies as feasible alternatives to roll-out further within the municipalities. During the discussions, one participant mentioned that “*the IPRDP technologies such as CARRS and the pour-flush toilets have gained traction within certain municipalities such that municipal budgets are allocated for scaling up*”.

## 5.2 ENABLERS OF INNOVATION UPTAKE

According to participants in FGDs, capital cost is a key factor in decision-making about innovative technologies. Some participants were of the view that municipalities should consider cost vs benefits in providing basic services using conventional approaches vs decentralized technology approaches. The participants noted that citizens should be enablers over the full life cycle of the service delivery value chain i.e. planning, design and management.

Some key stakeholders observed that there is a need for policy redesign to allow beneficiaries to use innovation and technology to improve and provide basic services to themselves. They further noted that Municipalities should look at deploying social innovation models to allow them to play a catalyst role and layout rules that enhance communities’ access to basic services and contract with municipalities.

## 5.3 BARRIERS TO INNOVATION UPTAKE

Barriers to innovation uptake identified by key informants and participants in FGDs are summarised into five key themes: (1) limited capacities at local level to implement innovative services delivery through cost-effective measures; (2) lack of technical capacity in municipalities, dedicated persons to champion and drive innovation; (3) challenges in terms of integration of technology and innovation in the delivery of basic services and municipal business processes; (4) lack of adequate innovation enabling policy instruments; and (5) lack of access to appropriate and validated innovative technology solutions by municipalities. In addition to these challenges, participants also cautioned that an innovation that is not tested and certified could lead to instability in communities, as these may be perceived as unfit and substandard.

Municipal officials in FGDs reported that innovation piloting is perceived as an additional, unfunded mandate, especially in municipalities with constrained financial resources. This is more so in municipalities where innovations are not integrated into municipal planning performance targets, development plans and operations. Most municipalities that participated in the IPRDP did not co-invest in technology demonstrations. This left the technology innovation project prone to cancellation, particularly in situations where other service delivery issues were prioritised over innovation projects. A DST informant reported that this challenge is compounded by the fact that in many instances, the demonstration of technologies to improve service delivery has been implemented without proper feasibility studies to understand the pre-legal requirements and regulatory constraints that could delay implementation. Similarly, technology demonstrations took place without contracting the municipal officials and other community stakeholders in sustaining implementation beyond project funding. The participants noted that other constraints included, high staff turnover, lack of political buy-in and the resignation of key personnel hindered project implementation.

Community stakeholders in the FGDs were of the view that innovative technologies should align with community priorities in a manner that would unlock community empowerment and socio-economic opportunities. They noted that in many instances where the IPRDP innovations were implemented, development outcomes such as employment, social health benefits and sustainability plans were not incorporated upfront in the project design. Some of the key informants felt that public participation could allow community members to influence the design and selection of technologies that are community interfacing thus, enhancing social acceptance of these technologies. Some key informants reported that none of the

technologies and innovations demonstrated had shown strong alignment with other government rural development initiatives, despite the IPRDP having been designed to support the comprehensive rural development programme.

Lack of norms, standards, and certification for “fit for purpose” of innovation as well as proper decision support tools to ease procurement of technologies were seen as a major factor driving municipalities to be locked into procuring conventional services. Some key informants reported that the lack of technical support in municipalities and training programmes designed to influence municipal officials to think innovatively, and to carry out operations and maintenance on the demonstrated technologies are barriers to adoption. Budgetary constraints also undermine the operations and maintenance activities.

The stringent requirement of Supply Chain Management policies and practices that fails to incentivise municipalities to mitigate risks related to conceptualisation, development, testing, demonstration, and uptake of locally-developed technologies designed to optimise efficiencies was also reported as barrier by Municipal officials. The lack of funding instrument to support innovation uptake remains a key barrier to municipalities to acquire, scale up and adopt technologies.

## **6 RECOMMENDATIONS TO ENHANCE THE UPTAKE OF INNOVATIONS TO IMPROVE BASIC SERVICE DELIVERY**

Innovation-based interventions in municipalities require intensive community participation in the design and selection of technologies, and in the management of the innovation interventions. Biljohn (2017) argues that encouraging citizens’ active participation in social innovation is critical to improving service delivery by local governments. Citizen participation is important because their experiences of local service delivery challenges position them to provide critical insights into how these challenges can be addressed (Matsiliza, 2012).

The adoption and scale-up considerations would have policy implications on norms and standards for service delivery, the openness of procurement specifications to innovative technologies; and the initial “disruption” of the existing conventional service delivery supply chain may be necessary. Policy implications for technologies should be assessed and discussed with relevant service delivery departments to inform and influence the policies of the delivery departments. Long-term and strategic support for innovation capacity development should be provided and embedded in training plans. Innovative solutions will be specifically adapted in resource-constrained municipalities and focus on pro-poor service delivery. Innovation policy dialogues should be conducted with service delivery departments and municipalities to ensure that innovation systems and technologies for service delivery are adopted through a systems approach.

To scale up and accelerate the adoption of innovations to improve service delivery, an Innovation for Service Delivery Programme (ISDP), supported and framed by various sector departments in a manner that aligns with other capacity building programmes for municipalities such as the Back to Basics (B2B) Programme is necessary as an anchor policy programme. Initiating national innovation for service delivery forum through government clusters will provide interdepartmental support and prominence of these interventions in the government hierarchy and increase policy consistency.

Innovation interventions should not only be about hard basic service delivery challenges in municipalities. It should increase capacity, performance, planning and operations of municipalities, as well as the maintenance of basic infrastructure for sustaining the standard of living and economic activity in communities.

Community-based models to strengthen the innovation capacity of municipalities should be explored. It is also important to ensure that innovations deployed are fit for purpose, and have been tested and certified to reduce social unacceptance risks. Institutional structures, as well as provincial and local institutional arrangements to coordinate innovation programmes, should be streamlined to minimise duplication of effort. This could require setting up provincial and municipal innovation forums coordinated by provincial and municipal innovation champions.

There is a need for the development of strategic partnerships among government departments and businesses to advance innovation for service delivery (Dirie ,n.d.) is of the view that examples of Public-Private-Partnership from around the world have shown that partnerships with capable private sector can address the needs of the poor. Where there has not been immediate improvements in service delivery to the poor, the introduction of technology is, undoubtedly, a powerful force to address some of the constraints to service delivery.

There is a need to conceptualise a service delivery index to measure and monitor innovation capacity in municipal environments. Such an index should be able to combine the theory of innovation measurement in

the public sector, learning capacity and fit-for-purpose performance measurement methodology. The development of such tools will be a response to the general lack of appropriate instruments for understanding and measuring the innovation capacities of local municipalities, as well as their officials in South Africa (Sinyolo *et al.*, 2018).

To address innovation procurement funding gap, a technology acquisition and deployment fund as a funding model for scaling up successfully tested, certified, locally developed technologies in the public sector is required. Deliberate investments to develop a local government “*systems of innovation*” will require deliberate policy intervention by the government to create an enabling policy framework to enhance technological innovation, adoption and diffusion (Oyelaran-Oyeyinka, 2014).

Key informants recommended that municipal grants should be designed to enable the adoption of technology to improve service delivery. A number of public sector entities and institutions are developing innovation uptake support instruments, but most of these instruments are not coordinated and aligned. For instance, the process of establishing a think tank to make recommendations on how to use municipal bylaws to achieve water efficiency at a household level could be supported by policy reviews and acquisition funds.

## 7 CONCLUSION

The aim of this study was to examine the benefits, challenges, enablers and barriers to innovation uptake in enhancing service delivery in rural municipal contexts. Findings of the study demonstrate the need for innovation for a service delivery policy framework that would streamline various policy tools, stakeholder effort and support instruments necessary to create an enabling policy environment for innovation to improve service delivery. Factors to be considered in such a policy framework include procurement, innovation acquisition, deployment, licencing, and accreditation mechanisms. Innovation uptake to improve service delivery cannot be the function of a single department. Rather, it requires a systems approach and a well-coordinated broad participation of various stakeholders.

Awareness of innovation benefits, innovation skills and capacities within the municipalities should be improved. Municipal funding instruments to accommodate technology and innovations for the delivery of services should be enhanced. This entails including innovation as a module in public sector induction, performance contracts and encouraging and rewarding innovation by officials and service delivery authorities, particularly municipalities. Furthermore, mechanisms to measure innovation readiness, performance and maturity by municipalities is key.

Policy lessons should be shared with municipalities, the National Treasury, COGT, and SALGA to enhance the diffusion of such lessons to municipalities across the country. The study noted that the adoption of technology and innovation to improve service delivery including the adoption of innovative sanitation technologies should be incorporated into the national minimum sanitation norms and standards. As a result, the national sanitation policies should be reviewed to incorporate innovative technology options.

The lead partner departments responsible for service delivery, such as the DWS, the COGTA, the Department of Agriculture Forestry and Fisheries, the National Department of Human Settlements, the Department of Rural Development and Land Reform, SALGA, and Municipalities should engage innovation champions within these departments to increase uptake. The delivery departments should open and commit resources to integrate innovation in service delivery including ensuring that municipal infrastructure and development grants make provision for innovative technology options. Further, cooperation agreements and innovation for service delivery plans and programmes should be developed between innovation policy decision making authorities such as the DST, and relevant service delivery departments and municipalities.

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## The barriers and enablers to innovation for water services delivery in rural South Africa – A case study

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### ABSTRACT

This paper presents evidence and learnings on the barriers and enablers to innovation in human settlements focussing on water services delivery in rural areas. The paper draws on the planning, implementation and outcomes of the Accelerating Sustainable Water Services Delivery (ASWSD) initiative. The initiative has, through two projects, sought to explore and demonstrate the role that context responsive technological innovation can play in the delivery of sustainable water services for the un- and underserved hard to reach communities. The projects have been implemented in two phases in the Eastern Cape, Limpopo and Mpumalanga provinces, across a total of seventeen villages. Over a variety of contexts, a diverse basket of solutions have been implemented, ranging from rehabilitation of existing hardware infrastructure and installation of new infrastructure to the rolling out of simple household based water treatment and safe storage interventions. These were supported by various initiatives such as community mobilisation, operator training and engagement of responsible authorities for post project operation and maintenance. The paper presents how the demonstration sites, technologies and implementation were carefully chosen with due consideration to context, to allow for learning and sustainability. Thus relevance, acceptability, stakeholder engagement and alignment with existing arrangements were key tenets of the project. The experiences and outcomes from the projects highlight barriers and enablers to innovation that were encountered both during and after the projects. These included staffing constraints within municipalities, budgetary limitations as well as users' and service providers' perceptions. It is concluded that due to the complexity of the water services challenge, approaches that allow for appropriate infrastructure (the hardware) and greater stakeholder engagement and creativity of solutions need to be considered to foster innovation.

Keywords: Innovation, drinking water, rural, service delivery

## 1 INTRODUCTION

This paper is a case study based on the planning, implementation and outcomes of the Accelerating Sustainable Water Services Delivery (ASWSD) initiative. Drawing on this initiative, the paper seeks to share insights into the barriers and enablers of innovation in water services for South Africa's rural settlements and how these demonstrate the need for complexity science to be embraced.

### 1.1 THE WATER SERVICES DELIVERY CHALLENGE IN SOUTH AFRICA

The water services delivery challenge in South Africa, in both urban and rural contexts is urgent and complex. Recent reports indicate that some 11.4% of the population do not have access to piped water (Statistics SA, 2017), with large numbers without water on site. The General Household Survey 2017 Statistical Report indicates that in 2016, less than half of South Africans accessed piped water inside their dwellings. Nearly 4% (3.7%), still relied on unsafe sources (rivers, streams, stagnant pools and dams, wells and springs (*ibid*). Furthermore, consumer satisfaction is reportedly declining quite rapidly, from a 'good' rating of 76.4% in 2005 to 63.9 % in 2017 (*ibid*). In addition to these service access gaps, the delivery of water services needs to also respond and align with the housing challenges, poverty and pressure for an inclusive economic development landscape, land reform and not least, climate variability that calls for greater efficiency in the exploitation of the resource.

There have been commendable efforts and encouraging results over the last 24 years towards provision of public services, including water, for all. Stakeholders, with state leadership have sought to facilitate the process through the creation of enabling legal, policy, financing and governance frameworks. However, despite significant investment into the sector and recorded gains in the provision of infrastructure and services to previously unserved segments of society, the voices of dissent demanding services are louder than ever, as millions remain without access to safe drinking water. Significantly, an even greater number of people do not have access to the safely managed water services as defined in the Sustainable Development Goal 6 indicators (WHO, 2017). There is, therefore, a strong focus to deliver services as quickly as possible with a number of accelerated programmes in place.

The challenge is two-fold:

- To reach those that have not been served in both existing as well as new settlements, and
- In addition, address the issues around non-functional infrastructure. Infrastructure that is not fully functional, does not contribute to the development targets of universal access to safely managed water services.

It has also been said that the traditional engineering solutions contribute to the lack of water services in rural areas due to the terrain and settlement patterns that amongst other things lead to prohibitive costs. Operation and maintenance failures as well as capacity constraints have also been cited as hindering efforts towards universal, sustainable delivery of services.

## **1.2 WATER SERVICES ACCESS IN THE ACCELERATING SUSTAINABLE WATER SERVICES DELIVERY (ASWSD) PROJECT AREAS**

In the first phase of the ASWSD in the Eastern Cape, the project areas had highly limited infrastructure, mostly comprising of one unprotected spring per village. The majority of communities in the areas relied on river water, unprotected springs or shallow hand dug wells for their drinking water. Phase II of the project was implemented in Limpopo and Mpumalanga Provinces. In these areas, the pre-intervention situation was characterised by non-functional piped scheme infrastructure. The communities were therefore using alternative, and at times, unsafe water sources. The use of unprotected springs, shallow hand dug wells and river water was common in addition to purchasing from private borehole owners.

## **1.3 THE ASWSD INITIATIVE**

The ASWSD initiative was thus conceptualised to explore and demonstrate the role and scope for technological innovation in the quest for universal access to safe drinking water by all. It focussed on rural areas, where service delivery carries unique challenges linked to the socio-economic context, revenue bases and terrain amongst other issues. The unique set of challenges in the rural context can make the uptake of innovation a challenge (Patel, 2017).

Since its inception in 2009, the initiative has over the years adopted an action research methodology with a focus on context and participation to deliver appropriate, sustainable technologies with varied outcomes, experiences and lessons. The first project in the Eastern Cape, was implemented in six villages across the Amathole District Municipality (ADM) and O R Tambo District Municipality (ORTDM). Building on the lessons learnt from the first phase, Phase II was implemented in eleven villages across four district municipalities (Ehlanzeni, Vhembe, Mopani and Sekhukhune) in Limpopo and Mpumalanga Provinces.

# **2 LITERATURE REVIEW**

## **2.1 WATER INNOVATION, UTILITIES AND INCLUSIVE RURAL DEVELOPMENT**

In a recent review article, Wehn and Montalvo (2018) note that there is an absence of academic studies of the dynamics of water innovation: how innovations come to be and are passed on, as well as how various actors interact in these processes. This is despite the urgent and acknowledged need for such innovation in both the developed and developing world in light of the threat that water crises pose to human and economic development (WEF, 2017). A few examples of the face of innovation, its dynamics in South Africa in rural and urban settlements exist in the literature. Of note, Basson (2012) describes innovation in access to water services in deep rural South Africa and the complexity of the phenomenon. This complexity is further explored

by Link and colleagues (Links *et al.*, 2014) who, although focussing on economic activities, highlight not only the complexity but the extent to which innovation in the 'real world' rural setting is rich, vibrant and challenges conventional understanding.

## 2.2 THE ARRANGEMENTS AND FRAMEWORKS FOR WATER SERVICES DELIVERY IN SOUTH AFRICA

Water services delivery is mainly framed by the provisions of the Constitution (Act 108 of 1996), National Water Act (Act 36 of 1998) and the Water Services Act (Act 108 of 1997). The Constitution confers on 'everyone the right to have access to water'. This has enshrined in South African water policy and strategies the concept of free basic water. Whilst commendable as a step towards the recognition of water as a basic human right, the concept has received criticism in two main aspects: not all service providers are able to deliver this free service and there are no mechanisms in place to protect the poor from high prices beyond the basic level of access. Nonetheless, water policy has made significant strides and continually seeks to build on the achievements to address inequalities and enhance the performance of the sector.

Together, the National Water Act (Act 36 of 1998) and Water Services Act (Act 108 of 1997) provide for the establishment of institutions tasked with the management and distribution of water. The national government, through the Department of Water and Sanitation, is the custodian of the country's water resources with a regulatory oversight and support function as provided in Strategic Framework on Water Services (2003). It has overriding responsibility for water services provided by local government. In the sector's institutional framework:

Water Service Authorities (WSAs) provide water services within their appointed areas. This includes metropolitan municipalities, many district municipalities and authorised local municipalities. WSAs may contract out service provision to external water services providers;

Water Services Providers (WSPs) provide operational water delivery and/or sanitation services (as a bulk or retail service). Where WSAs undertake any of these services, they are a water services provider; and

Water Boards (WBs) are regional or bulk water services providers (sell water to other water services providers). As WSPs, the Boards are accountable to WSAs whilst as organs of state, the boards are owned, controlled and regulated by the Department of Water and Sanitation and National Treasury (NT) as provided for in the Water Services & the Public Finance Management Acts.

The operations of the WSPs and WSAs are governed by provisions set out in the Local Government: Municipal Systems Act (Act 32 of 2000). The WSA as part of the "authority role" has the power to appoint and monitor service providers as well as the right to intervene in the case of poor performance. The "provider role" of the WSP is defined as "the delivery of services to end-users and may involve responsibility for the operational, maintenance and capital requirements of the service". The implementation of this delivery framework is facing challenges in the rural, poorer and second economy contexts. Initiatives such as the Municipal Infrastructure Grant (MIG), Municipal Water Infrastructure Grant (MWIG) and others that are put in place to support the municipalities are not yielding the full, anticipated impact as evidenced by the growing dissatisfaction with services.

## 3 RESEARCH METHODOLOGY

The ASWSD adopted an action research methodology in its implementation. Action research has been described as learning by doing (Paddock, 2015), a participatory approach that is geared towards a specific issue and context (Dudovskiy, 2018) and action undertaken by those who wish to learn and improve themselves (Sagor, 2010) amongst other definitions. Many useful definitions of the approach exist in research literature. The common theme among them is that the methodology is a platform for context dependent, collaborative learning for improvement. Koshy *et al.* (2011) provide a succinct summary of the characteristics of the methodology as a method used to improve practice, participatory towards a common purpose, situation and context specific, reflection based on interpretation of results, knowledge from action at the point of application, problem solving (if the action leads to improvement), as well as findings that emerge from interpretation after implementation.

At its core, the action research methodology has four main steps (Figure 1), which are planning, action, observation and reflection. The reflections lead to further planning for improvement, resulting in a spiral of steps that progressively leads to increased understanding and improvement of the issue at hand.

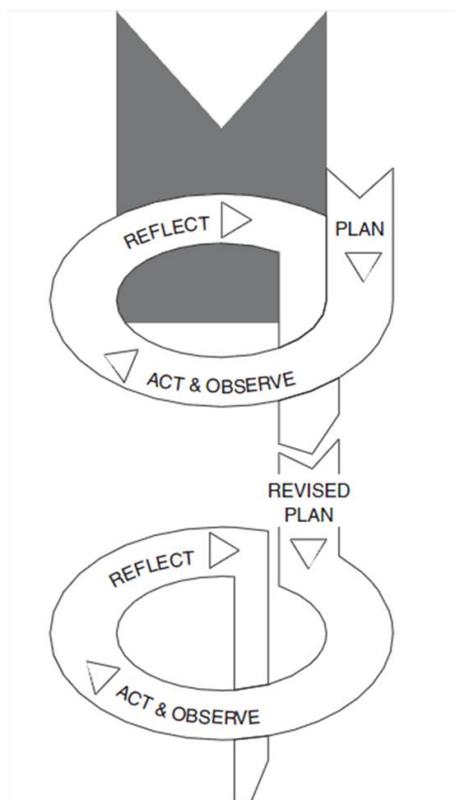


Figure 1 The action research spiral, Source, Dudovskiy (2018)

In the first ASWSD project (Phase I), the interventions were informed by desktop and secondary data analysis to develop a suite (of interventions) that sought to deliver faster, effective and uninterrupted access to selected villages. The suite was guided by the rationale that interventions would cause minimum disruption and instead build onto existing systems and practices. Based on field experiences and feedback from the social mobilisation processes, the planned interventions were modified as necessary, within the budgetary and time constraints of the project. This overlap in the action research steps (action, planning) is acknowledged in the literature with plans changing due to a number of factors (Dudovskiy, 2018).

The Phase I project planned interventions thus comprised the following:

A communal water station (CWS) to abstract and treat water from a river and provide safe access through taps. These would be constructed at or as close as possible to the existing water collection points in the project villages.

- A borehole management plan to ensure that all borehole water would be safe and to minimise breakdowns of borehole pumps. Boreholes and springs were known to be an important source of drinking water in rural South Africa and because of this, the plan was included in the suite of interventions.
- A household-based water treatment technology to act as a back-up intervention in case of breakdown of the communal water stations. This was planned to be a locally produced ceramic filtration technology. The ceramic filters were to treat water that the households would collect from the springs and the river in case they did not walk to the CWS. The ceramic filter technology was selected based on desktop assessments of its cost effectiveness, project budget, potential acceptability and the sustainability of the intervention in a rural South African setting.

Project villages were selected in consultation with the municipalities. The communal water stations were constructed, with some reticulation added to minimise walking distances. Two of the CWS were powered by solar. These two communities were mobilised and made aware of the maintenance and the advantages of a solar system to optimise the chances of sustainability. The borehole management plan was changed to a groundwater management strategy after initial assessment in the project villages revealed that there were virtually no boreholes. Instead, the communities relied on unprotected springs, rivers and hand dug wells for

their drinking water. Ceramic filters were distributed as originally planned although they were eventually sourced from outside South Africa. Despite being well received by the households, the filters became redundant within months of distribution. They clogged due to the high turbidity of river water and the clay pot also cracked within a year as it was quite fragile. Clogging slows down the rate of filtration and cracks impair the disinfection efficacy of the clay pot.

There was a social mobilisation component that primarily sought to raise awareness about safe water and hygiene, as well as building support for the project in the participating communities. In addition, for sustainability, the project also sought to establish innovative arrangements for operation and maintenance (O&M) in terms of both hardware as well as the preservation of water quality. The municipalities were engaged as far as possible in the (already selected) technology design and other project implementation processes, such as construction of the CWS and introduction of the ceramic water filters. The ceramic filters selected, groundwater plan and water quality monitoring proposals were all aligned as far as possible to the requirements, existing activities, systems and capacity of the respective municipalities.

Based on the lessons from the first phase, the subsequent project (Phase II) adopted processes that allowed for greater incorporation of locality and context in the choice of interventions. Decisions on interventions and their implementation were taken, collectively, at key points as activities were carried out and information became available. The project process thus entailed the following:

Selection of sites in a systematic manner to maximise demonstration and learning.

- A comprehensive assessment of each identified project village. This included technical engineering investigations of existing infrastructure; a community based survey to determine user practices, attitudes and experiences with respect to water services as well as an institutional assessment for operation and maintenance.
- Proposition of technological interventions towards access to water services based on the context assessment. The final intervention was decided upon by all stakeholders: the researchers, community and the water services authorities and providers. Asset transfer agreements were negotiated as part of the process for operation and maintenance purposes.
- Implementation of support mechanisms. This comprised training of operators, provision of manuals, negotiation and conclusion of asset transfer agreements as well as a targeted water related health and hygiene education campaign.

The context assessment revealed that in all the sites, there was infrastructure that was not operational or operating at sub-optimal levels due mostly to inadequate operations and maintenance. The intervention therefore, focussed on building onto existing infrastructure and plans to bring systems to full operational capacity. This entailed refurbishment of boreholes, networking them where necessary to ensure sufficient water supply without compromising the resource, and provision of additional storage capacity. In one area that lacked suitable groundwater resources, water was drawn from a nearby river, chlorinated and subsequently pumped to users. Extension of reticulation networks was a common feature of the interventions in the project to ensure reasonable walking distances for the users.

In Thambonkhulu, in Mpumalanga, the project introduced a South African developed household based water treatment and safe storage technology, the AmaDrum. The AmaDrum is able to provide households in the village with 50 litres of treated water that meets SANS 241 standards, within the hour. The technology was well received by users who, after careful and repeated training, were able to operate and maintain it effectively. However, approximately a year after the intervention, the community received piped communal water and they preferred this to treating their own water. The AmaDrum units were then converted to storage devices for the piped water or simply stored away.

## **4 FINDINGS AND DISCUSSION**

The ASWSD projects sought to demonstrate the role that innovation could play in rapidly delivering sustainable water services. In the process, a number of useful insights into barriers and enablers of innovation for sustainable water services provision emerged. Outcomes evaluation of the project indicates that the interventions provided relief to the project communities when they were implemented. However, five years later a significant proportion of the infrastructure was again non-operational. This despite having signed asset transfer agreements in which the municipalities undertook to maintain the infrastructure amongst all the other measures described above. Similarly, the point of use technologies provided to households (ceramic filter and AmaDrum) fell into disrepair or broke and were not used anymore, or used for unintended purposes.

## **4.1 THE SPACE FOR INNOVATION IN RURAL WATER SERVICES**

### **4.1.1 The enablers**

The innovation enabling factors that emerged from the ASWSD include:

- The pressure to deliver that is bearing on municipalities as WSAs and WSPs has created an opportunity for innovation. Officials in the ASWSD project sites were open to and keen on participating in innovative processes. Furthermore, willingness was evident, albeit to various degrees, to embrace alternative technologies such as the ceramic filters in the Eastern Cape and the AmaDrum in Thambonkhulu.
- Stakeholder participation is key for the entry of alternative technologies. In both cases where alternative technologies were introduced, the users were highly receptive and this appeared to make officials more receptive as well. In the stakeholder consultation forums on the proposed interventions, the decision was mostly up to the community representatives.
- Alignment with existing operations and administrative processes appeared to aid the acceptability of technological innovation. In the majority of the Phase II villages, the intervention consultations after assessment progressed rapidly with stakeholders reaching consensus fairly quickly. The negative association with this was that the emphasis on process innovation was reduced as the municipalities and communities focussed on the final product that did not challenge the norm. However, the lesson was different in Mopani where the spring protection intervention enhanced the already existing practice of spring water harvesting.
- Timely demonstration of the impact of innovation on service delivery targets facilitates uptake. In the project areas where the ASWSD interventions resulted in immediate and drastic changes or benefits, the municipalities showed greater interest in replicating the process in other areas, e.g. the spring protection intervention in Mopani generated great interest for replication of the intervention in other areas with similar resources.

### **4.1.2 The barriers**

The project implementation and its outcomes have highlighted a number of barriers to sustainability of services that also impact on the outcome of any innovation (process, social, technological) within the water services framework. The barriers identified in the ASWSD projects were the following:

- The limited human, technical and financial resources at the municipalities have significant negative impacts. There is high staff turnover in often already under staffed institutions. The introduction of new products or systems needed greater stability to champion these and also to see the processes to completion, with the necessary support into the future. In Phase II, two asset transfer agreements could not be concluded, despite extensive engagement, due to a high staff turnover. In one of the cases, this was coupled with instability and uncertainty in the municipality as an institution.
- The operation and maintenance culture was weak and did not provide sufficient support for the deployment of new technologies nor sustenance of the conventional. For a number of reasons, ranging from local government performance management systems to lack of funds and expertise especially at local level, operations and maintenance of water infrastructure are not prioritised. More importantly, the significance to the long term service delivery performance of the municipality, as well as its cost implications, appears to be unrecognised. In this regard, it may be worthwhile to consider issues such as simpler, more robust technologies and community based management. Regardless, capacity development in the area of O&M is a critical need.
- Preference for certain technologies by both service providers and users closes the space for innovation. This is at times linked to expectations on the part of users in the democratic South Africa and the pressure that accrues on the part of the service provider to satisfy these expectations. A similar phenomenon exists where some service providers with certain technologies are viewed as inferior although they may suit the resources and capacity contexts.
- Inadequate stakeholder participation leads to rejection of technologies that may otherwise have been accepted. This was seen in the reluctance by municipal official to introduce alternative technologies that could be perceived as inferior by the users. However, when the targeted users would appear receptive to the 'unusual' intervention, officials were happy to go ahead. Nonetheless, the alternatives were viewed as temporary and the long term goal was to work towards piped or tap water.

- Cultural and other societal conceptions impact the acceptability, or otherwise, of innovations. For example, a water purification technology was rejected because it resembled an enema syringe. It is important to package and present the innovations in culturally and socially acceptable forms.

#### 4.2 INNOVATION AND SUSTAINABILITY OF SERVICES

Sustainability has been a key underlying principle in the ASWSD initiative. This relates to both the expectations from the infrastructure delivered to the ownership of knowledge that would result from the research processes and the projects themselves. This was sought through continuous and active engagement of all stakeholders particularly the beneficiary users and the relevant municipalities. Beneficiary communities were engaged from the start of the project. This continued throughout the assessments and implementation through various forums. The choice of technological interventions was done in close consultation with the stakeholders with workshop sessions that presented the interventions proposals along with the outcomes of context (situational) assessment on which they (proposals) were based. Asset transfer agreements were also drawn up in close consultation with the water service authorities to ensure acceptability and commitment. This yielded some impact in the project areas but seems to depend on the existing institution framework for sustenance in the long term.

### 5 CONCLUSION AND FURTHER RESEARCH

In the planning, implementation and outcomes of the ASWSD projects, evidence on the barriers and enablers to the uptake of innovation in rural water services delivery has emerged. The evidence is documented in a manner that clearly illustrates the complexity of the challenge. Significantly, it (the evidence), demonstrates that whilst technological innovation has potential to contribute to universal access to services, stakeholders will need to embrace the complexity of the task for sustainable (technological and non-technological) innovation to take place. Thus for innovation to lead to sustainable access, it will need to respond to a complex and evolving human, economic, institutional and environmental context or fabric. This is in line with the observations by Zanella *et al.*, 2013 that the capacity for innovation in low income countries is a function of the dynamics between geographical, socio-economic, political and legal subsystems. To this effect, approaches that seek to embrace complexity, such as design thinking, are recommended for work that can further unpack the water services challenge in human settlements and seek sustainable solutions.

### ACKNOWLEDGEMENTS

The two ASWSD projects were both funded by the South African Department of Science and Technology.

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## Mapping housing research methods: Enhancing the link between research theory and methods in African housing studies

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### ABSTRACT

Relevant, empirical research creates the foundation for better informed decisions. Poor research that employs inappropriate methods or is without a broader theoretical foundation can lead to poor decision making and the misallocation of resources. This paper seeks to make a methodological contribution by improving our understanding of the potential range of housing research methods, and how housing theory can and should link to choice of method.

The paper reviews a number of methodological frameworks with the purpose of identifying what was regarded as conventional housing research, and then to explore potential emerging areas of research methodology that would be useful in advancing housing studies. By mapping housing research methods it becomes more feasible to relate research *objectives*, in each case, to the more rigorous selection of appropriate research *methods* and mixes of methods to satisfy those objectives.

The broader goal is to contribute to a process of more deliberately establishing housing research as a science so as to meet the growing complexity of the housing challenges that the continent faces, and to build innovation for inclusive development (Kruss, Petersen, Rust, & Tele, 2017).

Keywords: Housing studies, research methods, methodology, theory

## 1 HOUSING STUDIES AND RESEARCH METHODOLOGIES

*“Data are not free-floating objective facts but are of necessity socially constructed to answer particular kinds of questions.” Jim Kemeny and Stuart Lowe, 1998*

Housing research as it has emerged over the last century has tended to be more a broad field of study than a coherent academic discipline. Contributions to theory in housing studies have mostly been derived from parent disciplines including sociology, political science, economic history (Lawson, Haffner, & Oxley, 2008), economics, geography, health sciences, and the built environment disciplines (architecture, engineering and planning, for example). And so housing studies has been a fairly amorphous grouping of interested parties each focusing on different aspects. The apparent inability of early housing research to develop coherent theories of housing for its own field (Jacobs & Manzi, 2010; Oxley, 2001) can be attributed to the relatively wide scope of the field, and the broad grouping of involved disciplines: *“The basic reason for being suspect about theory of housing is that housing itself is not a research topic but a common denominator of a number of research topics: housing policy, housing provision, housing organizations, housing choice, housing mobility, housing tenures, uses and meanings of housing, housing inequalities, and more. There is no one “theoretical object”. Rather there are many theoretical objects linked with housing, and theorizing them is more or less connected with theoretical debates elsewhere”* (Ruonavaara, 2018).

### 1.1 POSITIVIST VERSUS CONSTRUCTIONIST

Over at least the last five decades, increasing numbers of universities have offered Housing Studies as a course at undergraduate level or as a postgraduate degree. The demand, mainly from government and global multilateral agencies (UN Habitat and the World Bank, for instance), for empirically sound housing research (Tipple & Willis, 1991; Kemeny & Lowe, 1998) was one of the factors that gave rise to the need for recognized tertiary qualifications.

Early research by professionals in the various fields mentioned tended to be very applied, with governments commissioning research to understand, explain and solve housing challenges (for example, see Malpass, 1976). This early period was therefore characterised as being mostly positivist, empirical, policy-focused, and somewhat lacking in conceptual foundation, as described by several commentators (Clapham, 2018; Kemeny & Lowe, 1998).

Referring to the 1960s and 1970s, Jacobs and Manzi state that “... *although the absence of explicit theory remains a defining characteristic of mainstream housing research, it primarily relies upon a positivist epistemology. Within this paradigm, the task of the housing researcher is one of discovering objective facts, presenting them in a descriptive format in the expectation that policy makers will take notice and act accordingly*” (Jacobs & Manzi, 2010, p. 35). Oxley concurs with the view that housing research was lacking in theoretical depth: “*A major fault in international housing research is that some work that claims to be analytical and comparative has in fact stopped short at precursory description. The aim of research projects is often unclear. It is unsurprising then that the methodology is frequently not explicit*” (Oxley, 2001, p. 90).

The positivism evident in the early period was perhaps partly because housing research was influenced by post-war thinking in Europe where one of the key objectives of the refocused social sciences was to collect and apply empirical evidence to influence the policy agenda to improve social policy and administration (Jacobs & Manzi, 2010). This was also true of housing research.

The same authors then trace the emergence of ‘*social constructionism*’ in housing studies from the mid-1990s to facilitate greater depth of interpretation of housing policy and practice. “*A constructionist epistemology purports that an individual’s experience is an active process of interpretation rather than a passive material apprehension of an external physical world. A major claim advanced by those adopting a social constructionist epistemology is that actors do not merely provide descriptions of events, but are themselves constitutive of wider policy discourses and conflicts. Viewing society and social policy as malleable and subject to power struggles, constructionists do not accept social facts as permanently “accomplished”. This emphasis on contestation is important in offsetting any tendency by actors to objectify social phenomena or reify abstractions into material realities*” (Jacobs & Manzi, 2010).

This kind of thinking opens up more space to construct higher level philosophies and theories of housing more capable of interpreting empirical evidence useful for generating recommendations for social and economic policy change. It also makes the underlying theories and assumptions of any given piece of research more explicit than was the case in the earlier period of housing studies: “...*since all research contains implicit underlying epistemological assumptions, it is important to make these explicit so that research can be properly evaluated and understood. In addition, theory has a role in highlighting the ideological assumptions that inform housing research and establishing the political context in which research is undertaken*” (Jacobs & Manzi, 2010).

The more empirically-based, positivist approach has some advantages in that observations (admittedly not unbiased) and evidence lead directly to policy recommendations. This works reasonably well in fairly homogenous and non-complex study environments. The limitation is that in the absence of a higher level interpretive model, it may not be easy to extract generalizable characteristics in situations where there is greater heterogeneity and more diversity in the realities being experienced and observed. On the other hand, a theoretical model that is too rigid can lead to the over simplification of the diversity of realities observed on the ground. Kemeny and Lowe (1998) discuss this trade off in the setting of comparative housing research.

## 1.2 PARTICULARISTIC VERSUS UNIVERSALISTIC

Instead of employing the positivist versus constructionist axis, Kemeny and Lowe contrast *particularistic approaches* in comparative research “...*which are conceptually unexplicated and highly empirical and in which each country is seen as unique*” and *universalistic approaches* “...*in which all countries are seen as being subjected to the same overriding imperatives*” (Kemeny & Lowe, 1998). In between these two extremes they identify and discuss ‘*theories of the middle range*’.

To briefly summarise, Kemeny and Lowe hold that there are roughly three different schools or research traditions that are each ‘associated’ with different levels of generalisation. The particularistic approach holds that detailed analysis of localised case studies or situations using empirical methods reveals a wide diversity of realities that cannot and should not be generalised. Each country and place is unique. When collecting information across different countries and places, and presenting these alongside one another, such cases are ‘*juxtaposed*’ with one another without an attempt to identify patterns that would allow comparison between places. This approach tends to employ more qualitative research methods associated with the social sciences and to generate descriptive and localised studies.

The universalistic *approach* on the other hand holds that higher level theoretical frameworks can be helpful in creating the basis for generalisation of findings gathered at local levels. It tends to adopt a developmental view of the world, where the theoretical framework (which is inevitably a social construct) helps to determine in what direction nations and countries are moving, usually along a pre-defined trajectory. What is useful about this way of understanding these universalistic approaches, is that the theoretical framework as an imposed organising structure can come from any place on the political/ philosophical spectrum: "... all countries are seen as being subjected to the same overriding imperatives, whether this is 'the logic of industrialism', capitalist market failures, the structural drive to increasingly comprehensive welfare states or its opposite, the privatisation and recommodification of welfare. ... Much of this implies a form of 'unilinealism', according to which countries are not only converging but share a common trajectory of change" (Kemeny & Lowe, 1998). Research methods employed by adherents to this approach tend to be more quantitative and data based, in an attempt to extract significant patterns across many places.

The middle ground between these two extremes, described as *theories of the middle range*, are studies "...that propose typologies of housing systems derived from cultural, ideological, political dominance or other theories as the basis for understanding differences between groups of societies. Such approaches in the comparative housing literature are termed 'divergence' perspectives. The divergence approach does not argue for an unspecified process of differentiation between societies or suggest that the trajectories of social change are necessarily and/or randomly digressing. Rather, it is argued that developments in the last couple of decades have moved the debates from earlier highly particularistic analyses through the global generalisation approach that is currently dominant and towards the emergence of attempts at basic typologies of housing systems" (Kemeny & Lowe, 1998). Research methods are mixed in an attempt to generate typologies that meaningfully relate to localised, experienced reality.

### 1.3 FROM THEORY TO METHOD

How does all of this relate to the topic at hand? The intention of this paper is to propose a framework for mapping research methods used in housing studies (now and possibly in the future). In discussing the different groupings of research methods that tend to be employed by the three approaches described here, and indeed also by the positivist and constructionist positions covered earlier, we are moving towards a more nuanced understanding of how the adoption of different, higher level philosophies and approaches (refer Saunders, M., Lewis, P. and Thornhill, 2012)(Figure ) by research agents then influence the selection and application of research methods to suit their broader agendas.

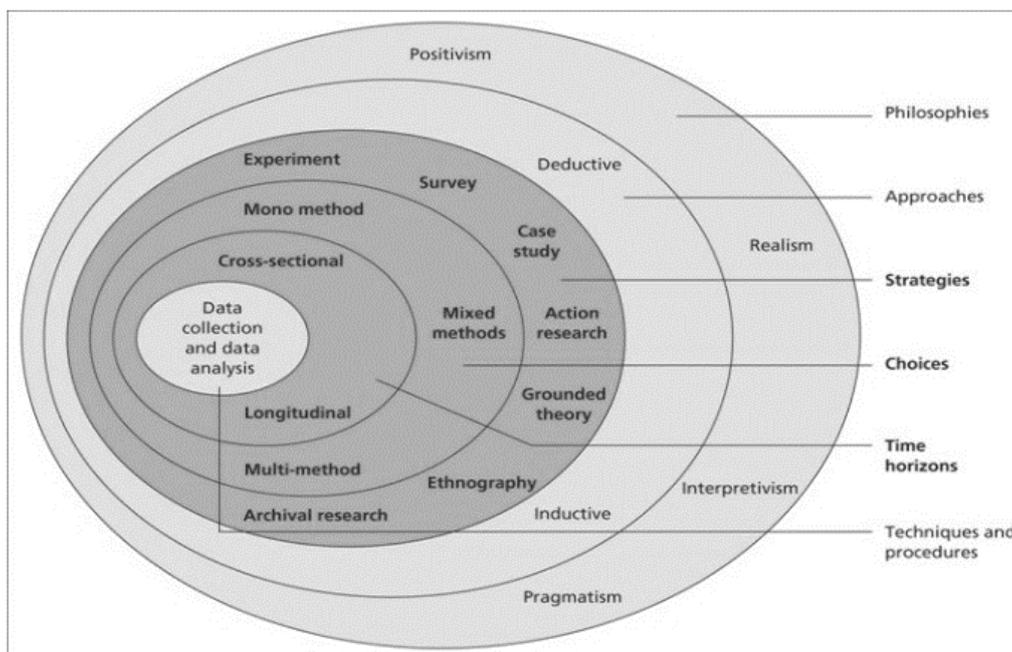


Figure 1 Levels of research (Saunders, M., Lewis, P. & Thornhill, 2012)

Best expressed by Kemeny and Lowe, "It is also important to note that the congruence between the schools of research—juxtapositional, convergence and divergence—and the levels of generalisation, respectively, the

*particularistic, the universalistic and the 'middle range', would appear to be related significantly to the research methodologies which are characteristic of each school. ... Ironically, both the particularistic and the most universalistic levels appear to have a common heritage in the empiricist tradition of research. ... Theories of the middle range adopt a more qualitative, culturally sensitive and historically grounded approach"* (Kemeny & Lowe, 1998).

From these commentaries about the development of housing studies and the emerging schools of thought, it would seem that a self-awareness about one's default (or considered) theoretical position in this landscape would be advisable for the range of academic institutions, research organisations and research consultancies operating in the housing studies space in South Africa. If there is not this conscious, reflective practice of research, one of the dangers of an overly positivist approach which is serving mainly a social policy function (i.e. research to inform state policy), is, as we have seen, that the housing theory of researchers tends to remain implicit rather than explicit, and secondly that the reality observed in one's own country or city/ town is assumed to be typical of other places, leading to the danger of ethnocentrism where our own reality is projected onto others making genuine comparison (that caters to diverse realities) more difficult (see Kemeny & Lowe, 1998).

## 2 MAPPING HOUSING RESEARCH METHODS

By mapping housing research methods it becomes more feasible to relate research objectives, in each case, to the more rigorous selection of appropriate research methods and mixes of methods to satisfy those objectives. This also assists in remaining more consciously consistent with one's research philosophy and one's theory of housing.

In following this path of mapping methods, the intention was also to add rigour to the practice of housing research and housing science in increasingly complex settlement and urban settings (so that the ability to interpret realities remains commensurate with observed complexity). The second intention was to explore some of the methodological advances in research theory, data collection and data analysis in some of the associated disciplines that contribute towards shaping housing studies.

Thirdly, we also wanted to make some comment on the potential of enhanced housing research to make a more direct link between advances in science, technology and innovation, and the improvement of sustainable human settlements and inclusive development (Kruss *et al.*, 2017). This is a very positivist, policy-oriented goal of course, but it might also be realistic to expect that one of the convergent theoretical constructs or some of the typologies built from empirical observations within a more divergent perspective, will assist in better understanding, for example, the national system of innovation or, as another example, understanding how the (formal and informal) housing sector works as a system at national, regional and local levels.

### 2.1 CONVENTIONAL RESEARCH METHODS

In addressing housing research, the focus was on exploring methodological frameworks that offered potential for new avenues of expansion from conventional methods. We did not fully explore the current political dynamics of housing research in South Africa and the African continent as there are various other sources that consider the fundamental, philosophical shifts required for adequately investigating the field in an African context. Such discourse advocates for a focus on locally-generated knowledge, reform of approaches and philosophies within research methodology, and local policy-orientated research (Parnell & Pieterse, 2016; Simon, Palmer, Riise, Smit, & Valencia, 2018; Sturtevant, 2015). Parnell and Pieterse call for a "repositioning of conventional modes of research" to address typical African research conditions "... where human needs are great, information is poor, conditions of governance are complex and the reality is changeable" (Parnell & Pieterse, 2016).

Not many academics have attempted to collect and arrange the vast array of methods that are and can be associated with housing studies, but through analysing treatises on research methods there are certain groupings of methods that can be said to be conventional in the field of housing research in the 1980s and 1990s.

An example is the 1991 edited book on "*Housing the Poor in the Developing World: Methods of analysis, case studies and policy*" (Tipple & Willis, 1991). Each chapter illustrates a research design that employed a method or mix of methods to address the objectives of a specific housing research project. The authors stress the

need to ground their research methods in each developing country context. They are comfortable with borrowing methods of analysis from various disciplines for application to housing studies.

They demonstrate that housing research can be addressed at various scales using appropriate methods, from neighbourhood to national levels. The methods documented range from qualitative field work, to participant observation, to contingent valuation and the use of cost-benefit analysis in housing finance, to mention a few. The approaches bring to the fore the respective roles of a range of research actors in contributing to a housing research capabilities framework, including researchers, economists and policy-makers.

The conventional set of research steps common to most fields also apply, including an initial literature review, followed by field or primary research (collection of observable data, participant data and descriptive data) which is then analysed to determine conclusions (McNelis, 2014). The field research conventionally includes various combinations of surveys, participant interviews and observations. This we would refer to as the conventional research methods employed in housing studies through to the early 2000s.

## 2.2 REVIEW OF ORGANISING FRAMEWORKS

In the quest to find an appropriate organising framework to chart conventional research methods and then to explore the potential usefulness of newer, emerging methods to the field of housing studies, we attempted to locate commentators who had attempted to adopt some form of logic to organise different types and mixes of methods.

At a strategic level Saunders (2012) offered a framework with a clear hierarchy of research philosophies (or theories), approaches, strategies, method choices, time horizons (i.e. cross sectional versus longitudinal studies), and data collection and analysis techniques (Figure ). With our focus being on research methods, the distinction between research method and research design was important. Du Toit assists: “*Research designs’ are logical plans involving strategic decisions to maximise the validity of findings... Well-known designs include surveys, experiments, case studies, etc. Research methods are detailed steps within a design, involving data collection, analysis and interpretation*” (Du Toit, 2010 ). The scope of this discussion includes both aspects.

Another way to link research theory through to research method was Dudovkiy’s framework that presented a choice matrix through from ontology<sup>1</sup>, to epistemology<sup>2</sup>, to research approach, strategy and method.

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<sup>1</sup> The science of being or the image of social reality upon which a theory is based. (Blaikie, 2009)

<sup>2</sup> “The theory of knowledge, especially with regard to its methods, validity, and scope, and the distinction between justified belief and opinion” (<https://en.oxforddictionaries.com/definition/epistemological>)

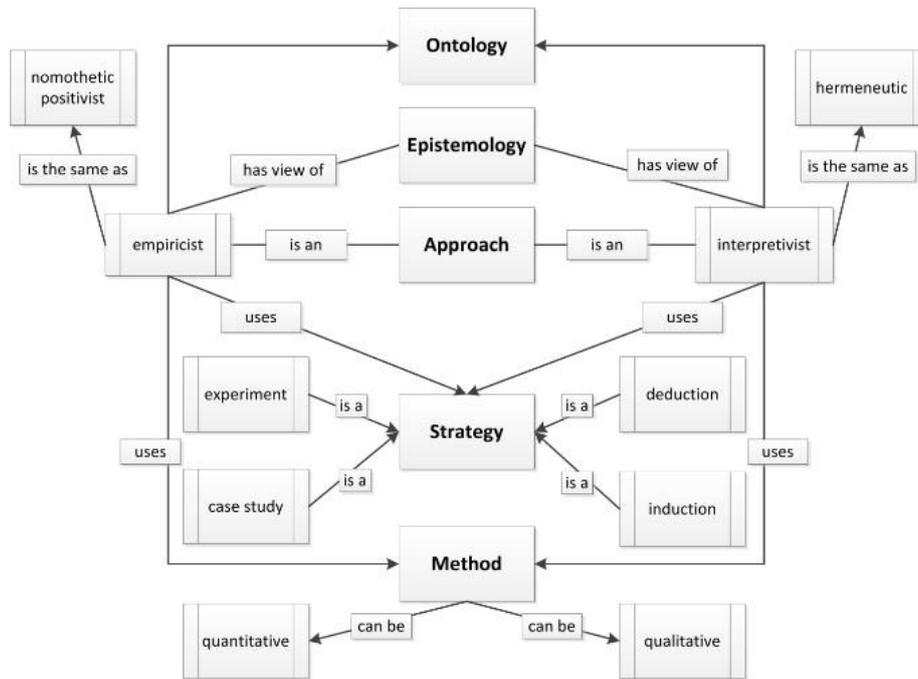


Figure 2 Impact of research philosophy on the choice of research method (Dudovskiy, 2018)

Dudovkiy’s diagram equates research strategy to what du Toit referred to as research design. The simplest distinction in the area of method is of course quantitative versus qualitative (or mixes thereof). However we require more detail than that. Tipple and Willis draw a distinction between research methods that employ personal judgement (subjective) versus those where the data are not derived using personal judgement (objective). They position the research methods described in their book along a continuum with intuitive judgement at one end (e.g. cultural analysis and participant observation) and scientific experiment at the other end, and with other gradations in between (Figur3).

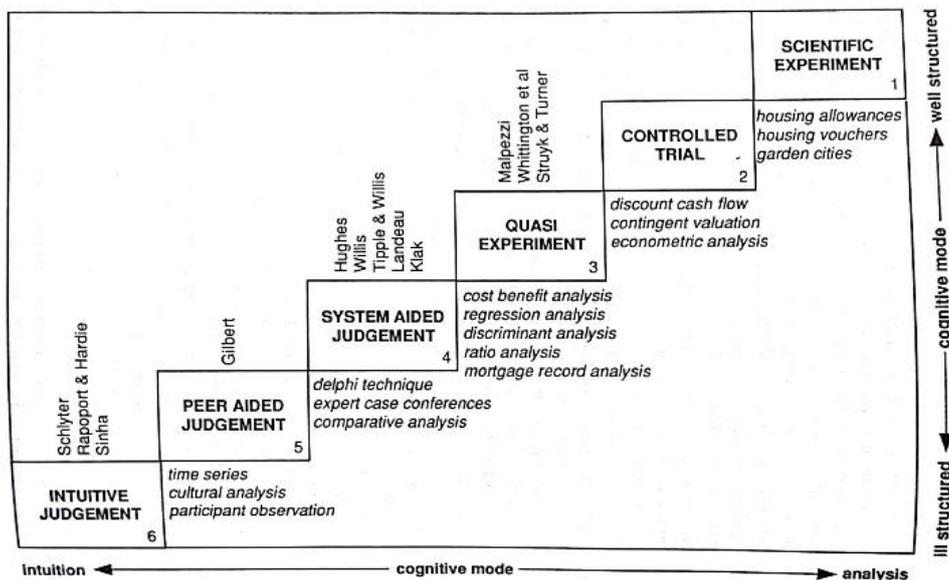


Figure 3 Modes of enquiry and analysis: based on Hammond's cognitive continuum (Tipple & Willis, 1991)

The next two frameworks explored linked a broader research intention with the subsequent selection of appropriate methods. This linked more closely to the Kemeny & Lowe (1998) logic where different groups of researchers would want alternatively to make more universal generalisations compared to other groups

wishing to be more descriptive, detailed and local, with less of a desire to compare across places. Both frameworks originated in the urban and regional planning disciplines rather than in housing studies *per se*.

The first such framework emerged from an endeavour to describe the work of the African Centre for Cities (ACC) based at the University of Cape Town. The stated objective of the ACC was to strive towards achieving *“the notion of translational urban research praxis” in its research and engagement. This notion “...captures more than the idea of applied research, or even co-production, and encompasses integrating the research conception, design, execution, application and reflection—and conceiving of this set of activities as a singular research/practice process.”* (Parnell & Pieterse, 2016). The translational urban research praxis approach described would seem to be closest to the *‘theories of the middle range’* (Kemeny & Lowe, 1998) described above, with a special emphasis on being locationally specific, embedded and grounded (Parnell & Pieterse, 2016).

Parnell and Pieterse’s framework uses ‘research mode’ as its main organising element (*Figure* ).

The modes include, amongst others, pure research, applied research and advisory services, embedded researchers and practitioners involved in the co-production of knowledge (e.g. between the university and the municipal government) and then other forms of engagement such as research laboratories, professional networks, exhibitions and published knowledge products.

What is particularly useful about this kind of organising framework is that the type of research or knowledge production is linked to appropriate methods and then through to an explicit purpose that the research institute wishes to achieve.

For example, the stated purpose of the pure research mode leans more towards the theoretical, divergent side, and the applied research mode leans more towards normative influence on policy (refer *Figure 4*).

The framework is quite specific to the organisation (the ACC), but the framework is a useful device to achieve an alignment between higher level approach (in this case ‘translational urban research praxis’) and designed research interventions employing consistent research methods.

| Research Mode                                           | Methods                                                                                                                                                         | Example                                                                                                                                                                                                                                                                                                                                                                   | Purpose                                                                                                                                                                                                     |
|---------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Pure research                                           | Data design, collection and analysis using established research theories and methods                                                                            | See UCT research reports ( <a href="http://www.researchoffice.uct.ac.za/research_reports/annual/">http://www.researchoffice.uct.ac.za/research_reports/annual/</a> )                                                                                                                                                                                                      | Understand past legacies; analysis of different aspects of urban complexity (e.g. politics, design, welfare, culture, resource flows, social identities, labour markets, regulation, curriculum reform)     |
| Applied research and advisory services                  | Driven by the client or partner, but nominally including conventional literature reviews, qualitative and quantitative methods                                  | South African National Urban Framework; position papers for UN Habitat or Cities Alliance; advice to donors on urban issues and urban/planning curriculum and professional reform                                                                                                                                                                                         | Engage with decision makers; influence the development agenda to advance a stronger urban focus; assert the normative base of African urbanism; impart useful knowledge and skills to urban practitioners   |
| Embedded researchers and practitioners in co-production | Driven by practitioners' generated data and policy imperatives                                                                                                  | City of Cape Town indigent policy, green economy, energy and climate policies                                                                                                                                                                                                                                                                                             | Language for understanding the current constellation; legitimate analysis of what needs to shift within public institutions; learn by using academic and local knowledge of practice                        |
| City labs                                               | Mixed methods characterized by a strong inter- and trans-disciplinary focus                                                                                     | Urban health, ecosystem services, human settlements, culture, ecology, alcohol, violence as well as area based city labs                                                                                                                                                                                                                                                  | Create epistemic communities or action networks within the academy and between the university and other knowledge actors; transdisciplinary and action research evident                                     |
| Professional networks                                   | Translational (see text)                                                                                                                                        | Hosting and enabling large comparative projects, e.g. MUF ( <a href="http://www.mistraurbanfutures.org/en/">http://www.mistraurbanfutures.org/en/</a> ) or AFSUN ( <a href="http://www.afsun.org">http://www.afsun.org</a> ) or Professional urban Networks e.g. AAPS ( <a href="http://www.africanplanningschools.org.za">http://www.africanplanningschools.org.za</a> ) | Insert an African component into international research and activities; build African urban research capacity and African networks; stimulate published research                                            |
| CityScapes                                              | Combining long-form reportage with visual methods; story-telling; opinion pieces to promote considered polemic                                                  | <a href="http://www.cityscapesdigital.net">http://www.cityscapesdigital.net</a>                                                                                                                                                                                                                                                                                           | Foster a compelling discourse across the global South between informed and lay urbanists that is trained on the emergent contexts in all of its richness                                                    |
| Exhibitions                                             | Articulating research findings through story-telling and visual method connected to research by design studios; gaming with youth to generate emergent insights | Draws an evidence base from all of the above                                                                                                                                                                                                                                                                                                                              | A creative means to engage a popular audience and instill a deeper societal interest in the city and urban policy issues and clarify where academic research remains obscure and unsure in its applications |

Figure 4 African Centre for City's multiple modes of exploration (Parnell & Pieterse, 2016)

The second purpose-driven organising framework was developed by Jacques du Toit originally as part of his PhD thesis at the University of Pretoria (Du Toit, 2010; Du Toit *et al.*, 2017).

The framework was developed to assist in analysing the nature of South African planning research theses, and built from the work of a number of 'methodologists'. A useful distinction between types of organising frameworks is made: "Methodologists differ in their criteria for classifying designs. Some criteria pertain to aspects of control (experimental vs. non-experimental designs), time (cross-sectional vs. longitudinal designs), methodological approach (quantitative vs. qualitative designs), etc." (Du Toit, 2010)

Du Toit's framework chose to employ core logics, or 'compact formulas', that indicate the objective of a study as a main organising element. These are then associated with research design types and sub-types. The core logics include generalisation, causal attribution, prediction/ illustration, hermeneutical interpretation,

ethnographical/ phenomenological interpretation, contextualisation, intervention, evaluation, and participation/ action.

Figure 5 indicates how the various core logics relate to research design types and sub-types.

| Research designs                                | Core logics                                                | Subtypes                                                                                                                                                                          |
|-------------------------------------------------|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Surveys                                         | Generalization                                             | Cross-sectional surveys<br>Longitudinal surveys                                                                                                                                   |
| Experiments                                     | Causal attribution                                         | True experiments (aka laboratory experiments)<br>Quasi-experiments (aka field/natural experiments)                                                                                |
| Modeling, simulation, mapping and visualization | Prediction/illustration                                    | Modelling; simulation<br>Mapping; visualization                                                                                                                                   |
| Textual and narrative studies                   | Interpretation (hermeneutical)                             | Content/textual analysis<br>Discourse/conversational analysis                                                                                                                     |
| Field studies                                   | Interpretation (ethnographical/ phenomenological)          | Historiography; biography<br>Ethnography (aka participant observation)<br>Phenomenology                                                                                           |
| Case studies                                    | Contextualization                                          | Single/multiple case studies<br>Comparative case studies                                                                                                                          |
| Intervention research                           | Intervention                                               | Site/settlement analysis and assessment<br>Plan/policy analysis and assessment                                                                                                    |
| Evaluation research                             | Evaluation                                                 | Diagnostic/clarification evaluation (aka <i>ex ante</i> evaluation)<br>Implementation evaluation; program monitoring<br>Outcome/impact evaluation (aka <i>ex post</i> evaluation) |
| Participatory action research (PAR)             | Participation/action                                       | Technical/scientific/collaborative PAR<br>Practical/mutual and/or collaborative/deliberate PAR<br>Emancipating/enhancing/critical science PAR                                     |
| Meta-research (Non-empirical studies)           | Various core logics depending on the objectives of a study | Literature reviews; research synthesis<br>Conceptual analysis<br>Typology/model/theory construction<br>Philosophical/normative/logical argumentation                              |

Source: Adapted from Du Toit and Mouton (2012, 128)

Note: Intervention, evaluation and participatory action research may also be considered ‘types’ of research rather than standalone designs considering that each of them often combine different designs. E.g., an evaluation may well include both a survey and field research component. Still, these three types of research are considered standalone designs here due to their unique core logics. Thus, if the overall logic of a reported study was evidently one of evaluation, we would have coded its design as such irrespective of whether the study included different sub-designs.

Figure 5 An index of designs applicable to planning research (Du Toit et al., 2017)

### 2.3 EXPANDING THE ORGANISING FRAMEWORK

Building upon these organising frameworks, especially du Toit’s, it is possible to begin to map some of the housing and urban studies research logics and associated methods (Figure 6). The first layer out from the centre of the diagram shows the core logics as conceptualised by du Toit (Du Toit *et al.*, 2017). To these we have added several extra categories, normative forecasting, sourcing and analysing big data, and research that is designed to produce policies, guidelines and frameworks.

Normative forecasting, such as scenario planning and roadmapping methods is often a mix of methods, but the combination of research and engagement activities are devoted specifically to generating and exploring varieties of future states. With rapid technological and spatial change being experienced globally and especially on the African continent, forecasting possible future states of housing, settlements, neighbourhoods,

precincts and urban conurbations can be a worthwhile endeavour. There are already an array of urban futures projects and projects to collaboratively re-imagine a more desirable future at various spatial scales.

In *Futures Research Methodology* (Glenn & Gordon, 2009), the authors distinguish between normative forecasting and exploratory forecasting to differentiate between method options. “*Normative forecasting addresses the question: what future do we want? What do we want to become? Exploratory forecasting explores what is possible regardless of what is desirable*” (Glenn & Gordon, 2009, p. 7). After using these distinctions to create a simple taxonomy of futures research methods, their ‘model of analysis’ helps to assess and understand methods from a futures perspective.

Futures research methods can be used by various disciplines as there is a general understanding of what constitutes a futures study, or a prospective study, which can be adapted accordingly. One element worth noting (as one of Sardar’s four laws of futures studies) is that these studies deal largely with complex, interconnected (sometimes referred to as ‘wicked’) problems (Sardar, 2010), which in turn require innovative strategies and solutions through thorough application of quantitative and qualitative methods.

There are some methods that are more applicable to futures studies, such as modelling, and these may be sorted into categories including heuristic modelling, decision modelling, agent modelling, and statistical modelling. ‘Scenarios’ is also an umbrella-term for a range of predictive methods. Other methods addressed include simulation, various methods of data and information analysis, case studies, trend impact analysis, and causal-layered analysis.

Secondly, the use of ‘big data’, or large datasets which are often combinations of interrelated datasets, to identify patterns and trends across space and society is a fairly recent entry into the research sphere. This allows observations of human behaviour at a much wider scale than was previously possible. Disciplines that work with such datasets are already developing and enhancing the computing power and the analytical tools to interpret such data. It is suggested that housing studies could look at this area more closely for potential new ways to understand complex systems such as growing cities and settlements, and the relationship between people, their choices and the built environment.

Thirdly, the production of guidelines, frameworks, policies and the like, although it might not fit into the primary research category, it is certainly a higher level, strategic research activity. The development of approaches such as Regulatory Impact Assessment to test the possible impacts of draft housing and settlement policies is a good example of a research approach that combines modelling, costing and scenario planning to predict likely outcomes of policy.

### 3 CONCLUSION

Although the process of mapping housing research methods as presented in this paper needs to be taken further, and we need to employ participative methods in its extension, this review of research concepts and organising frameworks has helped us to initiate the process.

By encouraging a conscious revisiting of research methods, this paper has attempted to contribute towards building of a more capable research community founded on increasingly rigorous and scientific methods. Quality research should inform practice (and vice versa). The adequacy of the results of research is dependent upon the adequacy of the methods used (McNelis, 2016) and, therefore, good decision-making requires adequate, effective data and information.

With more sophisticated housing theory (designed to interpret increasingly complex housing and urban systems), and more appropriate, rigorous and up to date research methods, the process and findings of research can make a stronger contribution to shaping housing policy and programmes, and influencing the many actors in the broader housing sector. A variety of theories and approaches addressing regional, national or local contexts is healthy, allowing us to triangulate results and compare recommendations. The more academic pursuit of higher level theories aimed at better understanding complex reality, developing sound normative positions (of what should be), and enhancing the ability to predict outcomes is as worthy a pursuit as both positivist, empirical, applied policy research, and the deep, qualitative documentation of unique, local realities.

Schools of thought that respectively apply universalistic approaches and those that apply particularistic approaches (Kemeny & Lowe, 1998) can benefit from frequent interchanges of knowledge. The identification of large trends and patterns across society provides part of the picture, and a deep knowledge of what motivates people to behave in certain ways, helps to understand some of the causal links and provides the

other part of the picture. Through mapping current and potential new research methods, it is hoped that the overlaps between the disciplines that can contribute to housing studies will become more apparent, thus highlighting areas of prospective multi-disciplinary collaboration. Each discipline tends to have specialised methods, tools and techniques, however, with changing trends in housing and urban research and the technologies that can assist with understanding complexity, there is a need for continuous review of the field's direction and the roles of different specialisations.

The increasing interest in recent decades in translating evidence into policy change has highlighted the need to disseminate the findings of research as widely as possible, through both academic and non-academic media. If advances in science, technology and innovation are to make a more effective contribution to achieving better housing, the role of sound research and effective knowledge sharing need careful attention from all researchers.

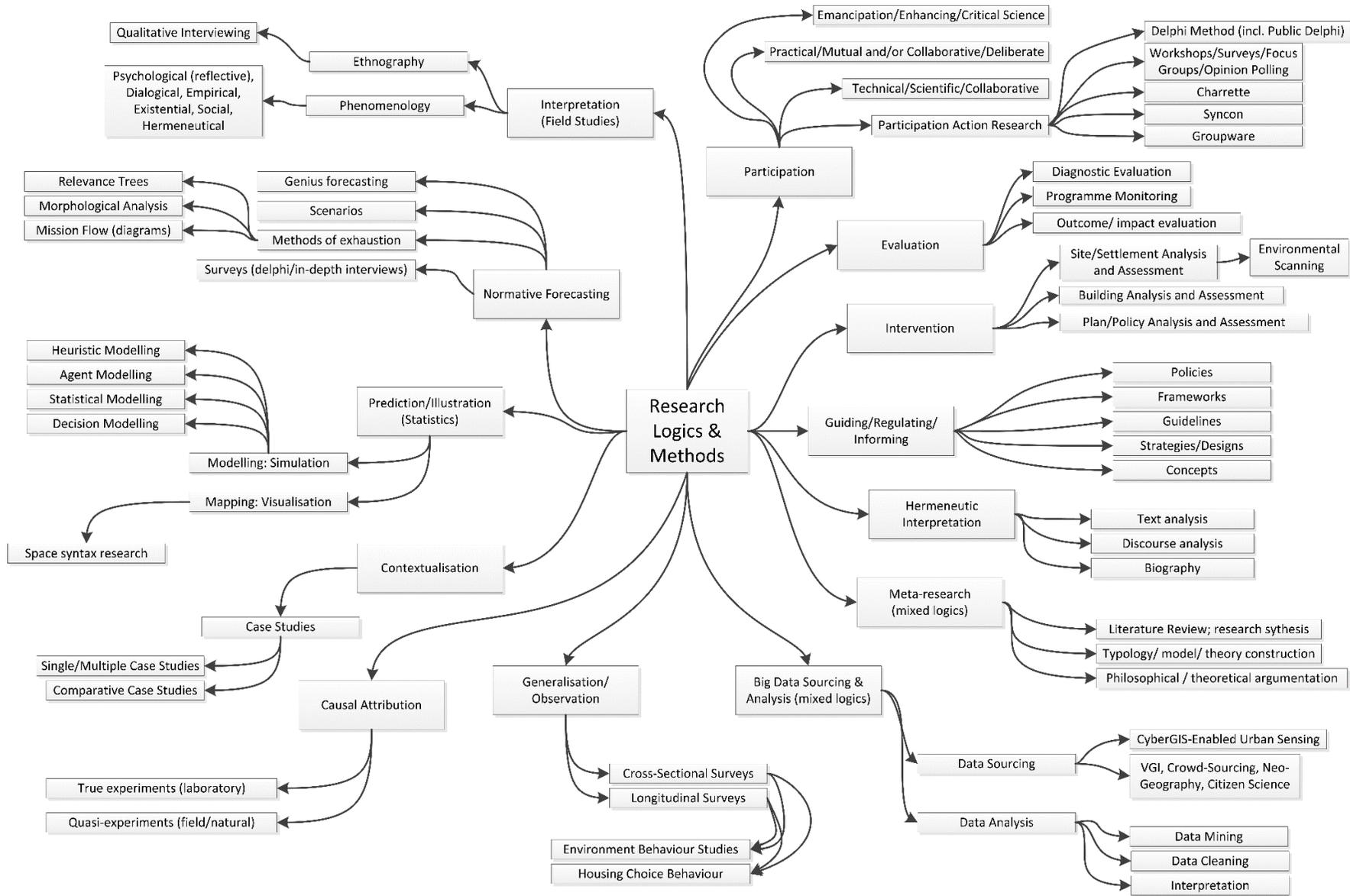


Figure 6 Mapping of research logics and methods (after du Toit)

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## Environmental and performance aspects of metakaolin as an alternative ordinary Portland cement extender

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### ABSTRACT

The primary objective of the study was to compare the CO<sub>2</sub> equivalent emissions of Ordinary Portland Cement (OPC) to that of Metakaolin (MK) produced using two coal-fired Vertical Shaft Kilns (VSKs). The secondary objective was to evaluate the compressive strength of several OPC/MK blends with varying metakaolinite contents. The environmental comparison was carried out with the Life Cycle Assessment (LCA) software tool SimaPro 8.1 and the Ecoinvent Database version 3; and the Life Cycle Impact Assessment (LCIA) method ReCiPe midpoint was chosen to generate the results in CO<sub>2</sub> equivalents. Four batches of MK, referred to as MK1, MK2, MK3 and MK4 were produced using the two coal-fired VSKs. Cement pastes containing 0%, 10%, 20% and 30% of MK were prepared at a constant water/binder ratio of 0.3 and cured at ambient temperature. The compressive strength of the cement pastes was determined at ages of 2, 7, 14 and 28. The results of the LCA study show that the partial replacement of OPC by MK can significantly lower the CO<sub>2</sub> emissions associated with cement use. The cement pastes containing MK exhibited higher compressive strength than OPC alone. The increase in compressive strength of the cement pastes with MK was more pronounced between 7 and 28 days. The results indicate that the cement pastes with MK3 (high amorphous phase content) have a higher compressive strength than the pastes containing MK1 with lower amorphous contents and this was due to the increased pozzolanic content. It was concluded that the optimum replacement level of OPC by MK to give maximum long-term strength enhancement was 30% for MK2 and MK3 while 10% was more favourable for MK1 and MK4. MK has the capability to replace silica fume as an alternative cement extender.

Keywords: CO<sub>2</sub> emissions, compressive strength, metakaolin, ordinary Portland cement, vertical shaft kiln

### 1 INTRODUCTION

Cement, the binding agent in concrete, is by far considered one of the most important and most produced building materials in the world (Hendriks *et al.*, 2003). The production of Ordinary Portland Cement (OPC) is a highly energy intensive process that releases large amounts of greenhouse gases (GHGs), mainly carbon dioxide (CO<sub>2</sub>) into the atmosphere (Ramezaniyanpour & Jovein, 2012; Suryawanshi *et al.*, 2015). Globally, the cement sector accounts for approximately 5-7% of total CO<sub>2</sub> emissions (Torgal *et al.*, 2011; Juenger *et al.*, 2011; Krajčič *et al.*, 2015). Several strategies to mitigate the CO<sub>2</sub> emissions have been studied. Due to the large amounts of CO<sub>2</sub> emitted during the production of OPC, interest has shifted towards cement blends whereby the clinker content of OPC is partially replaced by less-energy intensive Supplementary Cementitious Materials (SCMs) such as fly ash, Ground Granulated Blast Furnace (GGBFS) and silica fume (Palomo *et al.*, 1999; El-Diadamony *et al.*, 2016). However, the use of these materials is constrained by geographical availability. In South Africa, fly ash is localised in the Mpumalanga Province; and GGBFS and silica fume are localised to smelters in the Gauteng and the North West Provinces. Thus, there is a need to find alternative SCMs from local sources that are abundantly and ubiquitously available (Huat, 2006; Antoni *et al.*, 2012).

The use of metakaolin (MK) as an alternative SCM has received considerable interest (Wild *et al.*, 1996; Si-Ahmed *et al.*, 2012). Kaolinitic clays that are used to produce MK are abundantly available and widespread. The partial substitution of OPC with MK reduces the energy consumption and CO<sub>2</sub> emissions to the environment (Krajčič *et al.*, 2015). Besides the environmental benefits, the use of MK can also significantly improve strength and durability of concrete in comparison to OPC alone (Sabir *et al.*, 2001; Aiswarya *et al.*, 2013). Thus, metakaolin is increasingly being used to produce high-strength,

high-performance concrete (Barbhuiya *et al.*, 2015). MK exhibits similar performance to that of silica fume and has the capability to replace silica fume as an alternative material (Dinakar *et al.*, 2013; Khatib *et al.*, 2014). In spite of its special properties and several studies that show the performance and environmental benefits of utilising MK as OPC partial replacement, the industry-wide use of MK is still to happen due to its relatively high market price.

A low-cost process has successfully been developed for the production of MK using a coal-fired Vertical Shaft Kiln (VSK) (Dumani, 2017). Commonly, the calcination of kaolinitic clay to produce MK can be carried out using a rotary kiln, a flash calciner or a multiple-hearth furnace on industrial scales. Unfortunately, these processes are capital intensive and complex thereby increasing the price of metakaolin. The development of the VSK process was motivated by the need to produce MK economically thus ultimately reducing its market price. The VSK process is simpler in design and operation and has a lower capital cost than the other processes (Bes, 2006; Edwards, 2011; Okonkwo *et al.*, 2012; Eskelinen, 2014; Eskelinen *et al.*, 2015; Gebremariam, 2015; Teklay *et al.*, 2015). Traditionally, the VSK process is used for the calcination of limestone to produce lime. Vertical shaft kilns are fuel efficient and up to 80% can be achievable in well-designed VSKs (Okonkwo *et al.*, 2012; PEC Consulting, 2015). The development of MK using the VSK will contribute to economic growth; job creation across South Africa; and the building of sustainable and affordable housing.

The VSK process was successfully demonstrated using a 3.2 ton per day pilot VSK to determine optimized process parameters; followed by using the optimized parameters on a 12.5 ton per day semi-industrial VSK (Dumani, 2017). The samples of metakaolins produced using the VSKs differed in the amounts of amorphous (metakaolinite), mullite and cristobalite contents. The CO<sub>2</sub> emissions associated with the production of metakaolin using the VSK process was determined.

The primary objective of the study was to compare the carbon footprint (CO<sub>2</sub> emissions) of OPC to that of the metakaolin (MK) produced using the VSK process. The secondary objective was to evaluate the compressive strength of OPC/MK blends with varying metakaolinite contents produced using the 3.2 ton per day VSK and 12.5 ton per day VSK.

## 2 COMPRESSIVE STRENGTH

There have been several studies on the compressive strength of concrete/mortar/cement paste containing metakaolin. The studies have shown that partial replacement of ordinary Portland cement with MK can increase the compressive strength of concrete (Wild *et al.*, 1996; Dinakar *et al.*, 2013; Dubey *et al.*, 2015). According to Wild *et al.* (1996) there are three elementary factors influencing the contribution that MK makes to strength when it partially replaces OPC in concrete (Wild *et al.*, 1996). These are the filler effect, which is immediate; the ability of MK to accelerate the OPC hydration, which occurs within the first 24 hours; and the pozzolanic reaction of metakaolin with calcium hydroxide (CH), which has its maximum effect somewhere between 7 and 14 days of age.

Dinakar *et al.* (2013) examined compressive strength of concretes incorporating 5%, 10% and 15% MK by weight as partial replacement of OPC produced at a water/binder (w/b) ratio of 0.30. The compressive strength was found to increase with increasing MK content and 10% replacement level was optimal. Similar results were reported by Dubey *et al.* (2015) who studied the 28 days compressive strength of concretes in which OPC 43 grade was partially replaced with metakaolin at levels of 5%, 10% and 15% by weight. The results showed that the compressive strength increase with increasing MK content as compared with the control mixture and 10% replacement with MK was optimal.

Poon *et al.* (2001) also investigated the compressive strength of cement pastes containing 5% to 20% MK by weight, produced at a w/b ratio of 0.30. They reported that cement pastes containing 5% to 20% MK had higher compressive strengths than the control at all ages from three to 90 days, with the paste containing 10% MK performing the best.

Badogiannis *et al.* (2005) investigated the compressive strength of cement containing five metakaolins at 10% and 20% replacement levels up to 180 days. The metakaolinite contents in metakaolins MK1, MK2, MK3, and MK4 were 36, 37, 71, and 49%, respectively, but 95% in a commercial metakaolin (MKC) of high purity. They reported that metakaolin had a very positive effect on the cement strength after 2 days and specifically at 28 and 180 days. It was observed that 10% replacement was generally more favourable than 20%. Mermerdaş *et al.* (2012) also examined the compressive strength of four different types of calcined Turkish kaolins (CK) at replacement levels of 5% to 20% ranging from three

to 90 days. Additionally, commercial metakaolin (MK) of high purity, derived from the Czech Republic's Zettlitz kaolin standard, was used for comparison purpose. They reported that the partial replacement of OPC by MK enhanced the compressive strength of concrete at all ages, but the optimum replacement of OPC by MK to give maximum long-term strength enhancement was about 20%.

### 3 RESEARCH METHODOLOGY

#### 3.1 RESEARCH DESIGN AND APPROACH

The partial substitution of OPC by MK can significantly reduce the CO<sub>2</sub> emissions into the atmosphere. Life cycle assessment (LCA) methodology was used to calculate the CO<sub>2</sub> emissions associated with the production of OPC; and compare this to the CO<sub>2</sub> emissions of various OPC/MK cement blends. LCA is a method for evaluating the environmental impacts associated with a product by quantifying the resources consumed (energy, materials, water, and land) and the emissions to the environment (air, water and soil) at all stages of the product life cycle. The methodology used in this study follows the approach outlined in the two International standards ISO 14040:2006 and ISO 14044:2006. There are four phases (see Figure 1) in a LCA study:

- Goal and scope definition states the objective of the study, defines the system boundaries and the functional unit to be used in the investigation
- Life cycle inventory analysis (LCI): data collection and calculation of all materials, energy and emissions related to the system being investigated
- Life cycle impact assessment (LCIA): analysis of the LCI results to evaluate contributions to environmental impact categories
- Life cycle interpretation: evaluating the findings of the LCI and LCIA phase in relation to the stated goal and scope to reach conclusions and make recommendations

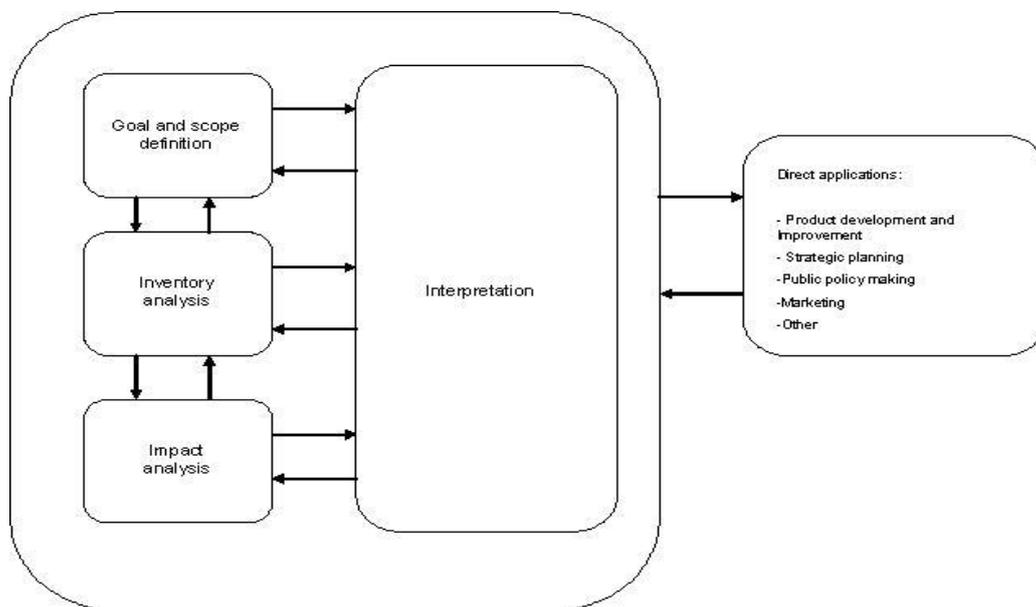


Figure 1 Phases of the LCA procedure – (Source: ISO/SANS,2006)

#### 3.2 GOAL AND SCOPE DEFINITION

##### 3.2.1 Goal

The primary objective of the study is to compare the CO<sub>2</sub> emissions of OPC to that of metakaolin produced using the VSK process. The secondary objective is to compare the CO<sub>2</sub> emissions of OPC to that of OPC/MK blends with different MK content of 10%, 20% or 30%.

### 3.2.2 Scope

The scope of the LCA study, as shown in Figure 2, is limited to a cradle-to-gate analysis. The only impact category considered in this study is climate change, that is, carbon footprint. The functional unit is kilogramme. Thus, 1 kg of 100% OPC will be compared with 1 kg of each of the OPC/MK blends.

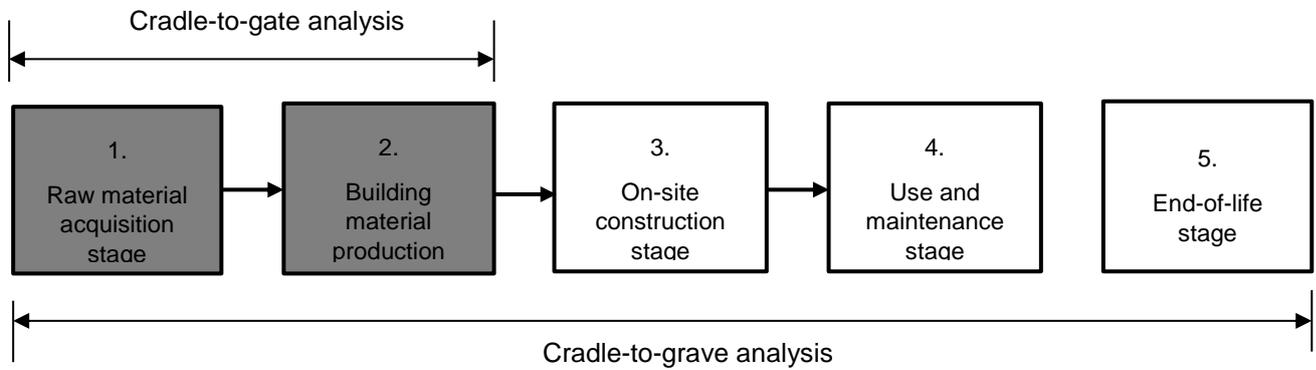


Figure 2 Generic life cycle stages of construction product

### 3.3 LIFE CYCLE INVENTORY AND LIFE CYCLE IMPACT ASSESSMENT

The life cycle inventory (LCI) phase of the study is concerned with the collection of the data and calculation procedures. The LCA software tool SimaPro 8.1 with the Ecoinvent Database version 3 was used to compile the LCI dataset for each material and then to perform the Life Cycle Impact Assessment (LCIA). South African-specific LCI data for each of the materials was difficult to obtain and therefore European industry average data obtained from the Ecoinvent Database 3 were modified and used in this study. The datasets were 'localised' by changing the electricity mix to the South African country mix in order for the datasets to represent South African production processes. ReCiPe midpoint (H), which is an LCIA methodology, was used to generate the results in CO<sub>2</sub> equivalents.

The kaolinitic clay was mined in Hammanskraal and transported to Pretoria. The CO<sub>2</sub> emissions associated with production of metakaolin include extraction and crushing of the kaolinitic clay; calcination of the kaolinitic clay; and transportation and milling of the metakaolin. The assumptions made in the study to calculate the CO<sub>2</sub> emissions associated with the production of metakaolin are summarised in Table 3.

Table 1 Life cycle inventory data – metakaolin production assumptions

| Unit process    | Sub-process           | Assumptions                                                                                                            | Source                       |
|-----------------|-----------------------|------------------------------------------------------------------------------------------------------------------------|------------------------------|
| Kaolinitic clay | Mining and extraction | Rest of the World (RoW) dataset for kaolin production used as a proxy                                                  | Ecoinvent 3 database         |
|                 | Crushing              | Rest of the World (RoW) dataset for crushing of limestone used as proxy                                                | Ecoinvent 3 database         |
|                 | Transporting          | Road distance, Hammanskraal to Pretoria (site) = 62 km<br>Transport = lorry, > 16-32t<br>Charging rate = 50%           | Ecoinvent 3 database         |
| Metakaolin      | Calcining             | Coal calorific value is 19.57 MJ/kg<br>Fuel efficiency of the vertical shaft kiln is 34%<br>Clay to coal ratio = 8.5:1 | Eskom integrated report 2016 |
|                 | Transporting          | Road distance, Pretoria (site) to Johannesburg = 94 km<br>Transport = lorry, > 16-32t<br>Charging rate = 50%           | Ecoinvent 3 database         |
|                 | Milling               | Rest of the World (RoW) dataset for quicklime, milled, loose used as proxy                                             | Ecoinvent 3 database         |
|                 | Transporting          | Road distance, Johannesburg to Pretoria = 79 km<br>Transport = lorry, > 16-32t<br>Charging rate = 50%                  | Ecoinvent 3 database         |

Ordinary Portland cement 52.5 N was obtained from PPC Jupiter and transported to Pretoria. The assumptions made in the study to calculate the CO<sub>2</sub> emissions associated with the production of OPC are summarised in Table 4.

Table 2 Life cycle inventory data – Ordinary Portland cement production assumptions

| Unit process             | Sub-process   | Assumptions                                                                                        | Source               |
|--------------------------|---------------|----------------------------------------------------------------------------------------------------|----------------------|
| Ordinary Portland cement | Manufacturing | Rest of the World (RoW) dataset for CEM I (class Z 52.5) used as proxy                             | Ecoinvent 3 database |
|                          | Transporting  | Road distance, PPC Jupiter to Pretoria = 74 km<br>Transport = lorry, 16-32t<br>Charging rate = 50% | Ecoinvent 3 database |

### 3.4 COMPRESSIVE STRENGTH

Four batches of metakaolin were produced and investigated in this study. The semi-quantitative mineralogical of the materials obtained using XRD is presented in Table 5. Initially, the calcination of kaolinitic clay was carried out in a 3.2 ton per day coal-fired VSK to investigate the effect of clay to coal ratio in order to determine the optimum VSK process parameters for the production of MK. Subsequently, three different ratios of clay to coal of 4:1, 6.75:1 and 8.5:1 were considered. Finally, using the optimised parameters obtained from the 3.2 ton per day VSK, the production of MK was demonstrated on a 12 ton per day semi-industrial kiln. These batches of metakaolin differed from each other primarily in the amounts of amorphous (metakaolinite), mullite and cristobalite contents present in each as shown in Table 3 The batches of metakaolin derived from clay:coal = 4:1, clay:coal = 6.75:1, clay:coal = 8.5:1 and the 12 ton per day VSK are referred to as MK1, MK2, MK3 and MK4 respectively. High grade kaolinitic clay containing 95% kaolinite, 4% quartz and 1% anatase collected from Hammanskraal was used to produce these batches of metakaolin.

Ordinary Portland cement 52.5 N was used in this study. The OPC/MK blended pastes prepared had MK contents of 10%, 20% and 30%. The pastes were prepared using a water/binder (w/b) ratio of 0.3. A normal OPC paste with no MK was prepared as a control. Polycarboxylate superplasticizer (SP) was used to produce an appropriate paste consistency.

Table 3 Mineralogical composition of the batches of metakaolin obtained using XRD

| Mineralogical composition | MK1   | MK2  | MK3  | MK4  |
|---------------------------|-------|------|------|------|
| Amorphous phase           | 76.5  | 82.6 | 90.7 | 81.0 |
| Quartz                    | 4.00  | 4.00 | 4.00 | 4.00 |
| Anatase                   | 0.71  | 1.04 | 1.58 | 1.10 |
| Mullite                   | 6.35  | 3.65 | 1.40 | 3.80 |
| Cristobalite              | 11.53 | 6.96 | 1.49 | 6.50 |
| Rutile                    | 0.94  | 0.70 | 0.84 | 0.80 |

Cube specimens of 50 x 50 x 50 mm in dimension were cast in steel moulds and compacted by vibration. The specimens were covered to prevent water loss and left overnight. The specimens were de-moulded and cured in water at ambient temperature. The compressive strength of each specimen was determined at the ages of 2, 7, 14 and 28 days. Compressive strength was computed from average of three specimens at each testing age.

## 4 FINDINGS AND DISCUSSION

### 4.1 LIFE CYCLE ASSESSMENT

The CO<sub>2</sub> equivalent emissions of OPC and metakaolin are shown in Table 4.1. The CO<sub>2</sub> equivalence of metakaolin was obtained to be 0.430 kg CO<sub>2</sub>eq/kg metakaolin at a VSK efficiency of 34% as shown in Table 4.1. Heath *et al.* (2014); Jones *et al.* (2011); Moropoulou, (2011); and NLK, (2002) reported similar results as shown in Table 6. In addition, similar results were obtained when using a carbon emission factor of 2.8814 kg CO<sub>2</sub>eq/kg coal from Eskom (Dumani and Mapiravana, 2017).

Table 4 Comparison of carbon equivalence of the VSK metakaolin with ordinary Portland cement

| Material   | Metakaolin comparison studies | kg CO <sub>2</sub> eq/kg |
|------------|-------------------------------|--------------------------|
| Metakaolin | This study (VSK process)      | 0.430                    |
|            | Heath et al. 2014             | 0.423                    |
|            | Jones el al. 2011             | 0.330                    |
|            | Moropoulou, 2011              | 0.401                    |

|                          |           |       |
|--------------------------|-----------|-------|
|                          | NLK, 2002 | 0.370 |
| Ordinary Portland cement | -         | 0.986 |

The VSK fuel efficiency was obtained to be low. The VSK fuel efficiency was determined as the actual energy required for complete dehydroxylation of kaolinitic clay to the energy available from the coal used for calcination as shown in Figure 3. The actual energy required for complete dehydroxylation of the kaolinitic clay was obtained from the differential scanning calorimetry (DSC) area under the dehydroxylation endothermic hump. It is observed from Figure 4.1 that significant reductions of CO<sub>2</sub> emissions associated with MK can be achieved by increasing VSK fuel efficiency. This can be achieved through better VSK insulation, modified VSK kiln design and flue gas energy recovery.

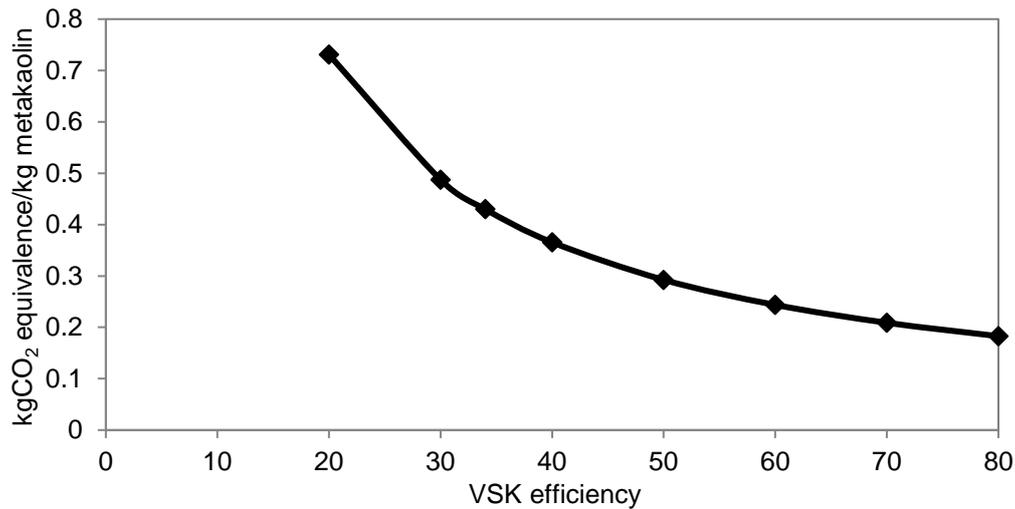


Figure 3 Calculated CO<sub>2</sub> equivalence emissions of metakaolin produced per kg by the VSK process as a function of VSK fuel efficiency

The CO<sub>2</sub> equivalent emissions of OPC and OPC/MK blends are shown in Figure 4. The CO<sub>2</sub> emissions of 100% OPC is greater than that of OPC/MK blends. Therefore, replacing 100% OPC with OPC/MK blends represents a major opportunity to improve the environmental performance of the cement industry.

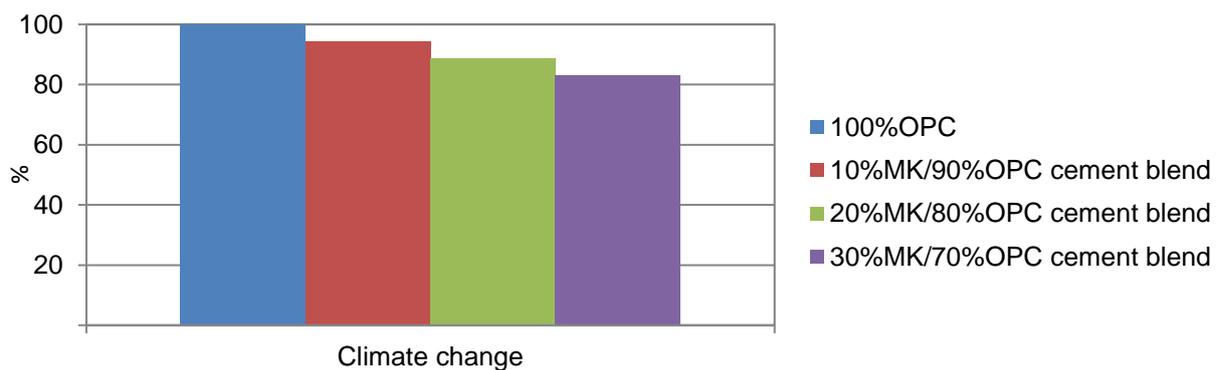


Figure 4 Results for comparison of OPC and OPC/MK blends

#### 4.2 COMPRESSIVE STRENGTH

The use of metakaolin as a partial OPC replacement has a positive influence on the compressive strength of the cement pastes owing to its pozzolanic properties (Mitrović *et al.*, 2013). The results of compressive strength of the control (OPC) and OPC/MK pastes are shown in Figures 5-7, where each value is the average of three measurements.

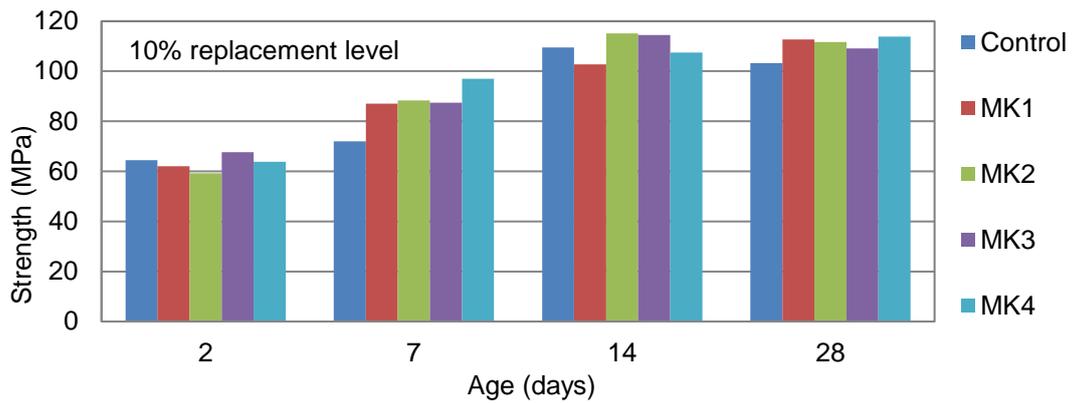


Figure 5 Compressive strength as a function of age of cement pastes containing 10% MK

The compressive strength of the control samples ranged between 64 and 103 MPa while the compressive strength of OPC-MK blended pastes varied between 42-115 MPa. After 2 days of curing all cement pastes containing MK showed lower compressive strength as compared to the control, with the exception of MK3 containing 10% replacement level. This was attributed to the fact that the filler effect did not adequately compensate for the decrease in the compressive strength as a result of reduction in cement content as well as the contribution by any pozzolanic reaction that still had not shown its effect (Mermerdaş *et al.*, 2012). However, the strength increase in cement containing 10% MK3 at 2 days is due to the filler effect which leads to initial acceleration of OPC hydration (Wild *et al.*, 1996; Badogiannis *et al.*, 2005; Sidek *et al.*, 2013).

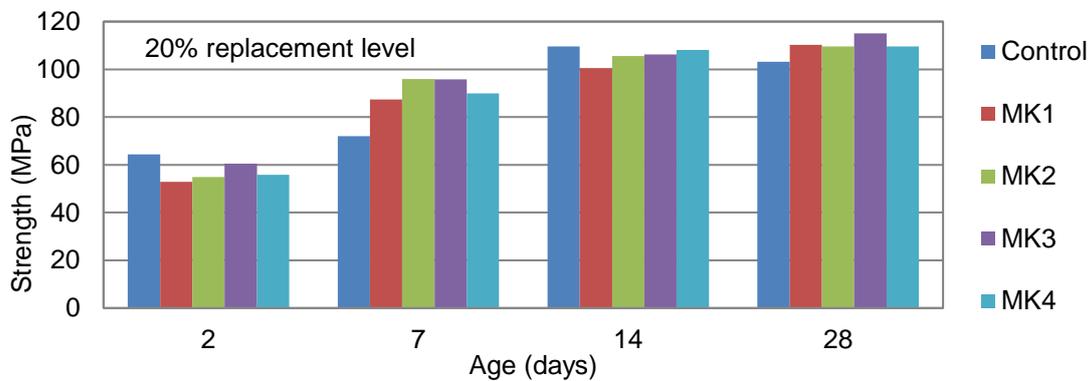


Figure 6 Compressive strength as a function of age of cement pastes containing 20% MK

The compressive strength of cement pastes containing 20% MK significantly increased in comparison to the control specimens between 7 and 28 days due mainly to the pozzolanic reaction of metakaolin with CH (Badogiannis *et al.*, 2005). The batches of metakaolin investigated in this study differ in their mineralogical composition as shown in Table 3.3. It was observed from the compressive strength results that the cement pastes containing MK3 had the highest metakaolinite content, lowest mullite and cristobalite contents, and exhibited the highest strengths in all cases due to their high reactivity in comparison to the other cement pastes. Cement pastes containing MK1 had lower strengths mainly due to their lower reactivity as compared to other OPC-MK blends. MK1 had the lowest metakaolinite content; and highest mullite and cristobalite contents. Cristobalite and mullite phases cause a decline in pozzolanic reactivity of metakaolin (Sabir *et al.*, 2001; Teklay, 2015). It is concluded from the results shown in Figures 5-7 that MK2 and MK3 are best used when a cement replacement level of 30% is required, while for MK1 and MK4, the appropriate cement replacement level is 10%.

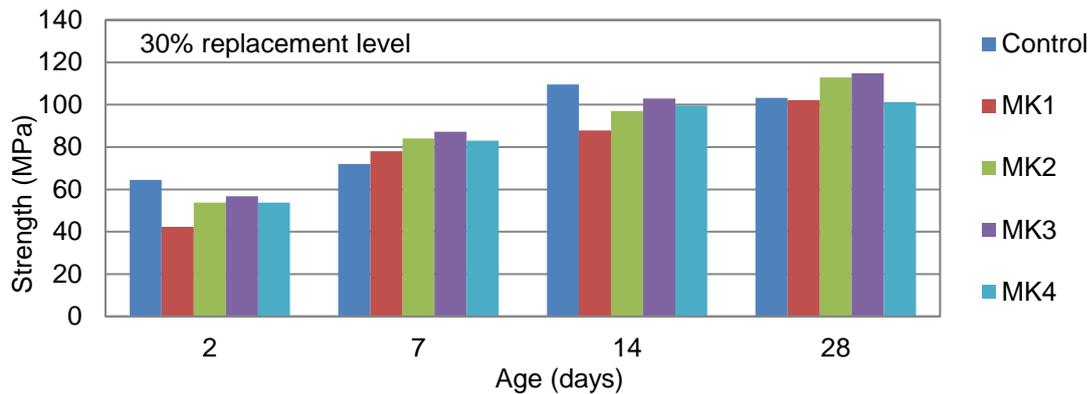


Figure 7 Compressive strength as a function of age of cement pastes containing 30% MK

## 5 CONCLUSION AND FURTHER RESEARCH

It can be concluded from the results that partial replacement of OPC with different MK contents can significantly reduce CO<sub>2</sub> emissions of cement. Moreover, further significant reductions of CO<sub>2</sub> emissions associated with metakaolin production can be achieved by increasing VSK fuel efficiency.

The compressive strength of cement pastes is influenced in a positive manner by the addition of metakaolin. The replacement level; the content of metakaolinite in metakaolin; and the reactivity of MK affected the compressive strength results of the OPC-MK blended pastes. The optimum replacement level of OPC by MK to give maximum long-term strength enhancement was found to be 30% for MK2 and MK3 while 10% was more favourable for MK1 and MK4. Mineral composition influenced the strength development of the batches of metakaolin investigated in this study. MK3 had the highest metakaolinite content and exhibited the highest compressive strength. MK1, which had the lowest metakaolinite content but highest mullite and cristobalite contents, showed the lowest compressive strength. The benefit of partially replacing OPC with metakaolin was most apparent between 7 and 28 days. Future studies will demonstrate the production of MK using a 30 – 100 ton per day industrial VSK kiln to produce sufficient MK/cement blends for commercialization.

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## **Using Foucault to explore technology diffusion: A case study of the Exalon QMS in managing human settlement projects in KwaZulu-Natal**

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### **ABSTRACT**

This study examined how decision support tools could facilitate the efficient and effective delivery of human settlements in South Africa using Exalon Quality Management System (Exalon QMS) as a reference point. The focus on Exalon QMS was informed by its critical support function in infrastructure development and as a solution provider in the human settlement sector. Using the empirical case study of the Vulindlela Housing Project and interview data from a related project on the identification of transformative decision support tool(s) to facilitate the delivery of sustainable human settlements, we examine the types of effects, visibilities, knowledge, techniques and professional identities amongst sustainable human settlement professionals using Exalon QMS. The theoretical contribution of the study lies in the application of Foucault's theory of governmentality, with insights from innovation diffusion as the process of market penetration by new products and services, which is motivated with or without consumers' explicit knowledge. We conclude by reflecting on challenges to innovation adoption and diffusion including resistance and trust deficit in the chain of actors receiving innovation, which, in this case is Exalon QMS.

Keywords: Decision Support Tools, Exalon QMS, Governmentality, Innovation, Technological Adoption, Technological Diffusion

### **1 INTRODUCTION**

One of the major challenges that the South African government is faced with is the ever-increasing housing backlog, and the slow pace of delivering low-income houses (Massey & Gunter, 2019). The National Department of Science and Technology (DST) has prioritised the development and uptake of decision support tools for improving policy instruments for innovation in service delivery. This would be co-produced to assist human settlement stakeholders to take strategic direction in the implementation of sustainable human settlements in South Africa. Currently, there is a dearth of research on technological diffusion and consumer interest that would respond to human settlement challenges (Myeni & Mvuyana, 2015). Moreover, we take note of the limited engagement with two critical concepts in contemporary debates – innovation and governmentality. The contribution of this study lies in the fact that it combines these theories – governmentality and the diffusion of innovation – thus enabling researchers to investigate the participation of innovators in housing delivery at micro level. Minimal engagement limits the understanding of the experiences of early adopters of decision support tools, who are the first group to critically assess the products employed to curb housing delivery challenges during the construction phase. Evidence in peer-reviewed work on the motivations and experiences of innovators provides critical insights into the advance of innovation; but with less-detailed case studies for housing delivery. Assessing the use of technological tool(s) can provide insight into future solutions for human settlement challenges, and increase the proportion of users who can play an active role in the market.

This study investigates how decision support tools are used to facilitate the efficient and effective delivery of human settlements in South Africa using the Exalon QMS as a reference point. The study also examines how the tool benefits construction professionals in the field of human settlements. The study argues that instead of merely identifying decision support tools, the focus should be on

understanding their impact in the co-production of knowledge that will respond to the challenges of human settlements.

This study adopted a qualitative research approach in an attempt to gain an understanding of the use of Exalon QMS as a human settlement project management and reporting tool. The Vulindlela Housing Project (used as a case study) is a catalytic project which the KwaZulu-Natal Department of Human Settlements approved on 10<sup>th</sup> March 2011. It is the largest single project in the history of the national housing subsidy scheme, amounting to R 2, 1 billion. The project was designed to provide 25,000 houses to the rural community of Vulindlela area of Msunduzi Municipality in Pietermaritzburg (Isikhungusethu Environmental Services, 2016). A case study approach allows for the use of different data collection methods such as interviews, observations and document analysis, and diverse approaches to data analysis. A weakness of single case studies lies in the fact that findings from such studies are not generalisable. Despite this shortcoming, single case study research does provide valuable and novel insights into the research subject. In addition, such findings could be instrumental in mapping out new research agenda as well as providing the base for a more comprehensive study (see Schweber, 2017). We take into cognizance in the literature that there has been a limited engagement with the concepts of innovation and governmentality. The preliminary findings of this study suggest that Exalon QMS as a decision support tool responds directly to sustainable human settlements challenges, which is less visible because of minimal engagement with the case study approach in understanding the benefits of decision support tools.

Following this introduction, the next section deals with a review of literature and begins by examining the works of Rogers and Foucault. We then discuss the research methodology adopted for this study. This is followed by a section that presents the discussion and the findings. The theory of governmentality draws attention to problem areas of housing delivery, subjects and populations, and discusses individuals' sense of responsibility in respect of the challenges of human settlements. The last section concludes with a call for detailed studies to be conducted on each decision support tool and cautions professional communities and the community of practice of built environment to consider innovation – either in the form of diffusion or adoption as drivers of sustainable human settlements.

## **2 LITERATURE REVIEW: INNOVATION AND GOVERNMENTALITY**

This section reviews literature on the concept of innovation from the seminal work of Rogers (1962) '*The theory of governmentality*', coined by Michael Foucault (1979) is also reviewed. This review of literature focused, particularly on technological innovation – that is its definition and the manner in which types of innovation are differentiated. Furthermore, we examine the meanings of technological diffusion and technological adoption as well as their inherent advantages and disadvantages. We take into cognizance the limited engagement with the concepts of innovation and governmentality.

### **2.1 INNOVATION: TECHNOLOGICAL DIFFUSION AND ADOPTION**

According to Frieman (2012), the word innovative means to make something new, generate or realise a new idea, which is developed into a product or translated into reality. Technology, when combined with innovation, changes the meaning of innovation. It elicits a notion of generating a novel idea informed by technology, capability or knowledge. Therefore, technological innovation becomes part of innovation. Frieman (2012) further argues that technological innovation is primarily about the successful integration of technology into products, services and processes. The dissemination of technology as a corpus of knowledge acts as the basic building block for technological innovation in research, design and development. Furthermore, Edosomwan (1989) defines innovation as an invention. By defining innovation in this manner, the author acknowledges the critical roles of creativity and novelty in innovation. Critical to this process is the practical application of what is invented. Without this focus, an invention cannot be innovative. For Berry and Taggart (1994), innovation encompasses the entire process beginning from when an idea is formulated to when it is sold.

Henderson and Clark (1990) group innovation into four categories (incremental, architectural, modular and social) respectively. Incremental innovation builds on existing innovation without a radical departure from the underpinning innovation. Architectural innovation is primarily about reconfiguring different parts of an existing system in a manner that leads to something new. In modular innovation, the principal

design concept of an existing innovation is changed while retaining the primary function of the product. Radical and system innovations are other forms of innovation in addition to the foregoing. According to Marquis (1969), an innovation is radical if the product it introduces brings about fundamental changes to an industry. Systems innovation, on its part, are those innovations that occur over a long period and requires the commitment of a considerable amount of resources (both human and fiscal) to achieve its outcome(s).

For the purposes of this study, we define innovation as a process, which conceives and produces a new solution through technical and scientific knowledge. Technological diffusion and adoption facilitate innovation. Peres, Muller, and Mahajan (2010) define innovation diffusion as market penetration of innovative products and services. Innovation diffusion could be driven by consumers' explicit knowledge but this is not a necessary precondition for innovation diffusion because social influences also play critical roles in innovation diffusion. Through technological diffusion, innovations such as novel processes, products, services and management methods proliferate across different societal sectors. Technological diffusion has been used in many fields including communication, agriculture, public health, public administration, social work, and criminal justice (Stoneman, 1985).

According to Hall and Khan (2002), technological adoption is the decision to acquire and use a new invention or new innovations. It is a sociological model, which tries to explain the acceptance of a new product or innovation according to demographic and psychological factors of the defined adopters. In this case, technological adoption concerns itself with the choice to acquire and learn more about an innovation, and it is the stage by which a technology is mentally accepted by individuals or organisations. Upon this acceptance, a decision is made to utilise and implement a technology to depict the extent to which the technology becomes accepted and incorporated into approved social practices (Hall & Khan, 2002).

There are advantages and disadvantages of innovation diffusion and adoption. Since diffusion explains, how over time, an idea or product gains momentum or spreads through a social system (Rogers, 1962), its apparent advantage is that people, as part of a larger social system, adopt a new idea, behaviour or a product. Some of the apparent disadvantages of the diffusion of innovations is the tendency to focus primarily on a product or innovating. By doing so, it ignores the complexities that influences social acceptance of innovation (Stoneman, 1985).

An inherent advantage of technological adoption is that it provides a framework for competitive advantage between organisations, and that new technology and innovations yield far more effective and efficient results, which save time, money and resources (Hall & Khan, 2002). Since firms need to adopt new technologies and structure themselves to be ahead in the market, technological adoption has the potential to enhance operational efficiency and effectiveness, in cases where an appropriate technology is adopted (Clark, 1990). The disadvantages of technological adoption are that since businesses have come to rely on technology to keep them up-to-date and ahead of competition in some instances, this very use of technology can be the reason why an organisation's profit margins are affected (Hall & Khan, 2002). This is because having cutting-edge technology is an on-going expense as purchase and maintenance costs are involved. Technological adoption also has the potential to bring about disconnections – as jobs are now often delineated – and people become disconnected from the final products. The use of technology also means that messages can be misunderstood in every-day communication (Markovich, 2018). The next section examines the concept governmentality for the purpose of this study.

## 2.2 GOVERNMENTALITY

Governmentality is the brainchild of the French sociologist Michael Foucault. He discussed the concept of governmentality in various public lectures in 1979. The ideas that Foucault introduced in these lectures has been developed by social scientists over the years. The core of Foucault's governmentality is power/knowledge. Governmentality *"refers to the way in which knowledge at the level of basic assumptions, assertions and claims, as well as the rationalities through which they are produced and the formal disciplines which inform them, are tied up with the exercise of power"* (Schweber, 2017: 295). Schweber (2017, 295) observes that the foregoing implies that *"Foucault's focus is not on power in the sense of the imposition one person's will or interests on others, but rather on indirect power or 'control'"*.

According to Higgins and Larner (2010), standards such as accounting standards is within the domain of governmentality. This is because such standards set the processes/parameters for actions in each

domain (e.g. calculations in accounting). Li (2007, 7) argues that these processes should be referred to as “*rendering technical support*” – which is a set of practices “*concerned with representing*” “*the domain to be governed as an intelligible field with specifiable limits and particular characteristics ... defining boundaries, rendering that within them visible, assembling information about that which is included and devising techniques to mobilize the forces and entities thus revealed*”. In essence, governmentality concerns itself with the relationship between discourse and practice as a way to understand the act of governing, and how the goals of governance are attained. The core idea of governmentality is that rationalities are informed by the “technologies” of government-standards, technical kit, accounting tools, as well as the daily practices and activities that ensures that ideas embedded in policies become practice (Higgins & Lerner, 2010; Li, 2007).

Governmentality expands our understanding of the day-to-day exercise of power at different levels of human interaction. Foucault sought to encourage people to consider power beyond those held by the state or the power held and exercised by various institutions including schools, hospitals, and psychiatric institutions. The power exercised by these institutions also include the knowledge they possess and how they use this as a tool for control. Seen from the perspective of the society, control over societal knowledge production influences societal discourses that become internalised by members of such societies and therefore constitute an important tool for control. Foucault’s work invites us to change our analysis from the centre and national institutions such as the state – not only because this affords the weak an opportunity to speak and be heard, but because those macro-spheres of authority are not necessarily the only focal conductor of power (Kothari, 2001).

### **3 RESEARCH METHODOLOGY**

The study used Exalon QMS as a case study to illustrate the use of decision support tools in the human settlement sector. The discussion of Exalon QMS is underpinned by multiple sources including primary data on the influence of Exalon QMS as a Human Settlement Decision Support tool. The first round of the exercise was aimed at identifying decision support tools for human settlements through desktop research, in-depth interviews, online surveys and stakeholder workshops. The workshop discussions included key stakeholders from the sector. The second round involved in-depth interviews with the owners of Exalon QMS. Contents from Exalon QMS website were also used to supplement the study data. Users of Exalon QMS from Dezzo Holdings were interviewed to understand their perceptions in using the tool to implement the Vulindlela Housing Project.

### **4 FINDINGS AND DISCUSSION**

This study drew from multiple sources including stakeholder workshops, online survey, desktop research and individual interviews. The study was underpinned by the concepts of technological diffusion and adoption and Foucault’s theory of governmentality to examine the use of decision support tools (using the Exalon QMS as reference point), and how it impacts on professionals working in the human settlements field. A total of 110 human settlement tools were identified through the multi-pronged data collection approach employed in the study. Slightly over half of the tools were identified via desktop research followed by approximately 37% that were identified through workshops. Less than a tenth of the tools were identified through online survey. This is largely due to the poor response rate. Poor response to online surveys has been reported in other studies (Padayachee, 2016).

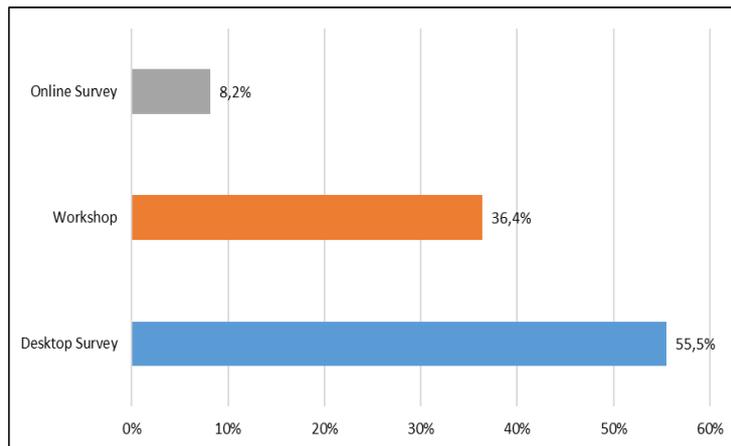


Figure 1 Sources of Decision Support Tools

#### 4.1 EXALON QUALITY MANAGEMENT SYSTEM (QMS) AS A TOOL

Exalon QMS was introduced to manage the construction of low-income housing. In the South African context, low-income housing projects are subsidised by the Department of Human Settlements (DoHS). Launched in 2012, Exalon QMS is used to manage beneficiary register, building contractor, and civil engineering inspections. All these activities are implemented on mobile android devices. The application is available for installation Google Playstore. However, the web interphase is available via tablets and desktop computers.

Since 2012, numerous Implementing Agents (IAs) – mainly from KwaZulu-Natal (KZN), the Eastern Cape (EC), Gauteng (GP) and the North West (NW) have been using this tool to manage housing projects. A key aim of this study was to examine the use of Exalon QMS as a decision support tool and its impacts on professionals working in the human settlements field.

Interview with a staff of the of Exalon QMS revealed that, as a software development company, its initial project was the development of an application for MR PRICE, a South African clothing and households' company. According to this respondent, the application is now used around the world by over 200 companies in the clothing sector. The company develops various kinds of softwares including "cloud applications, Windows Applications and multi-platform mobile applications for various sectors".

Exalon QMS is a multi-criteria project management tool for human settlement professionals. The tool seeks to positively affect the human settlement sector by empowering professionals with knowledge, techniques and professional identities. It has been noted that Exalon was initially limited to the clothing industry, but since 2012, Exalon QMS was extended for use in managing housing projects. Overall, these changes were influenced by *"adaptive planning, evolutionary development, early delivery, continuous improvement, and rapid and flexible response to change"* (Exalon Dynamic Systems, n.d.).

While Exalon is not the only entity that develops decision support tools for human settlements in South Africa, it is an entity that offers its clients a *"turnkey solution, from systems analysis, and website design to programming, installation and maintenance"* (Exalon Dynamic Systems, n.d.). Until around 2006, Exalon was not widely used by agencies in the human settlement sector. However, the number of users and clients has increased rapidly since then. The staff of Exalon that was interviewed reported that it has registered 84, 558 low-income housing sites on its database. Despite this increased uptake, this represents a small fraction of all low-income housing sites in South Africa.

Interview with a staff of Exalon QMS revealed that the tool was produced through collaboration, considering user requirements. This collaborative process was underpinned by rigorous scientific and technical considerations. The tool plays a key role in planning, implementing and monitoring human settlements projects with a specific focus on housing projects. In addition, it was designed, considering the traditional landscape of low-income housing projects in rural areas with limited/no cell phone coverage. The tool can, therefore, be operational in such contexts. However, active internet connection is required for document uploads/downloads. Another feature of the tool, according to the staff of Exalon QMS, is that the tool is highly flexible and can be reconfigured to suite the specific needs of individual client.

## **4.2 WHAT IS EXALON QMS USED FOR?**

Findings from interviews with owners and users of the tool revealed that clarity should be provided around what Exalon QMS is used for. Following the initial focus on the clothing industry, the company reconfigured Exalon QMS as a management tool for managing human settlement projects. Findings from users of the tool revealed that the tool requires training before it can be used. However, they noted that the tool was easy to use once training has been provided.

Users of the tool reported that site-based inspections using the tool is important for early warning on implementation challenges such as poor workmanship. This ensures that the number of failed structures to be demolish is reduced as quality standard are met. Through this, the tool plays a critical role in project costs reduction. In addition, early warning also enhances project accountability. Overall, interview with users of Exalon QMS revealed that housing development, such as those delivered using Exalon QMS, offers value for money. These benefits are linked directly to the following measures that have been put in place by the tool developers: standardised electronic quality system checks by all inspectors; comments are recorded with the inspections and uploaded to be viewed on the web interface by management to ensure that quick decisions are made, and that every inspection coordinates are captured. In addition, the tool is only operational within a constrained distance from the physical structure to be inspected. This ensures that the inspectors are on site before they can inspect a housing unit. In addition, each inspection report has date and time stamps thus ensuring accuracy of reporting.

Interview with a staff of Exalon QMS revealed that the tool was developed as a cost-effective tool that ensures sustainable value to human settlements or housing projects. It was also developed to assist Implementing Agents (IAs), Civil Engineers, Contractors, Geotechnical Engineers, municipalities and DoHs for efficient management of resources related to the provision of human settlements. Thus, the tool is presented as “one of the most useful tools available to Implementing Agents to ensure that the information relating to subsidised housing applications is recorded and processed properly, as well as ensuring the management of the project from beginning to end”.

Exalon QMS, is designed to ensure that the first items that professionals see are separate individual reports. This allows the professional to view all inspection comments and the comprehensive history of the construction project. Exalon QMS guarantees that human error associated with paper-based records are minimised by ensuring that information is captured and stored digitally. Most of the features, it should be noted, focus on the insertion of classifications contained in Exalon QMS into the everyday decision making of different actors, including construction professionals, building managers and owners. In addition, it enables multiple users in different locations to access information that is captured on the system thus allowing information sharing. By so doing, Exalon QMS allows project owners/managers to monitor the progress of their projects, generate a body of knowledge and expertise to support the assimilation of building standards into practice. This timeous availability of robust information also ensures that building contractors are paid on time for the projects they complete.

Interviews with owners and users of the tool revealed that the use of Exalon QMS is voluntary. Since it is not a directive from the DoHS, its adoption becomes a decision of the IAs. This is deeply problematic, in the sense that IAs may potentially institutionalise a limited definition of quality management, such that experts and construction teams may be committed to achieving a high-performance score on a specific aspects of housing development. This means that it is not the government that defines what is required in terms of quality. Rather, IAs have are able to define quality which might not meet the required housing standards.

## **4.3 POLICY MAKERS AND PLANNERS**

Very little has been documented on how policy-makers and other actors in the human settlement sector utilise Exalon QMS. Similarly, the role of government institutions in facilitating the adoption of the tool has not been documented. This study attempts to bridge this knowledge gap by assessing not only the benefits of the tools but also how relevant stakeholders engage the tool. A key finding of this study is that participants tend to interpret the tool mainly from the perspective of construction performance management. This resonates with several comments made by built-environment professionals who bemoan Exalon QMS as a quality management system. Officials from human settlements engage with Exalon QMS as a label but had little understanding of what underpins the tool. For example, interview data shows that there are diverse views held by people at provincial level where some officials argue that Exalon QMS manages information for big housing projects, while others argue that it gives more

approval powers to inspectors. In addition, there was also an apparent reluctance to adopt the tool. The reluctance could be attributed to the fact that the adoption of the tool is voluntary and there was no policy incentive to add to tool to their existing approaches to project management. The reluctance to adopt the tool could also be linked to the perception that the tool gives approval powers to inspectors. This points to the difficulty associated with innovation adoption and diffusion when key actors shape the discourses around an innovative technology. A further concern that emerged is the implications of storing the personal information of beneficiaries of government subsidised housing projects in a third-party server. For some respondents, this is against the Protection of Personal Information Act of 2013. Some participants also expressed concern about the need to have physical copies of documents for auditing purposes not only the digital versions. Lastly, interview with a staff from Exalon QMS revealed that some actors in the human settlement sector fear being replaced by the tool.

#### **4.4 PROFESSIONAL AND CONSTRUCTION TEAMS**

Professional and construction teams who produce the certificate of compliance constitute a community of practice that engages Exalon QMS. In the South African context, housing projects are registered with different compliance bodies such as the National Housing Building Regulatory Council (NHBRC). Unlike policymakers, it is obligatory for professionals of design and construction to focus on content of a given method instead of the label. The governmentality framework provides an analytical tool for understanding the challenges associated with various approaches to problematizing human settlement. Exalon QMS can be a useful tool for advancing government's development agenda as it relates to the provision of sustainable human settlement.

#### **4.5 DISCUSSION OF FINDINGS**

Using governmentality framework, we examined Exalon QMS as an innovative decision support tool in the human settlement sector. The argument advanced by this study is that the location of individuals in relation to an innovative tool influences how they perceive the tool. For instance, while users of the tool view it as a powerful instrument for enhancing the delivery of human settlements, others were of the view that the tool gives approval powers to inspectors thus undermining their roles.

There are various challenges (including poor accountability, workmanship, slow pace, etc.) bedevilling the housing sector in South Africa. This reality elicits for the development and deployment of innovative decision support tools that will translate the landscape of the housing sector to enhance effective and efficient delivery of human settlements. Findings of the study demonstrate that Exalon QMS is a potential tool that could fill this gap. However, negative perceptions about the tool could undermine its adoption and diffusion in the sector. This challenge could be severe in the government sector where limited understanding of the tool, coupled with apathy towards the tool by key decision makers, could constrain the adoption and diffusion of the tool.

Exalon QMS has become a mechanism of ordering human settlements projects, based on what is known as spatial regulation (Merry, 2001). The findings of this study show how space is widely controlled in human settlements' projects. Exalon QMS is increasingly becoming involved in how space is managed and controlled in project boundary, in what Merry (2001) may regard as "another regime of governance: control through the management of space". This indicates that the more programmers of the tool gain knowledge within the housing discourse, the more they control built environment experts from a distance. This means that the tool could regulate and shape the actions of experts by controlling their behaviour, in the sense that it dictates to them what to do, and what not to do in a given space. However, when the tool development is collaborative, the element of control is diminished since what is developed is tailored to suit the needs of the clients. The theoretical contribution of the study lies in the application of Foucault's theory of governmentality, with insights from innovation diffusion as the process of market penetration by new products and services, which is motivated with or without consumers' explicit knowledge.

## 5 CONCLUSIONS

This study examined the use of the decision support tool, Exalon QMS, and how it impacts on the work of professionals in the human settlements sector. The work of Rogers and Foucault constituted the theoretical foundations of the study. In reviewing the literature, the researchers focused on innovation, different types of innovation, technological innovation, technological diffusion and technological adoption, as well as the inherent advantages and disadvantages of technological diffusion and technological adoption. The study highlights how Exalon QMS can address several of the challenges that affect housing delivery administration. First, the tool offers a way to deal with corrupt practices associated with housing delivery administration and poor workmanship in the process of housing development. Secondly, users who are familiar with Exalon QMS assert that the tool is continually changing. Finally, Exalon QMS functions as a decision support tool for different actors in the human settlement sector including policy-makers, professionals, and experts responsible for certification in the process of housing development. Going forward, concerns raised by the study participants (including the need to have physical copies of documents for auditing purposes, fears of being replaced by the tool and storage of project beneficiaries' personal information) should be addressed.

## ACKNOWLEDGEMENTS

We wish to acknowledge the financial support of the South African Department of Science and Technology through Technology Innovation Agency for Sustainable Human Settlement Decision Support Project, and the following UKZN project team: Aubrey Mpungose, Onke Qwabe, Ndimiso Ndlovu, Kanagie Naidoo and Bongumusa Zamisa.

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## **Towards context specific water solutions for resilient and sustainable communities: Unconventional water delivery approaches**

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### **ABSTRACT**

Since 1994, the South African government has focused on eradicating service delivery backlogs, and this has largely been done through the deployment of conventional solutions. However, many rural communities continue to be marginalised as most conventional solutions are expensive to implement due to the settlement characteristics of such communities. Thus, this call for a new focus on context specific solutions targeted at areas that are hard to reach with conventional systems. This paper seeks to showcase the success in the deployment of unconventional solutions in yielding promising results for sustainable water services delivery. The paper uses a case study of a community of Meidingen in Limpopo from the ASWSD project. The interventions in this village were part of a social innovation project that sought to demonstrate the role of technological innovation towards universal access to safe drinking water. The paper therefore, shows how creative out of the box approaches have potential to pave the way for sustainable service delivery in human settlements.

Keywords: Appropriate technology, sustainability, water quality, rural

## **1 INTRODUCTION**

### **1.1 BACKGROUND**

Many of the rural areas in South Africa lack access to formal water services (DWA, 2010). Statistics South Africa's community survey report (2016) indicates that 10.1 % of households are without access to piped water, and people have no choice but to rely on other sources of water. This is attributed to the fact that water service provision through conventional water supply options that rely primarily on surface water sources, water storage and bulk reticulation network are expensive to implement due to the village characteristics, for instance a bad terrain (Nkuna *et al.*, 2014). For small municipalities, this is especially difficult considering that most rural communities cannot afford to pay for services.

This calls for a new focus on context specific solutions targeted at areas that are hard to reach with conventional systems. The rural municipalities need to change significantly, respecting local contexts (Moriarty *et al.*, 2013). This evolution towards a more context-based approach can lead to sustainable service delivery. Rural communities have very rich assets in a form of practices, infrastructure, networks, natural resources, or knowledge systems that if given attention can lead to communities meeting their current and future needs. These local knowledge systems within rural communities provide a sound platform for sustainable water services (Mahlangu and Garuts, 2014).

### **1.2 SUMMARY OF DEMOGRAPHICS**

The village is situated in Limpopo Province of South Africa and falls within Mopani district municipality respectively (See Figure 1).

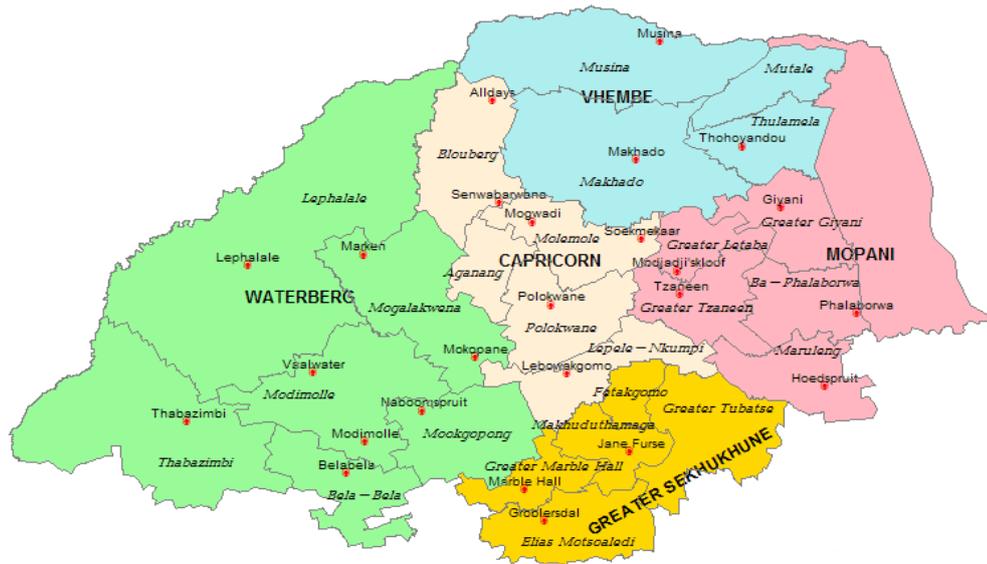


Figure 1 Map showing the location of Mopani District Municipality in Limpopo Province (Google maps)

This area was identified during the Accelerating Sustainable Water Services Delivery II (ASWSD) project. Meidingen is located on a hilly terrain on the outskirts of Kgapane Township in Greater Letaba Local Municipality about 45km from Tzaneen town and about 20km from Modjadjiskloof. The steep and hilly terrains make the village difficult to access especially during the rainy season.



Figure 2 Meidingen village (3D Aerial Photograph, source Google earth)

The most spoken language in the village and in the surrounding areas is Khelobedu, which is another dialect of Sepedi language. The demographics are summarized in table 1.

Table 1 Summary of key demographics of Meidingen village

| Village Name | WSA/Provider | Population (households) | Average HH size |
|--------------|--------------|-------------------------|-----------------|
| Meidingen    | Mopani       | 783                     | 5.3             |

Meidingen village is characterized by high unemployment rates, people rely on social grants and subsistence farming. About 55% of households in Meidingen are female headed with the highest educational qualification Diploma in 22% of the households and the average was Grade 12.

### 1.2.1 Aims and objectives

The aim of the study is to show how creative out of the box approaches have potential to pave the way for sustainable water service delivery in human settlements, particularly in rural communities in South Africa. It seeks to show how focusing on the context can yield sustainable solutions to the delivery of free basic water in remote and rural communities. The study was part of a project that sought to demonstrate the role of technological innovation towards universal access to safe drinking water without replacing or duplicating municipal services. The study specifically used qualitative and quantitative approach to gather data for the case study.

### 1.2.2 The findings of the study

The study indicated that community involvement and focusing on the context can yield promising results for sustainable water services. The community of Meidingen currently receive drinking water whilst still awaiting the municipal service of piped water.

## 2 LITERATURE REVIEW

### 2.1 WATER SERVICE DELIVERY CHALLENGES IN RURAL MUNICIPALITIES

Basic delivery of services can be imperative in the reduction of poverty, unemployment and strengthening of social capital. It can also serve to stimulate agriculture, tourism and other rural enterprises. An example being: A road infrastructure which connects rural areas to urban centres and eases the mobility of goods and people within the area, and water infrastructure, which depending on the nature and scale of technology has great potential for boosting small and large scale agricultural activities (National Treasury , 2011).

Substantial progress has been made delivering basic infrastructure in rural municipalities. However, there is a lot still to be done. The challenge is that the supply of these services has often been attempted using urban based technologies, which have proved expensive due to the dispersed nature of rural settlements. There has been a concern that the Municipal Infrastructure Grant that rural municipalities receive is not designed and managed in a manner that allows for eradication of backlogs in rural villages sustainably. Municipalities have a tendency to use it for upgrading and rehabilitating network infrastructure in towns, due to the fact that town-based households are more likely to pay for services. It is also suspected that there is a general lack of understanding with alternative, appropriate technology options that can be used to provide services to villages, given water shortages, low population density, and typology that render conventional technologies costly to install and operate (National Treasury, 2011).

It is indicated that the municipalities' inability to provide reliable water and sanitation services is mainly due to the lack of capacity, the misuse of funding, and/or the lack of funding for operation, maintenance, refurbishment and management of water and waste water infrastructure assets (National water and Sanitation Masterplan, 2018).

### 2.2 LEGISLATIVE FRAMEWORK FOR WATER SERVICES IN SOUTH AFRICA

The constitution of South Africa states in chapter two of the Bill of Rights, that everyone has the right, to have access to sufficient food and water and social security. Section 152 further indicates that it is the responsibility of local government to ensure the provision of services to communities in a sustainable manner; to promote social and economic development; and to encourage the involvement of

communities and community organizations in the matters of local government. In South Africa water is recognised as a common asset whose trusteeship lies with the state. There are two Acts that guides the water sector in South Africa, namely water resources management, guided by the National Water Act (1998), and water services provision, guided by the Water Services Act (1997). The National Water Act (Act 36 of 1998) mandates the Department of Water and Sanitation to ensure that all water resources are well managed and protected, developed and conserved “for the benefit of all persons” and in accordance with the constitution.

The Water Services Act 108 of 1997 governs the water use in South Africa, and recognises that everyone is entitled to a basic water supply and basic sanitation. In the late 2000 the Free Basic Water (FBW) policy came into effect (Muller, 2002). This policy stipulates that households are entitled to up to 6000 litres of drinking water every month at no cost (i.e. 25l per person per day). According to the Water Services Act, the water services provider should implement this policy. Furthermore, the FBW policy recognises that in most remote rural areas the cost of water service provision is too high, therefore providing 25l per person might not always be feasible. In this way WSA/Ps have discretion over the amount based on the water source or technology available to provide water. This makes provision for the municipalities to identify alternative sources of water to meet the needs of rural communities.

The National Water Resources Strategy II provides the framework for the protection, use, development, conservation, management and control of water resources for South Africa, as well as the framework within which water must be managed at catchment level. It also seeks to address the current and future water demands for South Africa (DWA, 2013). The strategy suggests using alternative sources of water (i.e. rain water harvesting, storm water harvesting) as opposed to relying on surface water schemes. This is a great advancement in that it allows for out of the box thinking when coming up with solutions.

Reconstruction and Development Programme (RDP) is a South African socio-economic policy framework implemented by the ANC government, this policy was aimed at correcting the injustices of the apartheid government. The policy makes provision for the infrastructure necessary to supply 25 litres of potable water per person per day within 200 metres of a household and with a minimum flow of 10 litres per minute (in the case of communal water points) or 6000litres of potable water supplied per formal connection per month (in the case of yard or house connections).

### **2.3 OVERCOMING THE WATER SERVICE DELIVERY CHALLENGES**

According to the National Treasury (2011) the rural communities need to be aware of the importance of using alternative technologies in order to optimise access to water given existing affordability levels of rural municipalities, and the availability of resources. There is greater need for innovation is required in the development and deployment of technologies that are appropriate to rural areas. These include water harvesting, ground water supply through boreholes for water; on-site sanitation options, and non-grid energy options. Managed properly, these are not only environmentally friendly service options, but could provide a more efficient and affordable way of supplying rural services (National Treasury, 2011).

## **3 RESEARCH METHODOLOGY**

The study is part of the Department of Science and Technology funded project “*Accelerating Sustainable Water Services Delivery II project*” which was a social innovation project that sought to demonstrate the role of technological innovation towards universal access to safe drinking water. The paper uses qualitative and quantitative methods of data collection for the case study of a village where unconventional approaches to water services delivery were implemented in Meidingen community in the Limpopo province. The study used interviews, water quality and quantity analysis, this included:

- Informal interviews with municipal officials in order to understand the institutional arrangements for water service provision, as well as challenges that the relevant municipality is facing with regards to providing water services to its respective rural communities
- Informal interview with the local leadership as well as meetings or focus group discussions with individual community members in Meidingen village in order to understand the water services in that community.

- Detailed field survey to assess the water sources and associated infrastructure in the village followed by recommendations on the most appropriate context based intervention to address the water challenges.
- The geo-hydrological and hydro-physical assessments were conducted to understand the feasibility of the identified springs in providing water to the specified households. The hydro-physical measurements were done to quantify the flow rate and these was done out using an OTT C20 current meter with OTT Z400 signal counter set and impellor # 1-239627 (diam. = 125 mm, pitch = 0.25 m) mounted on a 20 mm diameter steel rod.
- Hydro-chemical analysis were also conducted to assess the water quality, the physical parameters that were measured were temperature, electrical conductivity (EC), pH, Eh and oxidation reduction potential (ORP). The measurements were carried out using a Hanna model HI9828 multi-parameter probe.
- Microbiological samples were sent for analysis to the nearest laboratory

## 4 FINDINGS AND DISCUSSION

### 4.1 ACCESS TO WATER SERVICES



Figure 3 Water sources in Meidingen village

The main source of water in Meidingen village is groundwater, in the form of boreholes (4) and springs (5). Only three of the four boreholes are working and supplying the village. The boreholes have been networked and connected to two reservoirs of 100kl each. The network system is designed to have a single supply line that also serves as a reticulation line. This design has created a supply problem as the two reservoirs cannot fill up due to a lot of street tap connections that are directly connected to the supply line. As a result, the taps have become an unreliable source of water. There are also informal connections on the reticulation line. Figure 4 shows the concrete reservoirs and street tap.



*Figure 4 Tap connected to the two reservoirs serving Meidingen village*

The area is also characterized by a lot of natural springs. A total of five springs were identified. Some of the springs have had human intervention in order to harness the water, such as the Majonini spring, the yield tests conducted on this spring revealed that the spring produces an average of 0.36L/s, and was serving more than 50 households on a daily basis.



*Figure 5 Ha khelowa and Majonini springs*

The Hakhelowa spring located about 50m from the nearest household was identified and a yield potential of 0.1l/s was established. The spring is perennial and difficult to access. The spring was developed further in order to harness water. Springs are regarded as sacred in 100% of the households sampled, and as such are respected. Most of these springs in the area are perennial. All households indicated using water from springs for more than 20 years and continue to collect water from springs since it is the most reliable source of water. Households are able to collect water amounting to more than 100l per household on a daily basis. It should be noted that although the springs are a reliable source of water for the community, the water quality analysis showed the presence of faecal matter and high levels of nitrates (see Table 2). The high levels of nitrate could be attributed to the use of unsafe sanitation facilities in the village and lack of solid waste management (Figure 6). This water was thus not suitable for drinking and requires treatment.



Figure 6 Unsafe practices around springs

Table 2 Location and water quality of springs in Meidingen Village

| Name of spring     | Coordinates/Position   |                         |                       | Water Quality      |                                                      |               |                                |                                              |
|--------------------|------------------------|-------------------------|-----------------------|--------------------|------------------------------------------------------|---------------|--------------------------------|----------------------------------------------|
|                    | Latitude<br>(dd.ddddd) | Longitude<br>(dd.ddddd) | Elevation<br>(m amsl) | Variables detected |                                                      |               |                                |                                              |
|                    |                        |                         |                       | EC<br>(mS/m)       | pH<br>[-<br>log <sub>10</sub> (<br>H <sup>+</sup> )] | Turbi<br>dity | Microbiological                | Other parameters<br>out of spec<br>variables |
| Raophala Seep      | 23.63665               | 30.25220                | 1 068                 | 19.7               | 5.9                                                  | 4.9           | Ecoli&Ttotal coliforms<br>(TC) | Nitrate + nitrite N<br>Turbidity             |
| Khelowa Seep       | 23.63332               | 30.25042                | 1 099                 | 8.2                | 6.0                                                  | 1.1           | Ecoli & TC                     | Nitrate + nitrite N<br>Turbidity             |
| Majonini Spring    | 23.63593               | 30.24307                | 1 060                 | 11.9               | 6.3                                                  | 0.31          | Ecoli & TC                     | Nitrate + nitrite N                          |
| Masekhekhe<br>Seep | 23.63895               | 30.24457                | 1 036                 | 14.0               | 6.4                                                  | <0.2          | Ecoli,HPC,&TC                  | Iron Fe<br>Aluminium Al                      |
| Ke sa hlapa(1)     | 23.630417              | 30.256350               | 1072                  | 11.2               | 7.2                                                  | 2.2           | Ecoli, HPC & TC                | Nitrate + nitrite N<br>Aluminium,            |
| Ke sa hlapa (2)    | 23.630967              | 30.255233               | 1080                  | 22.1               | 6.4                                                  | 0.61          | Ecoli,HPC, TC                  | -                                            |

#### 4.1.1 Traditional Practices and local beliefs around water sources in Meidingen

There are strong cultural beliefs surrounding the springs in the community. The springs are regarded as sacred and it is believed that there is a snake that controls the yield of the spring. In all the springs that were identified there were certain indigenous trees called Mogo and villagers are discouraged from cutting it irrespective of where it is growing within the village. The most sacred spring, is the Majonini spring, it has been protected with concrete slabs and fencing and women and unmarried men are not allowed to enter the spring. It was also strongly encouraged to protect the springs using locally acceptable materials and methods, as this could interfere with the yielding potential of the spring.

#### 4.2 INTERVENTIONS IN MEIDINGEN VILLAGE

The inefficiency of the municipal system resulted in the community of Meidingen relying on springs for their daily water needs. Evidently, protection of springs was an obvious intervention guided by the value that the community of Meidingen attaches to the springs, and the reliability that springs have. This option entailed protecting the major spring (majonini with a yielding potential of 0.36l/s) to prevent external contamination, such as contamination by domestic animals, and installing small reticulation lines (gravity lines) from the springs to some storage tanks with communal collection points (See figure 7).



Figure 7 Interventions at Majonini spring

#### 4.2.1 Health and hygiene intervention

The evidence from the study indicated a strong need to educate the community of Meidingen on health and hygiene issues. The key focus areas of the health and hygiene education programme the safe collection and storage of household drinking water. Other relevant hygiene risk behaviours such as sanitation including waste disposal were also addressed. The method used were posters and presentation to communicate good health and hygiene practices as it is the common approach used by Environmental Health Practitioners (EHPs) to communicate with the community to address such issues. The importance of ownership and taking responsibility of the infrastructure was emphasized during the workshop. It was indicated that the community need to look after the infrastructure, use water wisely, report any breakdowns and make sure that there is no vandalism and informal connections.

## 5 CONCLUSION AND FURTHER RESEARCH

It is recognised that a lot has been done to improve water service delivery challenges in rural communities. However, there is still more to be done to improve and ensure sustainable service provision by municipalities. In this study the municipality is failing to provide sustainable water service to the community due to poor system design, insufficient water sources, inadequate funding and the dispersed and hilly terrain nature of the village. People in this community have no choice but to rely on springs that were found to be reliable but unsafe and have the potential to cause diseases. Upon further investigation, taking into account the needs of the community, and available water resources, springs proved to be a viable low cost option for delivering water to this community.

This further proves that the 'one size fits all' system of governance does not work and that community involvement in implementing solutions for them yield better results. It is therefore, necessary for the policy on technology choices to promote and recognise alternative technologies/sources as service coverage and not temporary solutions.

This paper therefore, recommends that the findings from studies such as this be reflected in national policy positions as means to promote their uptake and adoption. Policy should put more emphasis on initiatives that improve the capabilities of small municipalities so that the very objectives of growth and development (RDP) can be met.

## ACKNOWLEDGEMENTS

The authors would wish to express their sincere gratitude to the Council for Scientific and Industrial Research (CSIR) for supporting this project and the Department of Science and Technology for funding this project.

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## **Towards an incentive-driven local government customer management policy: Lessons learnt from piloting of the CARRS system**

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### **ABSTRACT**

Local government is the third sphere of government closest to the people and a tier through which basic services are delivered and its citizens' interests are represented. However, it has become a common occurrence across South Africa for citizens to be dissatisfied with the level and/or quality of service provided by their municipal councils. Failures in local government have in the recent couple of years manifested in unorthodox ways through which citizens engage with the public sector, such as sporadic and violent service delivery protests, which are also generally understood to be partly attributable to poor engagements between local government institutions and the affected citizens. On the other hand, however, there are policies and systems, such as the Municipal Systems Act, which make it a requirement for municipalities to establish customer management systems, and the Back to Basics (B2B) strategy, which also puts citizens at the centre of service delivery by identifying the need to establish accessible and effective communication platforms. This paper draws on lessons learnt from piloting of the Council for Scientific and Industrial Research (CSIR)'s Corrective Action Request and Report System (CARRS); a two-way incident management system used by citizens to report incidents that affect the delivery of basic services such as water supply. Preliminary findings indicate that whilst municipalities understand the concept of customer management as being central to their business, not all municipalities have embraced the implementation of effective systems that support this concept. From a policy perspective, this finding also indicates that there is lack of enforcement of customer management systems in municipalities despite the Municipal Systems Act making it a requirement. The paper concludes by making a recommendation for the development of an incentive-driven approach for enforcing customer management systems in local government.

Keywords: Customer Care, Incentives, Incident Management, Local Government, Service Delivery

### **1 INTRODUCTION AND PROBLEM STATEMENT**

South Africa is a democratic state that is governed through a three-tier system of governance which includes the national, provincial and local governments (Government Systems, 2017). Local government is the third sphere of government that is closest to the people. Amongst other things, key functions of local government, as clearly stated in Chapter 7 of the Constitution of the Republic of South Africa, are to ensure that communities receive services in a sustainable manner, to promote social and economic development of local communities, and to encourage the involvement of communities in the matters of local government. Basic services such as electricity, water and sanitation, and refuse removal, are critical services that should improve the lives of the people. It is encouraging to note that since 1994 government has made greater strides in improving the lives of its citizens through development of infrastructure and provision of basic services.

However, these notable improvements may vary between provinces, districts and local municipalities. A report of an in-depth analysis of the 2016 Community Survey that was conducted by StatsSA indicates that 75% of households (i.e. irrespective of geographic location) did not believe that municipalities were actively addressing issues they felt were most important for households in their respective municipal areas (StatsSA, 2016). This highlights a serious misalignment of priorities, and therefore lack of effective engagement and communication between local government and the communities it serves. Failures in local government have, in the recent couple of years, also manifested in unorthodox ways through which citizens engage with the public sector. These have arguably been demonstrated through sporadic events such as violent service delivery protests, which are also generally understood to be partly attributable to poor engagements between local government and the affected citizens (Municipal

IQ, 2013; Tapela, 2013). There is a need, therefore, for government to craft new, robust and effective strategies that would put the needs of people first while still delivering on its constitutional mandates.

To address some of the challenges identified and discussed herein, the CSIR, in partnership with the Department of Science and Technology (DST), developed and piloted an incident management system (known as the Corrective Action Request and Report System or CARRS), which is an ICT platform that could be used by communities to report faults that occur at service delivery points (e.g. water leaks and/or no water supply) to municipalities. This two-way platform could also be used by municipalities to report progress on and the statuses of the reported incidents. As much as it was clear that this technology was a great platform that addressed a specific challenge, there were a number of municipalities that did not fully embrace this concept of incident management. The paper discusses some of the successes with some of the pilot municipalities and also some of the challenges experienced with others.

## **2 SOME STRATEGIC CUSTOMER FOCUSED GOVERNMENT INTERVENTIONS**

There is evidence that suggests that government is aware of challenges that exist at the local government sphere, and that it has in the past developed strategies, systems and mechanisms in an attempt to try and redress these challenges. The following is not exhaustive but just a highlight of some of the key strategies, mechanisms and systems that are in place and are targeted at putting the needs of customers first.

### **2.1 THE MUNICIPAL SYSTEMS ACT**

Section 95 of the Local Government Municipal Systems Act, Act No. 32 of 2000, makes it a requirement for municipalities to establish customer management systems that aim to create positive relationships with their customers and through which customers can give feedback regarding the quality of services received. The Act further highlights the need for municipalities to provide accessible mechanisms for dealing with complaints from their customers, in addition to implementing corrective action. However, these provisions are only specified in Chapter 9 on "Credit Control and Debt Collection" in relation to levying of rates and other taxes by municipalities and the charging of fees for municipal services. There is evidence that demonstrates that most rural municipalities (e.g. mostly category B4) receive about 73% of their total budget from grants and subsidies (StatsSA, 2015). Therefore, the assertion as contended in Chapter 9 of the Act could inadvertently imply that municipalities largely serving indigent communities (i.e. where services are not charged or rates and taxes are not collected) may or should be exempted from having to establish customer management systems.

### **2.2 BATHO PELE PRINCIPLES**

First introduced in 1997, the principles applied an eight (8) pronged approach with the aim to enhance the quality and accessibility of government services by improving efficiency and accountability of public servants to the recipients of public goods and services. Of interest to this paper are two of the principles, which required public servants to (1) regularly consult with customers, and (2) remedy failures and mistakes (Department of Public Service Administration, 2014). To this date, these principles are still acknowledged at a high level, but there are no clear mechanisms that have been put in place to ensure that public servants are held to account accordingly.

### **2.3 BACK TO BASICS STRATEGY**

The Back to Basics strategy, announced in 2014, looks at how to build responsible and accountable local government. The strategy provides a step-by-step plan of what needs to be done in the inter-governmental sphere to improve the performance of municipalities (COGTA, 2016a). It further places open communication at the heart of what municipalities do by insisting that municipalities establish platforms through which communities can interact with officials, and emphasises that the interactions should ultimately result in timeous response to challenges.

## **2.4 ALTERNATIVE SERVICE DELIVERY (ASD) ARRANGEMENTS**

It is generally acknowledged that all spheres of government, particularly local government, may not always have capacity to deliver services in all areas and at all times as per constitutional mandate. However, this comes with the responsibility of exploring alternative ways through which services should still be delivered should such challenges be identified. This responsibility concomitantly lies across all the three spheres of government even when challenges only exist at the local government sphere (Bekink, 2006). In its basic definition, Alternative Service Delivery (ASD) entails continuing to provide some services or products, which have been provided traditionally by the Public Service, through or in partnership with organizations outside the Public Service (Treasury Board of Canada Secretariat, 1996). Therefore, the ASD approach requires acknowledgement of possible operational inefficiencies (where they exist) within the public service domain, and a radical approach in addressing them through either means possible in the ASD arrangements. This, in South Africa, and within the local government sphere, is also made possible through the Municipal Systems Act. However, these arrangements have been fraught with irregularities and corrupt activities that have almost collapsed the integrity of the public service.

## **2.5 INCENTIVISING SERVICE DELIVERY**

Service delivery incentives are not a new concept in the South African context. A few examples include the Department of Water and Sanitation (DWS)'s incentive-based Blue (drinking water) and Green (wastewater) Drop Regulation and Certification for municipalities/ Water Service Authorities that comply with 95% of the weighted criteria (Department of Water Affairs and Forestry, 2008). In addition to these, a Red (drinking) and Purple (wastewater) Drop is awarded to municipalities that are failing to comply with the set criteria. A green and blue drop award could, for example, be used by the municipality to market their towns to its residents and/or tourists. There are other proposals for developing incentive-based grants for improving the performance of municipalities. These include some existing stand-alone incentivised programmes such as the Department of Public Works (DPW)'s Expanded Public Works (EPWP) and the Special Public Works (SPWP) programmes (DPW, 2017), and the Department of Cooperative Governance and Traditional Affairs (COGTA)'s Municipal Infrastructure Support Agent (MISA) programme (COGTA, 2016b). There is a need to integrate an incentive approach into existing grants and possibly move towards a hybrid that includes the integrated incentives and stand-alone programmes. Robust and effective monitoring and evaluation (M&E) systems that provide scientific and objective foundations are also crucial for the successful implementation of a performance-based grant system.

# **3 GENERAL APPROACH AND METHODOLOGY**

This paper adopts a case study approach which focuses largely on lessons learnt through the piloting of the CARRS technology. A quick scan of some of the government strategies and policies that support customer management has been carried out and some inferences are also drawn with reference to the lessons learnt.

Key objectives of the CARRS initiative were to;

- increase accountability in local government and specifically within municipalities
- shorten the response times to handling and managing complaints
- increase the adoption of paperless and smart systems

The CARRS technology was piloted in a number of sites within eight (8) of the targeted priority districts of South Africa. These districts had exhibited common characteristics of high levels of unemployment and poverty, and more concerning, poor provision of basic services such as water, which is understood to have subsequently discouraged direct economic investment by businesses. In partnership with a number of stakeholders, the eight (8) priority districts were chosen for the pilot of the CARRS technology after following a mix of approaches which included; (a) a top-down approach, which entailed engagements with the Department of Rural Development and Land Reform (DRDLR) on prioritization of sites for the first phase of the Department of Science and Technology (DST)'s Innovation Partnership for Rural Development Programme (IPRDP) from a list of Priority Districts of South Africa, and (b) a bottom-up approach, which entailed having further engagements with the selected priority districts on

identifying specific needs and service delivery challenges, and gathering how the specific needs could be linked to specific service delivery and line departments. The selected priority districts were Amathole, iLembe, Ehlanzeni, Capricorn, Vhembe, Dr Ruth Segomotsi Mompati, Ngaka Modiri Molema, and Bojanala Platinum.

From the selected districts, further engagements were undertaken to prioritize and select sites within which municipalities experienced challenges in providing basic services. Water services were also prioritized for the demonstration of the CARRS technology. In each selected site and municipality the CSIR gathered an understanding of the challenges and how the municipalities have attempted to respond. The management of incidents that affected the delivery of water services was tackled by implementation of the CARRS technology. At the pilot stage the CARRS technology was implemented as a web-based system. Community-based Task Teams, which acted on behalf of communities in each of the selected sites and/or clusters, were recruited and established out of existing community or municipal council structures and also trained on the reporting requirements and mechanisms of the CARRS system. These Task Teams were further allocated computers with internet connectivity for purposes of incident logging and reporting.

Furthermore, Incident Command Teams were established out of existing structures and personnel of the municipalities that participated on the CARRS programme. The Incident Command Teams were mostly comprised of officials from the customer care and technical services responsible for managing complaints raised by citizens. These teams were also trained on the reporting requirements and mechanisms of the CARRS system.

Since this paper stems out of an on-going project, reporting on findings in this paper will be aggregated and the identities of individual municipalities will not be disclosed in the interest of protecting these municipalities, especially for those municipalities that did not exhibit effective customer management practices.

## **4 FINDINGS AND DISCUSSION**

It is encouraging to note that results from the on-going pilot are promising. The CARRS system has demonstrated a proof of concept, which indicates that complaints that are reported by communities can be reported using ICT communication platforms, and that services which had not been provided effectively as a result of faults and breakdowns can also be attended to and restored in the affected areas.

### **4.1 INCIDENT REPORTING (BY COMMUNITIES)**

The traditional practice of reporting service delivery faults and issues in local government is usually carried out through existing structures, such as Ward Committees. These structures are part of the municipal councils and they meet on a regular basis to discuss service delivery issues and plan on how such issues could be resolved. The introduction of the CARRS platform was not intended to replace these traditional methods but to enhance their effectiveness and the experiences of customers through the improvement of customer management processes. In the pilot stage, Task Teams were recruited, appointed and trained to report incidents on behalf of communities through the CARRS platform.

Figure 1 depicts the proportions of reported incidents that have been reported through the CARRS platform by category.

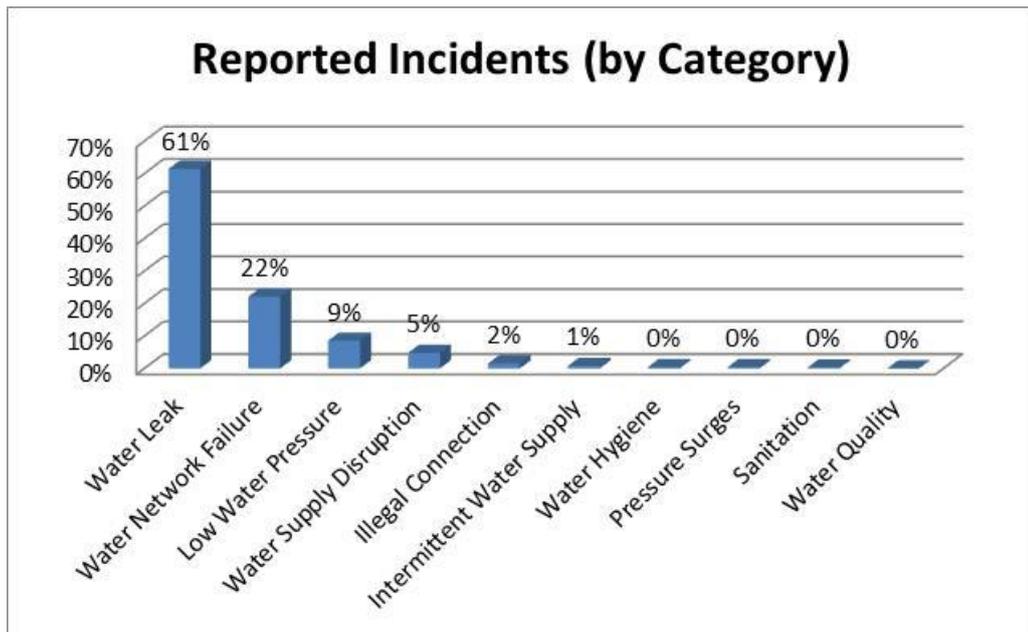


Figure 1 CARRS Reported Incidents by Category

As depicted in Figure 1, the majority (i.e. top three) of reported incidents across all municipalities in the pilot sites are related to Water Leaks (61%), followed by Water Network Failures (22%) and Low Water Pressure (5%). Water leaks indicate serious infrastructure weaknesses, and when coupled with water network failures the picture becomes a stark one. It is rather also interesting to note that Illegal Water Connections have also been reported as an issue of concern by communities.

#### 4.2 INCIDENT MANAGEMENT (BY MUNICIPALITIES)

A good measure of customer care management in local government is the responsiveness of local government institutions (i.e. municipal offices) in handling customer issues, especially those relating to issues of service provision. The CARRS platform has a number of categories that measure the responsiveness of municipalities in handling reported issues. These measures are guided by the incident management life cycle, which looks at how incidents progress on the workflow from one stage to another. For purposes of this paper, the statuses of incident life-cycle management would be used. Figure 2 depicts the statuses of all reported incidents by assigning an “open” and “closed” status. “Open” incidents are those that are still within the workflow and therefore are still being attended to, while “Closed” incidents are those that have exited the workflow and are therefore no longer active.

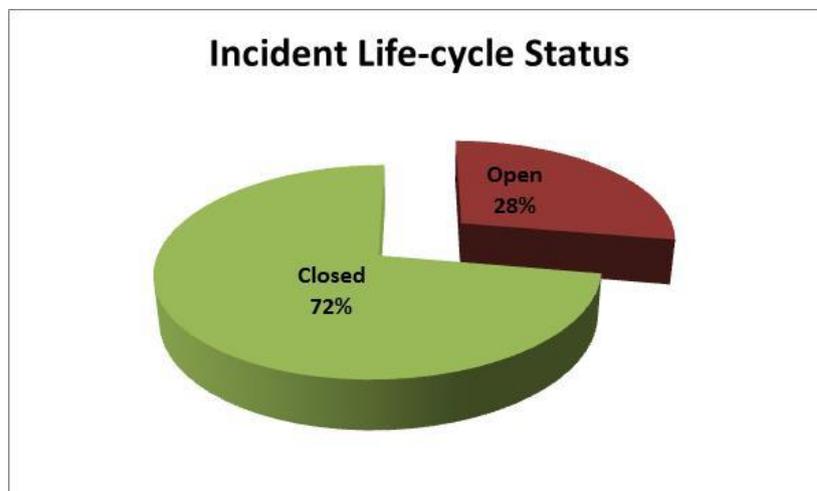


Figure 2 CARRS Reported Incident Life-cycle Status

As depicted in Figure 2, it is encouraging to note that the majority of incidents (72%) have a “closed” status. This means they have undergone all stages and have been resolved. If, for instance, these incidents had been mostly water leaks (as suggested in Figure 1), then a lot of water would be saved and more people would have access to the water that would have otherwise been lost through the leaks.

However, the 28% of “open” incidents are still a concern as it means there are some customers that have not received a service or the quality of a service that they receive has not improved even when the municipality has received the report of such incidents. It is also worth noting that not all participating municipalities had unattended “open” incidents. In fact, it was found that most of the “open” incidents were located in municipalities that also did not resolve any of the CARRS reported incidents. The CSIR has embarked on numerous stakeholder engagement processes in an attempt to get an understanding of what challenges these municipalities had faced but to no resolve. This finding has also generated an interest for the CSIR and forms part of the issues of interest for this paper.

It should also be noted that there are multiple stages through which incidents progress. In order to maintain a high standard of customer care, incidents undergo service level standards that guide how long they should stay at one stage before being flagged and escalated. When an incident takes longer to be attended to than stipulated in the respective service level standard, the incident gets marked with an additional status indicating breach of the standard. For example, if a reported incident was supposed to have been resolved within 48 hours and it took longer than that, it would be assigned an additional status indicating breach of standard. The incident would therefore carry the status throughout its life cycle. This means that even when it reaches closure, it will still carry a footnote indicating whether or not it had breached the service level standards during its life cycle. Figure 3 depicts the status of breach of service level standards on all reported incidents.

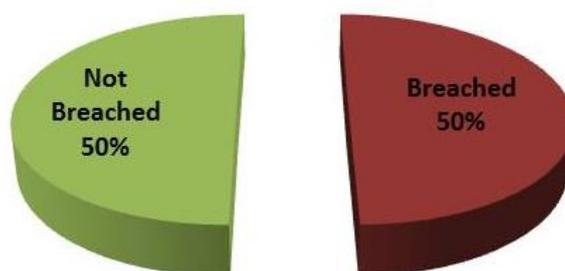


Figure 3 CARRS Reported Incident Service Level Standard Breach Status

As depicted in Figure 3, there is a fifty-fifty split between incidents that have breached and those that have not breached service level standards. Basically, this measure indicates that at least half the time municipal officials were rather slow in responding to reported incidents. It is also understood that the nature of some of the incidents could be complex in dealing with and therefore it could take municipal officials longer in responding as they might require further stakeholder engagements. For example, illegal connections are rather very sensitive and contentious in nature, and therefore would require more time and care to be exercised by municipal officials.

## 5 CONCLUSION AND FURTHER RESEARCH

From the lessons learnt through the piloting of the CARRS technology, there is ample evidence that suggests that there is a greater need for customer management systems that deploy a systematic approach in managing issues of service delivery. However, the findings from the CARRS pilot have also highlighted a need for an aggressive policy approach that would foster a positive culture of customer management. Despite the many government strategies and policies that emphasize the need for public service institutions (such as municipalities) to establish customer management systems and put people first, there were still some municipalities that did not fully embrace the uptake of customer management

systems. This is highlighted by the manner in which some municipalities chose not to address incidents that were reported on the CARRS platform, therefore leaving their customers unserved or poorly serviced.

This study has also highlighted the need to develop an aggressive customer management policy that is centred on incentivizing and rewarding positive customer management behaviour, and punishing and discrediting poor customer management behaviour. Through the piloting of the CARRS project, the CSIR has engaged with the Department of Science and Technology (DST) and its other partners, which include the South African Local Government Association (SALGA) and the Department of Cooperative Governance and Traditional Affairs (COGTA), to explore avenues through which such policies could be crafted and tested in order to foster service delivery especially in municipalities that have demonstrated poor responses in systematically addressing customer issues.

## ACKNOWLEDGEMENTS

The CARRS project is an initiative funded by the Department of Science and Technology (DST) under the Innovation Partnership for Rural Development Programme (DST). The author wishes to acknowledge Ms Nonhlanhla Mkhize, Mr Tshepang Mosiea and Mr Tiyani Ngoveni of the DST for the support they provided in setting up a platform for showcasing science and technology innovation. He also wishes to thank Dr Ryneth Mbhele, Mr Matome Mothetha, Ms Ednah Mamakoa, Ms Bongzi Maposa and Mr S'bonelo Zulu for their outstanding contributions on project implementation support and data collection.

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## **Wind storm damage to houses: Planning and design consideration**

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### **ABSTRACT**

Over the last decades, South Africa has experienced a number of devastating wind events occurring almost every year. A large number of housing developments, particularly in the low-income segment, are not engineered adequately and are thus susceptible to high wind speeds, resulting in substantial damage to houses and socio-economic losses. Preventing such wind events from becoming disastrous, as witnessed in recent years, requires improved technical standards and construction practices. In this paper, an examination of housing developments that were exposed to harsh climatic environments with high wind speeds, is made. Two case studies are investigated in Cape Town and in Gauteng. In Cape Town, the housing development is in a coastal area. The houses experienced structural damage of foundations caused by wind-induced erosion of loose unsaturated soils. The study comprised of site visits and assessment of structural damage to houses, analysis of climatic information pertinent to the area and limited wind tunnel tests. The output of the study provided an insight on spatial planning of houses in close proximity to each other, and the need to perform either a wind tunnel test or Computation Fluid Dynamics (CFD) analysis of a development as part of the planning process. The other study was that of a wind disaster in the inland province of Gauteng which occurred in December, 2017. The disaster resulted in damages to houses, substations and a roof of a mall in Protea Glen, South West of Johannesburg. Engineering modelling of the houses subject to these winds indicate a need to review the technical standards and construction practices, and these are highlighted in the paper.

Keywords: Planning, wind disaster, wind erosion, low-income housing, structural damage

### **1 INTRODUCTION**

This research paper is based on housing development case studies undertaken in the provinces of Gauteng and Western Cape in South Africa. These developments have been affected negatively by extreme weather conditions due to high wind speeds resulting in damages to the structures and foundations, and subsequent loss of lives.

Although a substantial amount of technical and legislative information on good house construction is available, there is limited guidance on planning and design of housing developments exposed to extreme weather conditions. Typical examples of houses damaged by high wind speeds are shown in Figures 1 and 2. The norms and standards published by South Africa's National Department of Human Settlements and the standards developed by the National Home Builders Registration Council (NHBRC, 2015) do not make provision for the planning and design of housing developments subjected to high wind speeds.



*Figure 1 Double storey structural damage*



*Figure 2 Roof tile and glazing damage*

In this research paper, two cases studies are considered, with one case study of a housing development in the coastal area of Cape Town and the other in the inland province of Gauteng. The choices of these developments were based on the extreme weather conditions experienced in these areas. The development in Gauteng is located in Protea Glen, in the South Western area of Johannesburg. This development was exposed to a tornado in December 2017 which resulted in structural damages and economic losses. Several public media reports have alluded to poor workmanship, non-compliance to technical standards, poor quality materials, etc. In this investigation, the adequacy of minimum technical standards for housing developments in extreme high wind exposures is reviewed, and recommendations on improvements of standards is made.

The other case study referred to Delft, within the coastal area of Western Cape. It summarises a pilot study, undertaken several years ago, on the request of South African National Department of Human Settlements, in response to a specific situation which had developed. Continuous exposure to strong winds resulted in wind erosion of loose unsaturated soil surrounding the foundations, compromising the structural integrity of the top structure. The damage caused by the wind erosion is illustrated in Figures 3 to 6. The results of this investigation, based on site investigations, wind tunnel simulations and modelling, provide an insight on planning and design consideration of housing developments in the coastal areas.



*Figure 3 Layout of Delft (Western Cape)*



*Figure 4 Wind deposition*



*Figure 5 Wind erosion on foundation*



Figure 6 Collapse of foundation due to erosion

## 2 LITERATURE REVIEW

As highlighted in the previous section, the consequences of damages due to extreme weather conditions are high. The determination of the consequence of a potential catastrophic event is particularly important for the community, national authorities and the insurance industry. This can usually be derived from historical data of extreme events, the identification of the most critical type of event and developing a scenario for such an event. Such a model should consider the changes in the influencing factors in time domain e.g.:

- the climatic patterns, affecting the probability of a damaging event;
- geographical distribution of assets;
- damage susceptibility (i.e. changes in design and construction methods); and
- the cost of repairs.

A literature survey revealed that no information is available on wind-induced erosion of soils within densely-spaced, single-storey housing developments. Several references (Iverson, 1981), Castro and Wiggs (1994), Borges and Viegas, 1988) were found on sand and snow drift, its modelling, measurements techniques and prevention. Bofah *et.al* (1991) considers general design considerations for buildings in sandy and dusty environments. It provides general rules of sand drift rate, sand erosion, abrasion and accumulation, and also includes a graphical interpretation of an empirical relationship between the size of dry, non-cohesive sand particle and the threshold wind speed (at a reference height of 10 m) required for its transportation. Errel and Tsoar (1997) describes a study based on full-scale sampling and subsequent laboratory testing of sand deposition at selected locations within a city. The possible outcomes of this paper may help standards developers, planners and designers in proper planning and design of densely-spaced housing developments.

## 3 RESEARCH METHODOLOGY

This research was based on identification of typical housing developments exposed to extreme weather conditions. This was then followed by detailed site investigations, limited wind tunnel tests where appropriate, desk-top studies and engineering modelling. The desk-top studies involved reviewing published records, weather studies, research papers and media reports. A site investigation which was undertaken was based on qualitative observations of damages, determining extent of damages, checking quality of materials and products used, as well as conducting interviews with the community and the house owners/beneficiaries. This was then followed by engineering modelling and some limited wind tunnel tests, were appropriate. In Delft (Western Cape), the site investigations were conducted during the month of August, which is characterized by fairly frequent spells of rain.

## **4 CASE STUDY: COASTAL HOUSING DEVELOPMENT**

### **4.1 SITE INVESTIGATION AT DELFT**

The township of Delft, in Cape Peninsula, is located on a plane with slightly undulating dunes, approximately three kilometres (km) east of Cape Town International Airport. Further away, it is flanked by two mountain ranges (to the east and west), with elevations of up to about one kilometre above sea level. An approximate distance between Delft and the Table Mountain is 20 km. From the geomorphological point of view, the area of Cape Flats once constituted a shallow seabed separating both mountain ranges, and was eventually formed as a result of intense sediment activity which took place about ten thousand years ago and more recently by a deposition of wind-blown sand dunes. These soil formations can easily be eroded by wind and water even when compacted. An extensive geological survey of the area by Hill and Theron (1981) suggests the sand layer to be more than 30 m thick. In certain places the sand has been consolidated by a solution and re-precipitation of lime but most of the deposit is loose and non-cohesive, with excellent natural drainage.

The Delft housing development, at the time of site investigation, consisted of two thousand low-income housing units divided into large clusters of buildings spaced in a regular pattern typically based on orthogonal grid as shown in Figure 3. Initial inspections were carried out in older and more established sections of Delft (Figure 3), where despite sandy ground conditions, no major signs of erosion were observed. Large percentage of occupants of houses introduced additional structures or objects in between the units, e.g. vegetation, boundary walls, additions, paving, carports etc. No wind-blown sand dunes were observed on the roads although these were noted in the vicinity of large undeveloped spaces between buildings, which became 'pick-up' areas of air-borne sand and debris.

Interviews with residents of Delft (Roosendal), confirmed that the erosion, transportation and unwanted deposition of sandy soil constitute significant factors which affects negatively the lives of local community. Several properties and open spaces within the township contained wind-borne dunes of substantial sizes (Figure 4). In some places the height of the deposit was up to two metres above the original ground level, and some sections of tarred roads were also totally covered by sand. According to residents the process of unwanted accumulation of huge volumes of sand was typically very rapid making any removal efforts fruitless. Several houses affected negatively by the erosion process were observed. Figures 5 and 6 shows the effects of the wind erosion on the foundations, with Figure 6 showing a totally exposed corner of a foundation, which has resulted in undermining of foundations and structural collapse of walls.

The issue of social responsibility and communal ownership of the built environment needs to be raised in this regard. In some parts of the township, local community and home owners made substantive efforts to prevent / limit the adverse effects of sand erosion and deposition by employing landscaping measures (e.g. vegetation, covering with rubble, screening or garden walls). However, in the investigated section of the township (in which housing units were owned by local municipality and rented out at a minimal cost) only a small percentage of structures showed any signs of preventative measures or retroactive fixings being considered or introduced. In most cases passive approach was adopted as, in residents opinion, the duration (i.e. several days of south-easterly spells) and severity of wind combined with the extent of erosion resulting in enormous volumes (and weight) of sand, makes it impossible for any re-instatement of soil to be successful. Figure 7 shows a house with sand-bags distributed over its roof. These are measures to prevent the roof from being blown away. Discussions with residents revealed several events which occurred in the past in which roofs of houses were blown away by wind.



Figure 7 Traditional way of securing the roof against uplift

#### 4.2 ENGINEERING MODELLING

To understand and assess the extent of wind induced erosion, engineering model scales of typical housing development were developed and tested in a wind tunnel. The wind tunnel had overall boundary-layer development length of 18 metres. A geometric scale of 1:100 was adopted and two generic layout of houses were investigated (presented schematically in Figures 8a and 8b), namely:

- orthogonal, in which houses were arranged in straight line in both directions, and
- Staggered, in which every second row of houses was 'shifted' by half a stand length. Based on full-scale observations, it was decided to concentrate the investigation on those housing units which were located within close proximity of open spaces and, therefore, for each arrangement six rows of houses were considered.

Typical size of low-income houses was adopted as 6.5 x 8.5 x 2.5m, with a footprint of 55m<sup>2</sup> (in full scale). A standard 3-degree slope mono-pitched roofs with no overhangs were adopted. The spatial distribution (i.e. density) of the houses was based on average stand size of 17 x 15m (255m<sup>2</sup>).

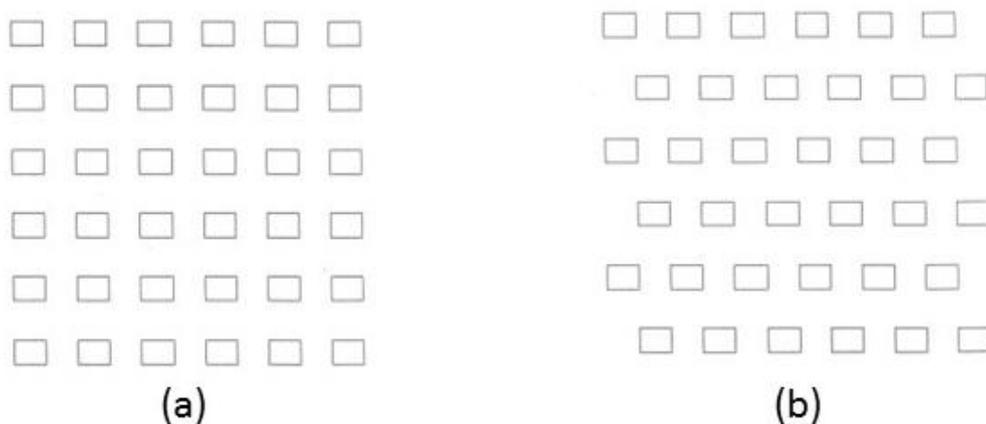


Figure 8 Generic layouts of houses

The simulation of boundary layer flow conditions at low elevations was not directed at developing specific wind profile but rather at simulating flow with approximately 20% of intensity of turbulence. The investigation was carried out using a sand-scour technique, which has widely been used in environmental studies of pedestrian level winds in large cities (Dzsö, 2006; Livsey *et.al*, 1990). For each experimental arrangement a uniformly thick layer of sand with particles between 300µm and 600µm was spread over the modelled site and subject to a flow with a mean wind speed of 3,3 m/s (measured in the free-stream flow at a height of 10 mm (1 m full-scale)) for a period of 25 seconds. The selection of above parameters was based on the experience obtained from previous wind-tunnel studies.

#### 4.3 ANALYSIS AND DISCUSSION OF RESULTS AT DELFT

Analyses of wind erosion patterns were conducted for wind directions between 0° and 90° with an interval of 15°, which was determined on the basis of preliminary tests on directional sensitivity. The erosion patterns which were obtained for both experimental arrangement of houses and for various wind directions were documented photographically. A sample of such a pattern is presented in Figure 9.

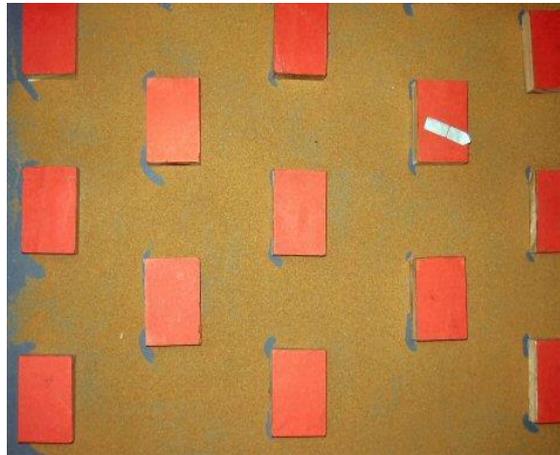


Figure 9 Sample of erosion pattern

A general confirmation of the full-scale observations was apparent in respect to the role of open undeveloped spaces. The extent of erosion around the initial rows of houses in the vicinity of open spaces was typically larger than around the houses located further within the grouping. The photographic documentation obtained from tests was subsequently digitised and converted to a graphical form. Two samples of erosion patterns, corresponding to 'orthogonal' and 'staggered' arrangements of houses, subjected to wind direction of 60°, are presented in Figures 10a and 10b.

An interesting trend was observed in which for the orthogonal arrangement, the extent of the erosion around the initial approach rows of houses was relatively large but the 'penetration of the erosion' into the following rows appeared to be small, especially so for wind directions between 30° and 90°. For the staggered arrangement this trend was not evident and a similar magnitude of erosion was observed across all rows. In view of the above trend an attempt was made to introduce some quantifiable measure of the relative extent of erosion, which would enable to compare the effectiveness (advantages) of one township layout vs. another.

An analysis of the relative extent of erosion has, therefore, been undertaken. In this analysis, for each row across the direction of wind a centrally located house unit was selected to be the representative for a given row. This was in order to eliminate/minimise the end effects and therefore to represent conditions within large grouping of houses. For each unit the recorded area of erosion was measured using the CAD poly-line function.

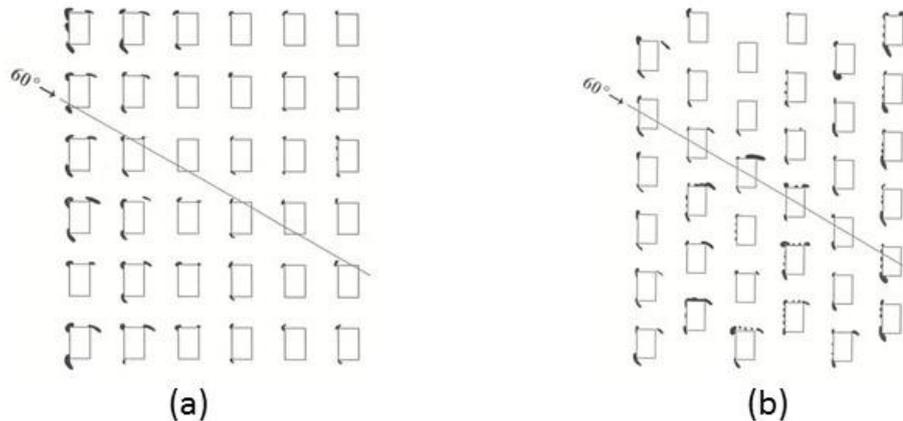


Figure 10 (a & b) Erosion patterns corresponding to wind direction of 60°

Figures 11 (a) and (b) combine the results of sand erosions obtained for wind directions between 30° and 90° in a form of envelopes of relative extent of erosion obtained for both arrangements. To be noted, the units on the vertical axis refer to the mm<sup>2</sup> in a CAD-scale of the respective drawing and do not relate to the model scale. These summaries indicate clear differences between the magnitudes of soil erosion which could be associated with both plan layouts of townships. This initial finding can be used to enable an optimisation process of future layouts of mass housing developments in the area of Delft to take place.

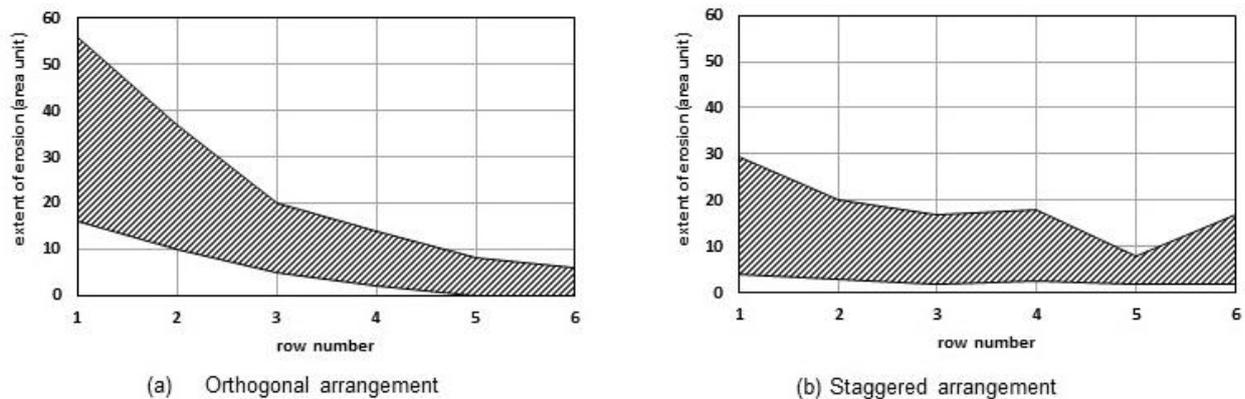


Figure 11(a & b) Envelopes of relative erosion

A set of indicative tests was undertaken to investigate other factors influencing the extent of erosion. These included the effects of boundary walls, geometry of roofs and degree of exposure of foundations. It appears that the presence of boundary walls does not necessarily reduce the extent of erosion. Furthermore, duo-pitched roofs (in this case 20° slope and 0, 5 meter overhang) may increase the erosion around down-wind units.

Discussion with residents suggested that once a portion of a foundation has been undermined the process of further erosion accelerates more rapidly. An attempt to simulate this process in the wind-tunnel was undertaken by partially raising one of the units. The scour pattern around this unit appeared to be larger than elsewhere and this finding supported the claims of residents.

## 5 CASE STUDY: INLAND HOUSING DEVELOPMENT

### 5.1 SITE INVESTIGATION AT PROTEA GLEN

In December, 2017, a tornado approached Extension 24 Protea Glen, South Western of Johannesburg. The tornado was moving from the west through an agricultural land earmarked for future extensions of the township. According to media reports, various industrial areas and townships distributed over the southern and western part of Johannesburg were affected. This research is based on a site investigation which was done a few months after the effect. The review of damage was based on the desk-top data obtained from the media reports and preliminary (unpublished) draft investigation reports by a number of authorities.

According to the public reports, 855 houses had damaged roof coverings and seven houses experienced major structural damages. The following were observed on the houses:

- Blown away eave, roof and ridge tiles,
- Broken windows,
- Damaged barge boards, and
- boundary walls damaged.

The photos of damages to the houses and boundary walls are shown in Figures 12 and 13 respectively. The photographs demonstrates two important characteristics of tornadic events, namely:

- the selective nature of the damage, with images of devastated roofs, while close by houses escaping 'unharmd', and
- the ability to inflict damage to standardised, well-engineered and manufactured elements of built environment, e.g. the telephone posts.

The collapse of boundary walls characterises all wind damage events across South Africa.



*Figure 12 Damage to roofs and tele pole*



*Figure 13 Damage to boundary wall*

## **5.2 DISCUSSION OF THE INVESTIGATION AT PROTEA GLEN**

The storm experienced at Protea Glen was classified by the South African Weather Bureau as a Tornadoic Supercell Thunderstorm with an EF2 damage rating on the Fujita/Pearson scale. An EF2 rating represents damage caused by wind speeds in the region of 178 – 217 km/h (i.e. 50 – 60 m/s). These wind speeds are significantly larger than the basic wind speeds prescribed by the South African National Standards SANS 10160:3 (2018). Besides causing structural damages, the catastrophe resulted in unfortunate loss of human lives.

Tornadoic events are characterised by several specific descriptors related to their physical appearance, aerodynamic noise, speed and direction of the translational movement, width and length of their paths etc. The strength of the events is determined on the basis of the evidence of physical damage. Based on these descriptors tornadoic events get confirmed and allocated the respective grade – based on Fujita / Pearson (1973) classification. The event of concern, can clearly be classified as an extreme event in which, with at least one tornadoic funnel, generated within a large-scale super-cell thunderstorm. Importantly, presence of the funnel has been confirmed by photographic documentation. In an event of this nature it is fairly difficult to identify, and separate, the damage inflicted by tornadoes vs the extreme outflow winds generated by thunderstorm.

Although the damage does not reveal features of exceptionally large event (on Fujita / Pearson-scale classification), there is no doubt that the wind speeds, which were reached, were comparable and higher than the minima values stipulated in the SA Wind Loading Standard (SANS 10160-3). In the opinion of the authors, the magnitude of winds at low levels above the ground, could have likely attained about 45 m/s (within a margin of, say, +/-15%). Such magnitude of wind speeds can generate free-stream dynamic pressures of about 1 kN/m<sup>2</sup>. In view of the variety of influencing factors (e.g. geometry, orientation, extent etc.) it is not possible to directly relate this magnitude of the free-stream dynamic pressures to loads which were generated over various elements of houses, but these could have been in the excess of 2 kN/m<sup>2</sup>.

## **6 RECOMMENDATIONS**

As part of the case studies investigation, the following recommendations are proposed:

- **Planning and Design of township developments**  
Following the climatic changes evident in the last decades which has seen extreme weather patterns being experienced all over South Africa, it is recommended that further research is required to investigate various aspects of wind-induced erosion of soils. This includes the optimal orientation of township layouts and the remedial measures to reduce the impact of wind-induced erosion. The use of wind tunnel tests as a planning tool may be expensive, and hence it may be necessary to explore the use of CFD software in township planning.
- **Review of technical standards**  
Research across the world has shown that the occurrence of large-scale devastating events is on the rise - both in terms of their frequency and ferocity. This implies that more of similar events, affecting large housing developments, are to come and should be taken into account in the development of technical standards. The shortcomings of the current NHBRC Home Building Manual (2015), in relation to wind loading specifications must be addressed. The current loads and load combination factors must be reviewed and aligned with recent publications (SABS, 2018) and other international best practices.
- **Construction quality improvement**  
Despite all the improvements in planning and design, there is a need to improve construction quality through education of building contractors, construction monitoring and supervision, and the use of approved quality building materials and products.

## 7 CONCLUSION AND FURTHER RESEARCH

The paper presented two case studies affected by extreme weather conditions caused by high wind speeds. The case of the coastal development suggests that a multi-disciplinary study into wind-induced soil erosion within mass housing developments in South Africa is required. The investigation included a literature survey, site investigations and interviews of residents, geological & geotechnical inputs, analysis of influences and correlation of climatic data on precipitation & wind occurrence and wind-tunnel pilot study. Results of the study demonstrate the benefits of multidisciplinary approach and also the applicability of wind modelling as a tool to predict the erosion around houses and investigate the optimal methods and remedies to reduce the negative impact of wind in dense mass-housing developments located on loose soils. Further research is required to investigate various other aspects of wind-induced erosion of soils affecting mass human settlements e.g. other layouts of township, application of remedial measures (like wind screens) or optimal orientation of townships in respect to the directions of prevailing winds. The second case study focused on the effects of extreme wind on inland housing development. It indicated a need for review of technical standards and loading requirements stipulated in these standards. Relevant awareness and training programmes of the building contractors to ensure construction quality complies with technical standards and specifications are also required.

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## **Contractor competence in cidb grades 2 to 4: A pilot study**

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### **ABSTRACT**

As part of its local economic development initiative the government continues to support the creation of women owned construction companies, especially in the provision of low-income housing. These small contractors are however plagued by issues of quality of production and sustainability of their enterprises, which impact on the overall delivery of housing. The Construction Industry Development Board (cidb) has developed a tool for assessing the competence of contractors registered in the cidb Grades 2 to 6. The cidb Competence Standard for Contractors establishes the minimum acceptable competences necessary for running a contracting enterprise and for supervising building and construction. The standard, based on nationally recognised contractor training programmes assesses the contractors competence in the areas of business management, building and constructions works management (operational and supervision) and legislation related to construction works. A pilot was undertaken to assess the competence of contractors who were enrolled in contractor development programmes across the country. Briefly, the contractors were subjected to a three-hour interview with a panel of industry experts to assess their knowledge, skills and application of different construction principles in their businesses. The results of the assessments indicate that many contractors have a good understanding of the skills and competencies required to manage sustainable construction companies. Significant gaps were identified in areas such as tendering, production and business management inclusive of cash flow projections. This pilot highlights some of the critical areas of construction that need to be emphasised in contractor development programmes to create profitable and sustainable contractors that deliver quality infrastructure.

Keywords: Local Economic Development, Contractors, Competence Standard, Quality Infrastructure

## **1 INTRODUCTION**

The human settlements in South Africa, indeed its construction and infrastructure sub-sectors, is an important segment of the country's economy. Yet, this important part of the economy is replete with infrastructure that is poorly designed, constructed and maintained. At the core of this problem is the lack of adequate competencies both at management and technical levels to manage the processes that create and sustain infrastructure assets. Dlungwana and Wall (2014) cite a number of South African studies (McGrath and Akoojee, 2007; Kraak, 2005 and cidb, 2007) that document the challenge of skills resources and needs and the negative impact the problem has on infrastructure environment and other economic sectors. The wastage due to poorly built and maintained buildings amounts to billions of rands. Fatalities and poor health hazards and other negative social impacts are occurring at an increasing rate as a result of inadequate skills, as happened recently when a landmark building in central Johannesburg was burned down (News24, 2018).

Some of the critical research questions that the study is attempting to address are:

- How can requisite competencies be attained by contractors who do not have the relevant industry qualifications?
- What improvements should be considered to enhance the current contractor development programmes?

While there is no shortage of contractor development programmes in the country, it is not clear that these programmes have a systematic and methodical approach of assessing the skills of contractors that can enable such contractors to sustain their businesses while providing safe and quality

infrastructure to clients. This study attempts to answer these questions and thus plug this glaring knowledge gap in the industry.

## 2 BACKGROUND

The Competence Standard provides for a standard method of assessment and recognition of the competencies of a contracting enterprise within a cidb Class of Construction Works and construction category. Recognition of minimum competence requirements within a construction category satisfies the recognition criteria for all lower construction categories within a Class of Construction Works.

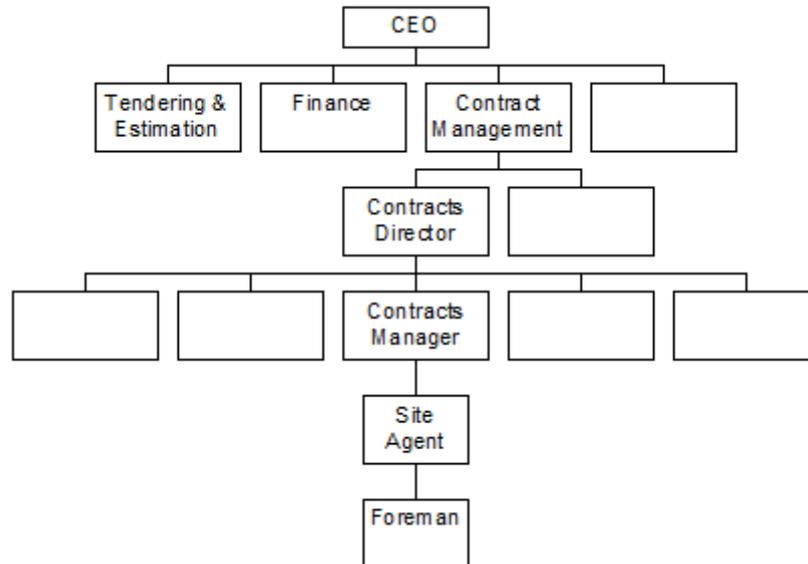


Figure 1 Organogram for a Contracting Enterprise

Figure 1 above illustrates the key functional roles in a conventional contracting enterprise. In a small contracting enterprise the owner performs most of the duties and only employs key staff as and when required. The most common configuration of companies registered in the lower cidb contractor categories of grades 1 to 6 is a company with an entrepreneurial owner with little or no knowledge of the construction industry. In these cases, the owner manages the business aspects of the company and employs construction professionals to supervise the technical aspects. Alternatively, old construction workers with technical expertise decide to start their own companies and invest in a construction enterprise. In such cases the technically qualified person employs a business management professional to undertake financial management roles and facilitate the success of the company.

This configuration is further reproduced in conventional contractor development programmes run and managed by provincial departments of public works and the Expanded Public Works Programme (EPWP). Consequently, the cidb Competence Standard for Contractors was designed to assess competencies of more than one person per contracting entity. The Competence Standard for Contractor provides for the competencies to reside with the owner and/or key nominated representatives of the contractor. Where the competencies reside with a nominated representative, the nominated representative must either be an employee of the company, or must be accessible to the company for the duration of any construction works to be undertaken by the contracting enterprise, and must be declared on tender.

In the case where a contractor or his/her nominated representative do not have the formal qualifications for the competence level applied for; cidb conducts an external assessment of their competencies through interviews and a submission of a portfolio of evidence; a process referred to as an Assessment of Prior Learning (APL). The APL is based on a set of standardised questions pegged against minimum National Qualifications Framework (NQF) requirements of formal qualifications for the required competencies. This paper presents the findings of the initial phase of the assessment of contractors as

they exited from client contractor development programmes. The paper looks at the attainment of the requisite competencies by contractors who did not have the requisite qualifications and makes recommendations for the improvement of contractor development programmes.

### 3 LITERATURE REVIEW: SKILLS DEVELOPMENT MODELS

Some of the scholars that popularised the concept of core competence or competencies include Hamel and Prahalad (1994). They defined core competence as '*a bundle of skills and technologies that enables a company to provide a particular benefit to customers* (1994:219).' Burgelman *et al.* (2004) describe core competencies as corporate resources that may be reallocated by corporate management. Critically, core skills/competence should result in a competitive advantage which in turn should sustain a business enterprise.

Historically, Excellence Models have been remarkable for their ability to develop skills and competence development of staff within business enterprises in many countries throughout the world. Perhaps, two of such popular models are the Malcom Baldrige National Quality Award developed in the USA (Brown, 1996) and the European Foundation for Quality Management's Excellence Model. Both models were developed by the quality movements in the USA and Europe respectively. Over the years many other countries have tweaked these versions and adopted them for their own use.

In South Africa, the South African Excellence Foundation developed the South African Excellence Model, based on similar successful models from other countries, and the model was adjusted accordingly for local conditions (Ladzani, 2006). The Council for Scientific and Industrial Research developed a construction sector version, the South African Construction Excellence Model (SACEM) (Dlungwana *et al.*, 2002). The SACEM is a business assessment tool developed to assess the performance of contractors by addressing a number of the competence areas categorised into logical evaluation criteria.

The common theme with these models is their ability to adopt best industry practices through the use of Total Quality Management (TQM) approach, including safety and environmental management. These models and many others have evolved over time but retain some common structures that have made them relevant for assessing the skills for small and large enterprises.

### 4 RESEARCH METHODOLOGY

An assessment tool was developed by industry experts using an iterative, peer review methodology. Briefly, the competences required to run a successful and sustainable business were defined using the literature and conventional business maturity models. The criteria, extracted from these models, were then used to identify business management competence areas inclusive of planning, financing, human resources and construction contracting. Supervision was assessed using criteria such as programming and project planning, productivity, health, safety and environment as well as quality management.

The draft tool was developed in a form of a case study that would elicit appropriate responses from the contractors based on their knowledge and experience. The tool was workshopped with a panel of industry experts to validate the content and appropriateness for assessing construction businesses. The tool was then adjusted and piloted with contractors who had been in the industry for at least ten years and were running successful construction companies. The pilot was intended to further validate the appropriateness of the tool for assessing the subject matter, standardise the terminology used, make it user friendly. The tool was lastly subjected to an evaluation of its reliability when applied by different assessors by comparing the outcomes of assessment of the same candidate by different assessors. Concurrence of the results of assessments conducted on the same candidate by different assessors was taken to indicate the reliability of the assessment tool and the validity of the method of assessment. The tools were then finalised and applied to a larger population of contractors.

The study population comprised of contractors exiting contractor development programmes run and managed by provincial Departments of Public Works and the Expanded Public Works Programme (EPWP). The EPWP contractor development programme offers training to two persons per contracting

entity, an owner business manager, who is trained in business management principles and a supervisor who undertakes the works management on site.

All contractors in the programmes had to be registered on the cidb register of contractors at the initiation of the programme, and participated in a three-year contractor development programme that entailed classroom instruction on different aspects of construction business and practical experience from projects awarded by EPWP client departments to apply their classroom learning. Lastly, all participants had successfully upgraded by at least one level on the cidb Register of Contractors. The sample of this study is all grade 2 to 4 contractors who exited development programmes in 2017 and presented themselves for assessments by the cidb panel of assessors.

Representatives of the contracting entity, namely, the business owner and supervisor were subjected to a three-hour interview by industry experts and all the responses recorded. The outcome of the assessment interview was compared with model answers indicative of what was expected from a competent construction practitioner to do in practice. All competence shortcomings were noted and recorded as recommendations for further training for the contracting entities assessed. In essence, the methodology used was a 'mixed methods' approach gathering both qualitative and quantitative data. For the sake of brevity to meet the prescribed length of paper, only quantitative data will be covered here.

This study reports on the findings of the initial iteration of the cidb contractor competence assessments and makes recommendations for the improvement of the client managed contractor development programmes.

## 5 FINDINGS AND DISCUSSION

There were in sixty four (64) contractors assessed in cidb grades 2 to 4 and the results are presented in Figure 1 below. There were 56% (36/64) contractors assessed as competent, 33% (21/64) not yet competent with 11% (7/64) being declared as inconclusive. The inconclusive results are cases where the interview over ran the three-hour time and the contractor was only assessed in one competence area, or where the contractor claimed to have academic qualifications in the competence area but had not yet submitted proof of qualifications.

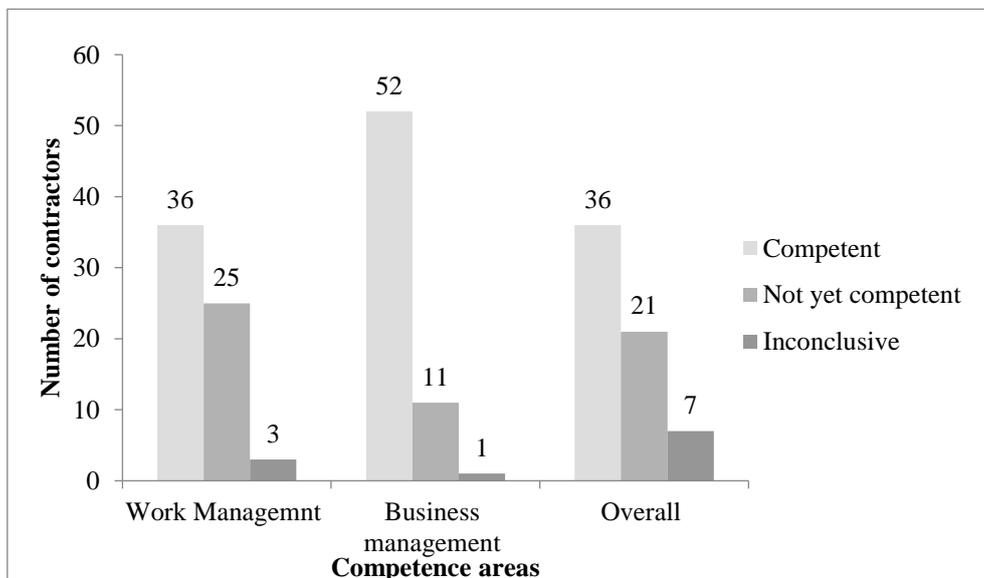


Figure 2 Competence results for grade 2 to 4 contractors

There were more contractors competent in business management (82%) than works management (56%). Business management competence enables the contractor to make profits on their projects, upgrade on the cidb register of contractors and become sustainable. The core areas of business

management in construction contracting include an understanding and application of construction contracts and legislation compliance, tendering and productions management, project programming and progress monitoring, business, and financial and resource management, including human resources management and health, safety and environmental management.

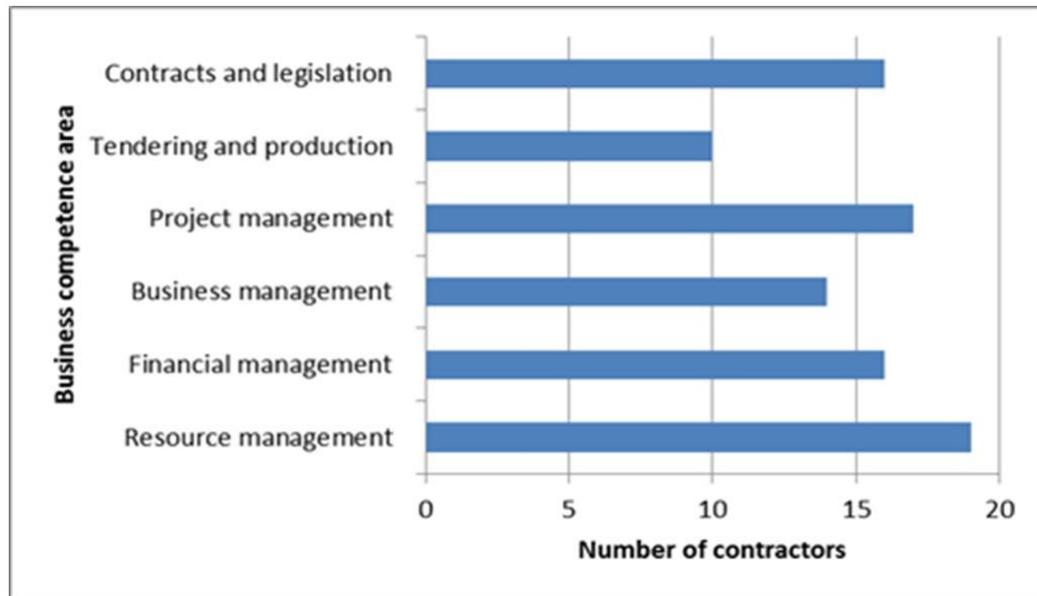


Figure 3 Training needs identified in business management

The assessment included an identification of competence areas where the contractors required further input to meet the requirements of the cidb Competence Standard for Contractors. Figure 2 above presents the areas that were identified as requiring further input within the business management competence area. According to Figure 2 above, the areas where most contractors required input were resource management (30%; 19/64), with 25% (16/64) requiring further training in financial management and contracts and legislation. The competence areas where most contractors demonstrated higher competence and therefore fewer needed top-up training are business management (11%; 7/64) and tendering and production (15%; 10/64).

The contractors showed the least competence in the areas of works management, with the least competence shown for technical skills (48%; 31/64). The works management area where contractors showed higher competence levels were planning with 19% (11/64) requiring input, resource and production management (25%; 16/64) and safety, health and environmental management (25%; 17/64).

Contractor performance and contracting enterprise sustainability are dependent on the technical and business management competence of the people running the company. When a company has technically sound people, they are able to price their jobs correctly, attain productivity rates that enable them to complete their jobs on time, to the quality specified by the client and ultimately make profit on their projects. Profitable construction enterprises are more likely to have an owner or personnel with sound business management practices

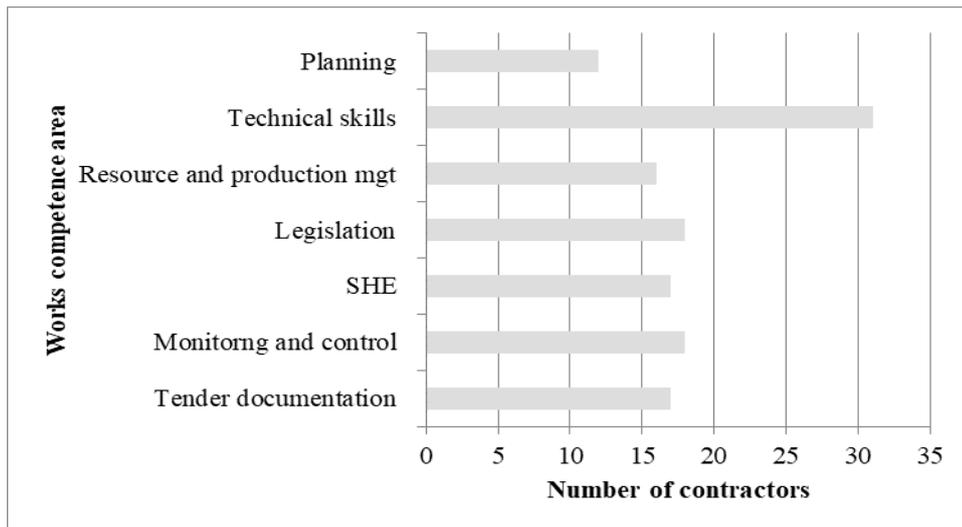


Figure 4 Training needs identified in works management

Contractor development programmes take entry level contractors and train them in business management and technical skills required to implement their projects successfully, within scope, time and cost. The findings of the competence assessments show that only 56% of contractors who have participated in a three-year development programme are regarded as competent on exit. There were more contractors assessed as competent in business rather than works management. This is of concern as the primary function of a construction entity is to deliver projects to clients. Low level of works management competence among contractor development graduates means that clients are at risk of getting poor quality workmanship that adversely affects service delivery. This is borne out by the cidb Construction Industry Indicators that have shown that clients were not satisfied with the performance of contractors on 16 per cent of the work carried out in 2015 (cidb, 2016).

About a quarter of the contractors (23%) were regarded as not yet competent in all of the criteria tested in the assessments. These are contractors who still require significant input and support to reach a level of competence regarded as sufficient to run a successful construction projects.

## 6 CONCLUSION AND FURTHER RESEARCH

The study concludes that only half of contractors enrolled on contractor development programmes exit the programme with industry relevant skills and competences posing a risk to clients who may use these contracts, as well as to the contractors who may lose money implementing unsuccessful, loss making projects.

The study recommends that in order to improve the outcomes of contractor development programmes and train contractors to levels of competence that can ensure successful project implementation, contractor development practitioners must pay particular attention to technical construction skills. Programmes must also enhance the overall works management training especially in areas of legislation, monitoring and control, as well as tender documentation.

This paper only reports on the assessment of grades 2 to 4 entry level contractors, who may have only been in the industry for a short time. Further this is an on-going project and the competence levels may change as the numbers of contractors assessed increases.

## ACKNOWLEDGEMENTS

The authors wish to acknowledge the construction industry development board for sharing its data and permitting information to be published. It is hoped that by contributing in this manner the stakeholders

in the human settlements sector will be empowered and informed about the development of skills promotion in the sector.

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## **The quantification of shading for the built environment in South Africa**

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### **ABSTRACT**

A bioclimatic analysis of South African towns and cities indicates that solar protection is the single most important passive design measure to reduce energy usage and to improve internal comfort for the built environment across all climatic regions. Passive solar buildings aim to maintain interior thermal comfort throughout the sun's diurnal and annual cycles whilst reducing the requirement for active heating and cooling systems.

There is a long history of methods to calculate the shading on buildings and a significant corpus of knowledge has been built up starting with purely graphical methods 60 years ago to recent parametric simulation with energy simulation software using weather files.

This paper reviews the various shading calculation systems devised over the years. The effect of climate zones on the requirements of building shading design is also investigated. Different climate zones change the requirements of the size of horizontal overhangs on the northern façade (elevation dominated solar angles) and the periods when the eastern, western and southern facades (azimuth dominated solar angles) should be protected.

An experimental research platform has been developed to support this investigation. This method enables the calculation of required shading angles where there is a balance between the hot periods (requiring cooling) and cool periods (requiring heating). Over and above the calculation of current solar angles this method also facilitates the calculation of the increase in overhang sizes that will be required with climate change such as with the expected A2 climate change scenario (business as usual scenario) for South Africa.

This method is able to recommend different northern overhang sizes for cities and towns on the same latitude such as Upington, Kimberley and Bethlehem in South Africa. These three locations are on the same latitude but in totally different Köppen-Geiger climatic zones, i.e. respectively BWh, BSh and Cwb and altitudes.

The current rigid geometric solar elevation angle approach does not take account of locations on the same latitude with different climatic regions and altitudes. This method proves that it is possible to analyse and quantify solar protection on building facades resulting in a rational balance between the hot and cold periods without using the current practice of extensive parametric simulation with energy simulation software. It is also able to distinguish between cities and towns on the same latitude but in totally different climatic regions.

Keywords: Solar protection, horizontal overhangs, shading

## **1 INTRODUCTION**

A previous bioclimatic study, by means of Climate Consultant v6.0, of the three main Köppen-Geiger climatic regions of Pretoria, clearly indicated the importance of protection against the summer sun by means of sun shading of windows in the predominantly hot South African set of climates (Conradie, 2017). This becomes even more important with the expected climate change in South Africa.

A bioclimatic analysis of Upington (28.433° S, 21.267° E, 814 m altitude), Kimberley (28.8° S, 24.767° E, 1 197 m altitude) and Bethlehem (28.25° S, 28.33° E, 1 682 m altitude) that are in different climatic regions and altitudes, proves this further (Table 1). These three locations are almost on the same latitude but in totally different Köppen-Geiger climatic regions, i.e. respectively desert (BWh), steppe (BSh) and warm temperate climate with dry winter (Cwb).

Table 1 below quantifies the actual changes in design strategy for the current climate and with an A2 climate change by the year 2100. According to recent research by Engelbrecht *et al.* (2016), the A2 climate change scenario is the closest to reality for Southern Africa. A2 is also known as the “*business as usual*” scenario. Projections of future global climate change such as A2 that are described in Assessment Report Four (AR4) of the Intergovernmental Panel on Climate Change (IPCC), are based on coupled Global Climate Models (CGCMs) that simulate the coupled ocean, atmosphere and land-surface processes. By means of Climate Consultant v6.0, the smallest number of different passive design strategies that can potentially achieve closest to 100% or 100% comfort were determined. The surprising result is, even with an A2 climate change scenario, it is still possible to achieve 100% comfort in all cases, with a large portion totally passive and with some mechanical intervention in extreme situations by means of hybrid solutions. If hybrid intervention is not used then the theoretical passive maxima, as analysed in Climate Consultant v6.0, in Upington, Kimberley and Bethlehem become respectively 89.2%, 82.8% and 74.6%.

Table 1 Suggested passive and hybrid design strategies for the BWh, BSh and Cwb climatic zones, currently and with climate change. The contribution of each strategy is expressed in hours per annum. (Author)

| Design strategies                       | BWh (Upington) |                   | BSh (Kimberley) |                   | Cwb (Bethlehem) |                   |
|-----------------------------------------|----------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                                         | 2009           | 2100 <sup>3</sup> | 2009            | 2100 <sup>3</sup> | 2009            | 2100 <sup>3</sup> |
| Comfortable                             | 2336           | 2102              | 2050            | 1905              | 1506            | 2065              |
| Sun shading of windows                  | 2017           | 2450              | 1560            | 2165              | 631             | 1724              |
| High Thermal Mass                       |                |                   |                 |                   | 137             |                   |
| High thermal Mass Night Flushed         |                | 1859              | 1295            | 1486              |                 | 1236              |
| Direct Evaporative Cooling              |                |                   |                 |                   |                 |                   |
| Two-Stage evaporative Cooling           | 2158           |                   |                 |                   |                 |                   |
| Natural Ventilation Cooling             |                | 670               |                 |                   |                 |                   |
| Fan-Forced Ventilation Cooling          |                |                   |                 |                   |                 |                   |
| Internal Heat Gain                      | 2413           | 1844              | 2907            | 2097              | 3276            | 2683              |
| Passive Solar Direct Gain Low Mass      |                |                   |                 |                   |                 |                   |
| Passive Solar Direct Gain High Mass     | 2082           | 1501              | 2327            | 1669              | 2623            | 2048              |
| Wind Protection of Outdoor Spaces       |                | 16                |                 | 24                |                 | 19                |
| Humidification Only                     |                |                   |                 |                   |                 |                   |
| Dehumidification Only                   | 116            | 260               | 279             | 758               | 256             | 867               |
| Cooling, add Dehumidification if needed | 133            | 1729              | 134             | 1445              | 19              | 403               |
| Heating, add Humidification if needed   | 697            | 381               | 1095            | 507               | 1968            | 710               |

Comfort(able) (Table 1) as used in the Climate Consultant v6.0 software is clearly defined in the ASHRAE 55-2010 (ASHRAE 55-2010) standard. This standard uses operative temperature. Operative temperature (OT) integrates the effect of air temperature and radiation, but ignores humidity and air movement. It is unsuitable for application above 27°C (Holm *et al.*, 2005). The range of operative temperatures presented is for 80% occupant acceptability. This is based on a 10% dissatisfaction criterion for general (whole body) thermal comfort based on the predicted Mean Vote/ Percentage Persons Dissatisfied (PMV-PPD) index, plus an additional 10% dissatisfaction that may occur on average from local (partial body) thermal discomfort (ASHRAE 55, 2010). Two comfort zones are used, one for 0.5 clo (summer) of clothing insulation and one for 1.0 clo (winter) of insulation. These insulation levels are typical of clothing worn when the outdoor environment is warm (summer) and cool (winter) respectively. This comfort zone described in the ASHRAE 55 (2010) standard differs slightly from the older new Effective Temperature (ET\*) delineated comfort definition used by researchers such as Givoni (1969), Watson and Labs (1993). New Effective Temperature (ET\*) is described as the DBT of a uniform enclosure producing the same heat exchange by radiation, convection and evaporation as the given environment. It allows for body, clothing and space interaction. ET\* lines coincide with DBT values at the 50% curve of the psychrometric chart (Holm *et al.*, 2005). The quantified results in Table 1 were

<sup>3</sup> A weather file with an A2 climate change scenario as defined by the IPCC (2000) has been used to calculate these values.

calculated by means of Climate Consultant v6.0 and used the latest ASHRAE 55 (2010) definitions and dual summer/ winter comfort zones.

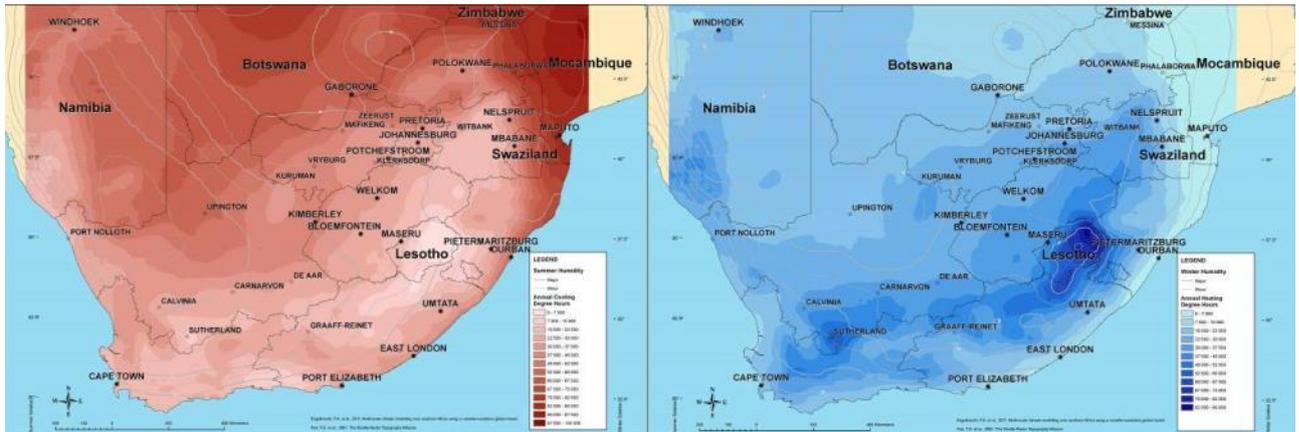


Figure 1 Separate Cooling and Heating degree hour maps before combination into a single map (Conradie et al., 2015)

In all cases the benefit of proper “Sun shading of windows” increases significantly with climate change. It is evident what the effect of climate change is in the significant reduction of the number of “comfortable” hours due to the significant increase in temperature and solar radiation.

An analysis of Figure 1 above indicates that Uptington currently requires between 52, 500 and 60, 000 annual Cooling Degree Hours (CDH) and only between 7, 500 and 15, 000 annual Heating Degree Hours (HDH). Kimberley requires between 37, 500 and 45, 000 annual CDH and between 15 000 and 22 500 annual HDH hours. Lastly Bethlehem, being very cold in winter requires only between 15 000 and 22 500 annual CDH and between 30, 000 and 37, 500 annual HDH.

## 2 PRECEDENTS FOR THE CALCULATION OF SUNLIGHT AND SHADE

Over the past 66 years, many different methods have been devised to determine the amount of sunlight and shade on building facades. Initially, the focus was solely to determine the extent of shade for a given time of day and specific latitude. There was no established methodology to accurately determine when solar protection should really take place and the determination of shade was mostly qualitative. In one of the earlier systems developed at the former National Building Research Institute (Richards, 1952) a set of accurately printed solar charts and a special transparent protractor was developed for South African latitudes of 20° to 34° (2° spacing) south. Inter *alia* the same publication included suggested periods for maximum shading, summer cooling period and the winter heating period. For example in Bloemfontein (close to Kimberley in the present study) the winter heating period was suggested as from 1 May to 31 August, summer cooling period from 29 September to 2 April and the suggested period for maximum shading 6 October to 8 March. In an improved reprint of the original publication in 2004 (CSIR Building and Construction Technology, 2004), the suggested solar protection and winter period should remain unaltered, although a significant amount of climate change has already taken place.

Olgay (1963; 2015) extensively discusses various solar control measures including a discussion of shading effectiveness. The shading effects of trees and vegetation are also discussed. The concept of overheated period charts, methods to determine the position of the sun and methods to determine the type and position of the shading device are described and illustrated. Olgay (2015) has already noted that inside shading protection devices can only intercept the solar energy which has just passed through the glass surface and can eliminate only that portion of the radiant energy which can be reflected through the glass again. It is evident from Olgay’s analysis that horizontal overhangs on the northern or southern side (depending on the earth’s hemisphere) and outside moveable vertical louvres/ fins on the eastern and western side are very efficient with shading coefficients of respectively 0.25 and 0.23 to 0.10.

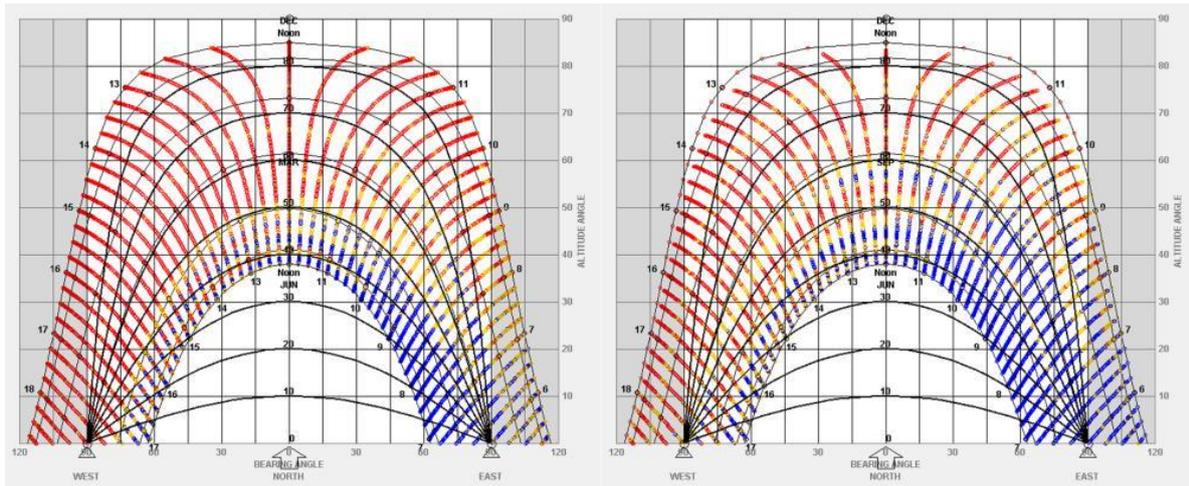


Figure 2 A *Climate Consultant v6.0* implementation of the original Mazria (1979) solar chart. The two halves of the year are illustrated for the hot climate of Upington. The image on the left is for 21 December to 21 June and the right hand for 21 June to 21 December.

Mazria (1979) made a significant contribution in the further understanding and quantification of solar protection. His biggest contribution was the invention of a special solar chart with a horizontal axis marked in degrees (azimuth) and a vertical axis marked from 0° to 90° (elevation or altitude). This enabled him to introduce a shading calculator that was used to generate a shading mask. The curved lines that run from the lower right-hand corner are used to plot horizontal obstruction lines parallel to a window and the vertical lines on the calculator serve to plot vertical obstruction lines parallel to the window. This original on-paper concept is currently used in the modern *Climate Consultant v6.0* software. One of the refinements in said software is the introduction of the display of the two halves of the year. The one half spans from 21 December to 21 June and the other half from 21 June to 21 December (Figure 2). This became necessary as the two halves of the year are not symmetrical from a climatological point of view.

Closer inspection of Figure 2 reveals that the 21 December (Summer solstice) to 21 June (Winter solstice) half is significantly hotter than the 21 June to 21 December half. This was not recognized by Mazria as weather files were not freely available.

Another complication in the use of this particular solar chart system is that it is really not suitable for use in the tropical band, i.e. north of the Tropic of Capricorn and south of the Tropic of Cancer. This was practically tested with the South African town of Musina that is just north of the Tropic of Capricorn (22.338° S, 30.042° E, 543m) (Figure 3). The December 21 to 21 June part of Figure 3 (left hand image) appears to be a correct presentation of the weather file data. However the 21 June to 21 December part (right hand figure) does not correctly reflect the amount of solar radiation on the southern façade. The only way a Mazria type chart can show a town north of the Tropic of Capricorn is to distort the diagram by adding additional projecting “ears”. A similar technique than the Mazria chart is used by the University of Oregon Solar Radiation Laboratory in the generation of a diagrammatic solar chart (University of Oregon, 2018).

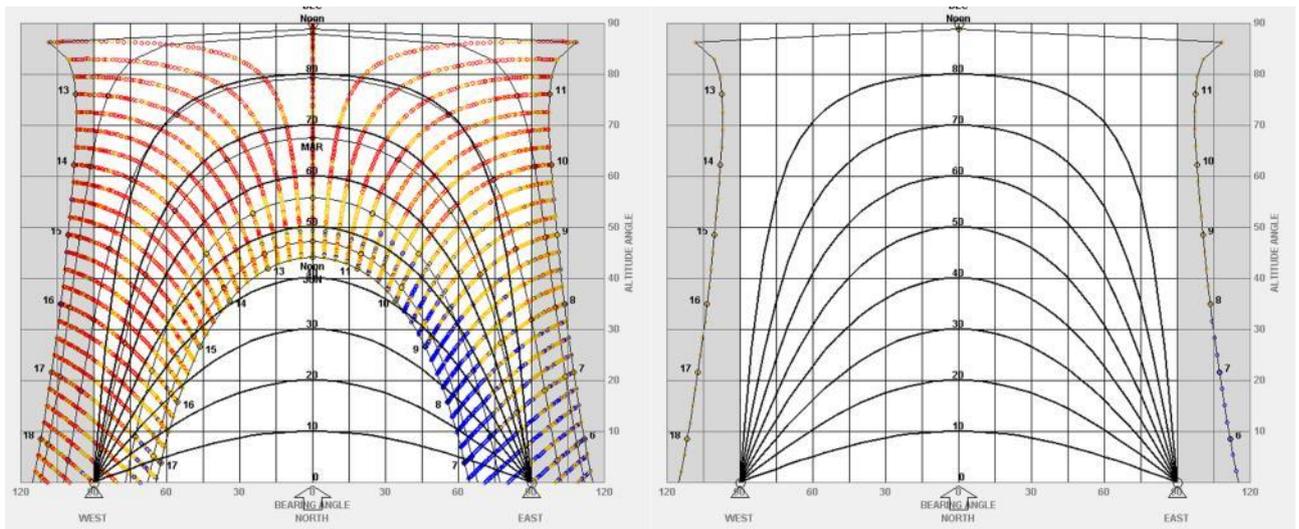


Figure 3 A Climate Consultant v6.0 analysis for the South African town of Musina. The image on the left is for 21 December to 21 June and the right hand degenerated one for 21 June to 21 December.

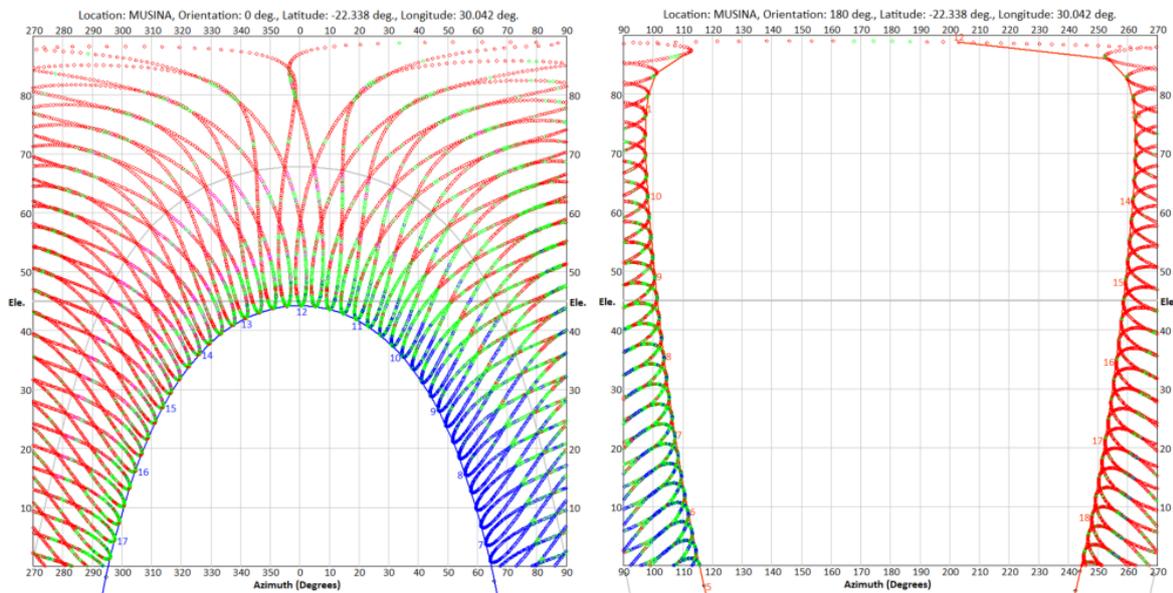


Figure 4 The experimental research platform analysis for the South African Town of Musina (slightly north of the tropic of Capricorn) using the same weather file as in Figure 3. The image on the left is for the whole year with a bearing of 0° (north). The image on the right is also for the whole year with a bearing of 180°. It correctly shows that, during noon on summer solstice, the sun do fall on the southern façade.

Szokolay (2004) also describes various solar design aspects and alludes to two important aspects for designers, i.e. the apparent movement of the sun (the solar geometry) and the energy flows from the sun and how to design for it (exclude it or make use of it). Sun path diagrams or solar charts are the simplest practical tools for visualising the sun's apparent movement. The sky hemisphere is represented by a circle (the horizon). Azimuth angles (i.e. the direction of the sun) are indicated on the perimeter and altitude (also called elevation) angles (from the horizon up) are indicated by a series of concentric circles, 90° (the *zenith*), being in the centre. Several different methods are used in the construction of these charts. The orthographic, or parallel projection method is the simplest, but it produces very compressed altitude circles near the horizon. The *equidistant* method is in general use in the USA, however it is not a true geometrical projection. The most widely used type is the stereographic chart. These are constructed by a radial projection method, in which the centre of the projection is vertically below the observer's point, at a distance equal to the radius of the horizon circle (the nadir point).

According to Szokolay (2004) solar radiation can be measured in two ways:

- Irradiance is a measure in  $W/m^2$  and is the instantaneous flux- or energy flow density or power density.
- Irradiation expressed in  $J/m^2$  or  $Wh/m^2$  is an energy quantity integrated over a specific period of time.

The latter irradiation was used below to calculate the critical solar angles along with a specific temperature threshold described in detail below. Szokolay (2004) suggested the use of a shading mask, which can be constructed with the aid of a shadow angle protractor. He improved somewhat on the ideas of Mazria (1979).

At least 12 different generic shading devices can be identified (Figure 5). Generally speaking shading types that exclude the sun externally during the overheated period and allow it in during the cold period are more efficient. In contrast fixed screens, although they are very efficient, have the disadvantage that they exclude the sun even during the cold period and hence the energy saving opportunity by balancing the overheated with cold period is unfortunately lost.

#### **A: HORIZONTAL OVERHANG (FIXED)**

This type of overhang is mostly suitable for altitude/ elevation (sun is far above the horizon) dominated solar angles, typically on northern (or near northern) facades. It can take various forms such as illustrated in A to E. This could also be in the form of a projecting awning or sun blind.

#### **B: FIXED VERTICAL SCREEN**

This configuration is a variation of A and is intended to exclude the lower rays of the sun, thereby reducing the glare problem.

#### **C: SIDE FIN/ VERTICAL PROJECTION (FIXED)**

The side fin used on its own is suitable for use on facades where the solar altitude/ elevation is mostly azimuth dominated, i.e. low solar angles above the horizon. This option is often combined with A for facades that are not due north and where there is a mix of altitude/ elevation and azimuth dominated solar angles that need to be excluded.

#### **D: LIGHT SHELF (FIXED)**

This is another variation of A and is used to improve the natural light penetration in a space by means of a reflecting light shelf.

#### **E: HORIZONTAL LOUVRES (FIXED OR MOVEABLE)**

This is a variation of A and if it is moveable it is more flexible than A. Is typically used with altitude/ elevation dominated solar angles. This have the advantage of permitting air circulation near the façade. Slanted louvres give better protection than vertical ones.

#### **F: VERTICAL LOUVRES (FIXED/ MOVEABLE)**

This protection device is found in different forms. In its simplest form it could be a fixed vertical screen some distance away from the building façade. In a more complex form it could consist of multiple louvres set right in front of the window or some distance away from the façade. The most sophisticated variation would be a moveable system with or without computer control.

#### **G: INTEGRAL BLINDS**

In this system blinds are built into a double glass system. This has some advantages such as the protection of the blind. These systems are normally moveable.

#### **H: SPECIAL GLASS SUCH AS HEAT ABSORBING, REFLECTIVE AND PHOTOCROMIC.**

This is the weakest type of shading device as it depends on the treatment of the glass and can ultimately not avoid heat gains in the interior.

#### **I: VERTICAL EXTERNAL SCREEN**

There are many types of this screen. In its simplest form it could be a fixed fine woven metal mesh. More complex systems consist of special screens that can be opened and closed when desired.

**J: EXTERNAL LOUVRES, INSULATED LOUVRES, LOUVERED BLIND AND VERTICAL ROLLER BLIND**

These types are mentioned by CIBSE (2014) and there are many variations with varying degrees of durability. Some researchers even suggested the integration of screens with flexible photovoltaics (Sampatakos, 2014). Insulating blinds are mentioned by Kristinsson (2012).

**K: INTERNAL SCREEN, LOUVRE DRAPES, BLINDS OR CURTAINS.**

This family of solar protection devices are not that efficient to reduce heat in a space as it is not excluding the solar radiation from the outside. This causes the gradual built up of heat in the space due to the hot house effect. However it is useful as a means to control solar glare with low solar angles in the early morning and late afternoon. Ideally these types of devices should be used in conjunction with well-engineered external solar protection devices. This type of screening could venetian blinds, vertical louvered retractable blinds, fabric roller blind and fabric curtains.

**L: DOUBLE-SKIN FAÇADE**

This the most sophisticated type of façade. This façade takes many forms depending on the specific façade application and is successfully used in hot climates. Three fundamental types can be recognized, such as Buffer Façade, Extract-air Façade and Twin Face Façade.

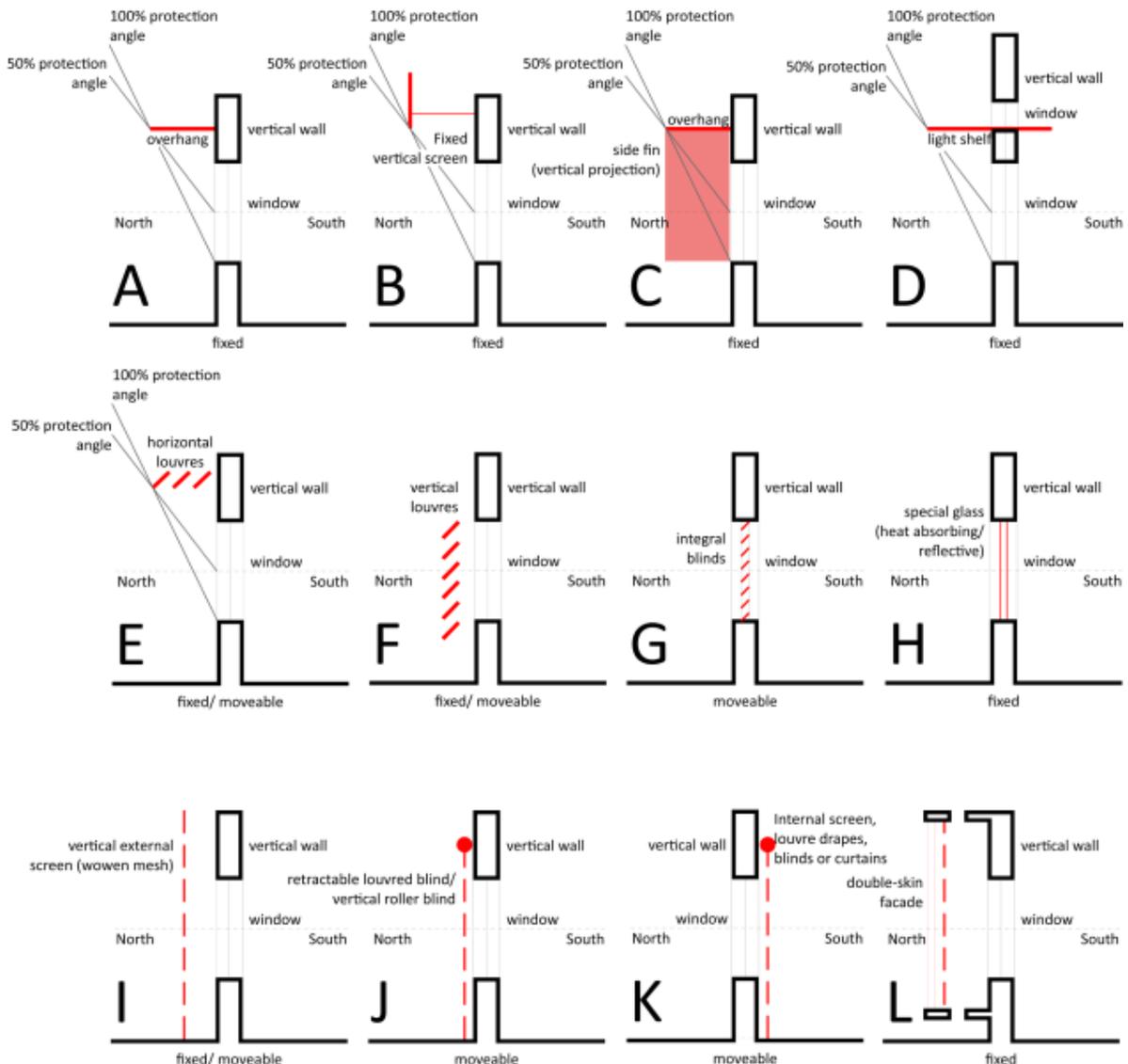


Figure 5 Different types of shading devices (Author after Olgay,2015; Bellia et al. 2014; CIBSE, 2014)

### 3 METHODOLOGY

The primary aim of this paper is to investigate the effect of climate zones on building shading design, by means of quantifying the size of horizontal overhangs on the northern façade, using weather files, and also to provide a quantitative indication of the periods and time of day when the eastern, western and southern facades should be protected. It is clear from Figure 5 that types A to E would benefit from a quantification of horizontal overhangs if the overheating problem was solar elevation related as would typically be the case on the northern façade and parts of the eastern and western facades. If the solar radiation was azimuth dominated such as found on the eastern, western and southern facades types F to L would be applicable and the platform should be able to provide a set of azimuth angles when these façades should be protected.

To achieve this, a bespoke research analysis platform was developed. The first step was to generate detailed weather files for the current climate with the Meteororm software for Upton, Kimberley and Bethlehem using typical meteorological years specifically based on measured data. A second set of weather files were also generated to quantify the effects of climate change up to the year 2100 using an A2 climate change scenario of the Special Report on Emission Scenarios (SRES) for the period 1961-2100 using the first set as a baseline. Although typical meteorological years are currently used for energy simulations a significant amount of research is currently taking place to improve the accuracy of weather files and also to have more specialized weather files available (Herrera, 2017).

The second step was to develop a software parser to read the weather files in Energy Plus weather file format (.epw) into MS Access (U.S. Department of Energy, 2018). For each of the 8 760 records (number of hours in a year) the following fields were read (A total of 19 data fields):

A1: City  
A2: State Province Region  
A3: Country  
A4: Source  
N1: WMO  
N2: Latitude [-90,90]  
N3: Longitude [-180,180]  
N5: Elevation  
N1: Year  
N2: Month [1,12]  
N3: Day [1,28] ^ [1,30] ^ [1,31]  
N4: Hour [1,24]  
N5: Minute [1,60]  
N6: Dry Bulb Temperature (°C)  
N7: Dew point temperature (°C)  
N8: Relative humidity [0,110]  
N14: Direct Normal radiation in (Wh/m<sup>2</sup>)  
N15: Diffuse Horizontal radiation (Wh/m<sup>2</sup>)  
N22: Total Sky Cover [0,10] (Amount of sky dome in tenths covered by clouds or obscuring phenomena at the time indicated.)

Three special fields were added to contain calculated values for solar azimuth, elevation/ altitude and a single date record transcribed from the separate year, month, day fields (Fields N1 to N3).

Table 2 Verification of the accuracy of the analysis platform compared against values generated with the NREL solar position algorithm.  $\alpha$  is the sun topocentric azimuth, measured eastward (clockwise) from North in decimal degrees.  $\gamma$  is the sun topocentric elevation angle, with atmospheric refraction correction, in decimal degrees.

| Date and Time                 | Upington                          |          |               |               | Bethlehem                         |          |               |               |
|-------------------------------|-----------------------------------|----------|---------------|---------------|-----------------------------------|----------|---------------|---------------|
|                               | Analysis Platform (Based on NOAA) |          |               |               | Analysis Platform (Based on NOAA) |          |               |               |
|                               | $\alpha$                          | $\gamma$ | NREL $\alpha$ | NREL $\gamma$ | $\alpha$                          | $\gamma$ | NREL $\alpha$ | NREL $\gamma$ |
| Summer Solstice (21 December) |                                   |          |               |               |                                   |          |               |               |
| 08h00                         | 102.43                            | 29.26    | 102.4329      | 29.2681       | 99.95                             | 35.32    | 99.95258      | 35.3245       |
| 12h00                         | 57.97                             | 81.05    | 57.96346      | 81.0554       | 12.94                             | 85.07    | 12.90543      | 85.0722       |
| 16h00                         | 263.72                            | 43.59    | 263.726       | 43.5859       | 260.92                            | 37.41    | 260.9242      | 37.4055       |
| Autumnal Equinox (20 March)   |                                   |          |               |               |                                   |          |               |               |
| 08h00                         | 80.58                             | 17.08    | 80.58627      | 17.0756       | 76.84                             | 23.19    | 76.8504       | 23.1926       |
| 12h00                         | 21.47                             | 59.86    | 21.48589      | 59.8584       | 7.43                              | 61.59    | 7.451924      | 61.5968       |
| 16h00                         | 292.21                            | 34.90    | 292.2156      | 34.9071       | 287.42                            | 29.12    | 287.4337      | 29.1264       |
| Vernal Equinox (23 September) |                                   |          |               |               |                                   |          |               |               |
| 08h00                         | 78.60                             | 20.34    | 78.596        | 20.3463       | 74.70                             | 26.41    | 74.69621      | 26.4255       |
| 12h00                         | 14.19                             | 61.02    | 14.17527      | 61.0198       | 359.49                            | 61.94    | 359.4749      | 61.9450       |
| 16h00                         | 289.36                            | 31.96    | 289.3592      | 31.9541       | 284.89                            | 26.08    | 284.8911      | 26.0741       |
| Winter solstice (21 June)     |                                   |          |               |               |                                   |          |               |               |
| 08h00                         | 59.49                             | 5.74     | 59.4946       | 5.7408        | 55.67                             | 11.02    | 55.67584      | 11.0242       |
| 12h00                         | 10.61                             | 37.39    | 10.60568      | 37.3983       | 2.47                              | 38.28    | 2.465389      | 38.2883       |
| 16h00                         | 311.34                            | 18.73    | 311.3458      | 18.7277       | 306.8                             | 14.03    | 306.799       | 14.0313       |

The third step was to accurately calculate solar azimuth and elevation angles for each of the 8 760 hours per annum and merge it with the weather file data. This was the most challenging part as a large number of rather complicated astronomical calculations need to be performed. The detailed documentation of these complicated mathematical formulae is beyond the scope of this paper. There are various algorithms for sun position calculations available (Blanc *et al.*, 2012) such as the sun position algorithm from the National Renewable Energy Laboratory (NREL) (Reda *et al.*, 2008), Algorithm Solar Geometry from the European Solar Radiation Atlas (ESRA, 2000), Algorithm from the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) (Grena, 2008), Algorithm from Michalsky (1988), the SG2 algorithm (Blanc *et al.*, 2012) and finally an algorithm from the National Oceanic and Atmospheric Administration (NOAA). The calculations in the NOAA Sunrise/Sunset and Solar Position Calculators are essentially based on equations by Meeus (2015). The original code is written in Java. The most accurate known algorithm is the NREL one that achieves a standard deviation of only 0.0003° (1") for the period -2000 to 6000 (Reda *et al.*, 2008). This very high accuracy is achieved by means of tables containing the Earth Periodic Terms in addition to a set of astronomical equations found in most of the abovementioned solar position algorithms. These so called secular factors are irregular and can only be obtained by means of direct astronomical observation. It was decided to use the less accurate and sophisticated NOAA algorithm as a basis as it would be more than adequate for built environment shading applications (Table 2). An implementation of the NREL algorithm was obtained and compared with the NOAA based algorithm for a number of critical points at 08h00, 12h00 and 16h00 for the annual solstices and equinoxes (Table 2). Hours closer to sunset and sun rise were excluded in this comparison as solar refraction has a large impact at these low solar elevation angles. Table 2 compares the accuracy of the research platform using algorithms based on NOAA and Meeus (2015) against the very accurate NREL solar angle calculation. Once the platform was established the experimental part of the research could start.

The fourth step was to calculate the Degree-days and hours to discover the fundamental energy requirement differences between the three locations using the platform and compare it with the values in Figure 1 that was previously calculated with totally different method (Conradie *et al.*, 2015) Degree-

days are essentially a summation of the differences between the outdoor temperature and a base temperature over a specified time period. A key issue in the application of degree-days is the definition of the base temperature, which, in buildings, relates to the energy balance of the building and systems. This applies to both heating and cooling systems, which leads to the dual concepts of Cooling Degree Days (CDD) and Heating Degree Days (HDD). (CIBSE, 2006). The most rigorous and precise method of calculating degree-days is to sum hourly temperature differences to the base temperature and divide these by 24 (CIBSE TM41, 2006). This method takes the often significant diurnal temperature variation in South Africa into account. Equation 1 was used for the calculation of heating degree days and Equation 2 for cooling degree days.

$$D_h = \frac{\sum_{j=1}^{8760} (\theta_{o,j} - \theta_b)_{((\theta_{o,j} - \theta_b) > 0)}}{24} \quad (1)$$

$$D_c = \frac{\sum_{j=1}^{8760} (\theta_b - \theta_{o,j})_{((\theta_b - \theta_{o,j}) > 0)}}{24} \quad (2)$$

Where:

- $D_h$  is the heating degree-days for a year
- $D_c$  is the cooling degree-days for a year
- $\theta_b$  is the base temperature. 18 °C is used.
- $\theta_{o,j}$  is the outdoor temperature in hour  $j$

In both formulas the subscripts denote that only positive values are taken into account in the relevant calculation. Using a 2005 typical meteorological year weatherfile from *Meteonorm*, the HDH for Upington, Kimberley and Bethlehem are respectively 18888, 25907, 44842 and the CDH for Upington, Kimberley and Bethlehem are respectively 47947, 32241, 11338. These values differ a bit from the values determined from the maps in Figure 1 (Conradie *et al.*, 2015) as these maps already factored climate change. The difference is already indicative of what can be expected with climate change.

The fifth step was to develop an analytical graphical screen to display the temperature/ radiation combinations with solar azimuth on the horizontal axis and elevation above the horizon on the vertical axis. The azimuth is expressed in degrees clockwise from 0° (north). The elevation is expressed in degrees from the horizon to vertical (0° to 90°). This facilitated the study of the annual temperature and radiation distribution and to determine the times when solar protection and shading would be necessary. Four temperature categories were colour mapped on each chart to make the trends more visible:

- Cold (Blue): Drybulb temperature  $\leq$  18 °C
- Comfortable (green): Drybulb temperature  $>$  18 °C and Drybulb temperature  $<$  23.8 °C
- Warm (Magenta): Drybulb temperature  $\geq$  23.8 °C and Global Horizontal Irradiation  $<$  315.5 Wh/m<sup>2</sup>
- Hot (Red): Drybulb temperature  $\geq$  23.8 °C and Global Horizontal Irradiation  $\geq$  315.5 Wh/m<sup>2</sup>

Unlike the Mazria (1979) and the Climate Consultant v6.0 method the new research platform supports a bearing of any angle including due south. The diagram initially only used the 8 760 points from the weather file leading to a very coarse diagram with only hour values. It was therefore decided to create more data points with 15 minute intervals by means of a Lagrange formula for polynomial interpolation (Press *et al.*, 1990). This produced a much larger smoothed dataset of 35 037 points.

Once this was achieved six solar analysis charts were generated for Upington, Kimberley and Bethlehem. Three of the charts are for current climatic conditions and three are for climate change with A2 climate change scenario. To simplify comparison only a northern façade orientation was used.

The sixth and last step was to devise an algorithm to calculate recommended elevation and azimuth angles for horizontal and vertical fixed solar protection devices for the three towns. Various statistical methods were studied and tried. Initially it appeared that histograms might give an indication when solar protection might be required. During testing it was determined that it is rather difficult to determine a recommended solar angle using histograms as climate is a complex mix of cold, comfortable, warm and hot periods. It was decided to use a *K-means clustering* method originally proposed by MacQueen (1967) to cluster the different overheated areas into representative clusters with representative centroids. K-means clustering is an unsupervised learning technique used to automatically partition a given dataset into  $k$  representative clusters/ groups. It proceeds from an initial set of  $k$  clusters that are predefined or programmatically allocated and then iteratively refine them as follows (Wagstaff *et al.*, 2001: 577-578):

- Each data instance  $i$  is assigned to its closest cluster centre.
- Each cluster centre  $j$  is updated to be the centroid of its constituent instances.
- The algorithm converges when there are no further changes in the assignment of instances to clusters.

The general formula can be written as:

$$J = \sum_{j=1}^k \sum_{i=1}^n \|x_i^{(j)} - c_j\|^2 \quad (3)$$

Where:

- $J$  is an objective function.
- $k$  is the number of clusters where  $k$  is predefined.
- $n$  is the number of cases or hot points in the weather file being analysed as defined above.
- $\|x_i^{(j)} - c_j\|^2$  is a function to determine the Euclidian distance between case  $i$  and the centroid for cluster  $j$ .

Seven clusters were used for the elevation and two sets of four clusters each for the azimuth angles, i.e. one set for the morning and one set for the afternoon.

The last step was to determine which elevation and azimuth angles should be protected for a given façade orientation and to draw red lines to indicate the recommended angles. The previous step created a set of cluster centroids numbered E1 to E7 in elevation and A11 to A14 and A21 to A24 in azimuth that are the best representatives of a surrounding set of hot points. There are three types of mean, i.e. arithmetic, geometric and harmonic mean. Initially arithmetic mean was used. However during simulation it was noticed that an outlier centroid tends to distort the calculated average angles significantly. The lesser known Harmonic mean method was therefore used (Formula 4) as this reciprocal form of mean resists outliers more efficiently.

$$H = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \dots + \frac{1}{x_n}} = \frac{n}{\sum_{i=1}^n \frac{1}{x_i}} = \left( \frac{\sum_{i=1}^n x_i^{-1}}{n} \right)^{-1} \quad (4)$$

Where:

- $H$  is the harmonic mean.

$n$  is the number of cluster points (7 has been used for the elevation and two pairs of 4 for the azimuth).  
 $x_1 \dots x_n$  are the elevation and azimuth cluster points used in the various solar angle calculations.

## 4 RESULTS

Table 3 Result of the solar angle calculations for Upington, Kimberley and Bethlehem. The elevation and azimuth solar angles were calculated by means of arithmetic mean (AM) and harmonic mean (HM) averages. The values were also calculated for an A2 climate change scenario by the year 2100.

|                           | BWh (Upington) |                   | BSh (Kimberley) |                   | Cwb (Bethlehem) |                   |
|---------------------------|----------------|-------------------|-----------------|-------------------|-----------------|-------------------|
|                           | 2005           | 2100 <sup>4</sup> | 2005            | 2100 <sup>3</sup> | 2005            | 2100 <sup>3</sup> |
| Elevation (Degrees) (AM)  | 62.9°          | 62.9°             | 64.1°           | 63.1°             | 67.5°           | 64.1°             |
| Azimuth 1 (Degrees) (AM)  | 57.3°          | 64.4              | 65.7            | 50.9°             | n/a             | 55.2°             |
| Azimuth 2 (Degrees) (AM)  | 291.1°         | 297.3             | 289.3°          | 296.5°            | 295.4°          | 291.2°            |
| Elevation (Degrees) (HM)  | 61.7°          | 61.7°             | 63°             | 61.9°             | 66.5°           | 63°               |
| Azimuth 1 (Degrees) (HM)  | 54.3°          | 61.1°             | 63.2°           | 46.6°             | n/a             | 49.3°             |
| Azimuth 2 (Degrees) (HM)  | 287.2°         | 292.1°            | 285.4°          | 291.4°            | 287.3°          | 287°              |
| Heating Degree Hours      | 18 888         | 10 045            | 25 907          | 12 656            | 44 842          | 18 000            |
| Cooling Degree Hours      | 47 947         | 70 365            | 32 241          | 55 915            | 11 338          | 35 433            |
| Daylight hours on surface | 3 918.25       | 3 918.00          | 3 929.00        | 3 930.00          | 3 913.00        | 3 913.75          |

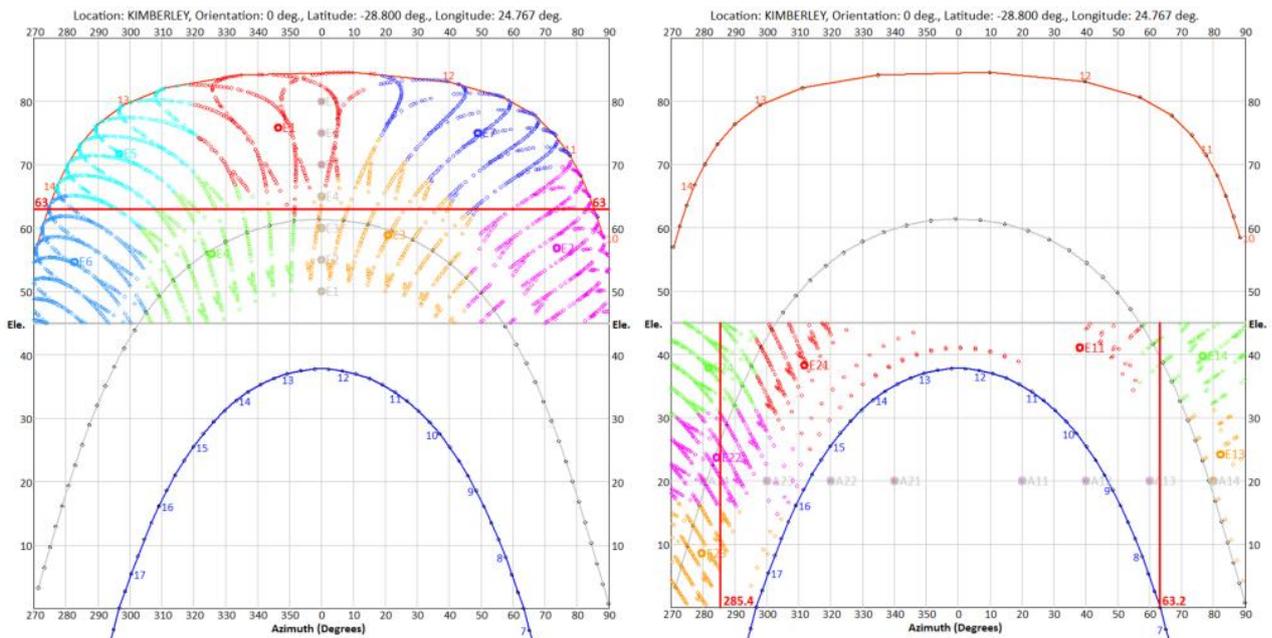


Figure 6 The recommended elevation and set of azimuth solar protection angles for Kimberley calculated with the experimental research platform analysis by means of K-means clustering and the application of harmonic mean to determine the final recommended angles.

## 5 CONCLUSIONS AND FURTHER RESEARCH

The research indicated the importance of appropriate solar protection within the predominantly hot South African climatic zones. A bioclimatic analysis indicates that all the South African climatic zones still have a very high passive design potential. This will reduce with climate change, however solar protection will continue to remain the single most important measure.

<sup>4</sup> A weather file with an A2 climate change scenario as defined by the IPCC (2000) has been used to calculate these values.

It is possible to calculate solar position angles very accurately. In this research the author's algorithms were compared with the most accurate solar position algorithm currently available. On the other hand weather files are not yet that accurate due to many technical reasons. However the accuracy and specialization of weather files are currently rapidly increasing with better remote sensing and advanced statistical methods being applied. Weather files are increasingly required for many different types of specialized energy simulation applications beyond just the typical meteorological year applications that do not take account of extreme conditions that could potentially have a devastating effect on structures.

The research indicated that it is possible to quantify and recommend solar protection angles for the different facades of a building turned at any bearing for both elevation and azimuth dominated solar angles. These calculated angles vary significantly between different climatic regions and altitudes as indicated by an analysis of Uppington, Kimberley and Bethlehem that are all on almost the same latitude. Climate change will have a very significant impact on the recommended solar protection angles and significantly more shading will be required. Climate change will also significantly change the amount of heating and cooling degree hours.

The unsupervised K-means clustering algorithm used in the prototype research platform was able to recommend solar angles in combination with a harmonic mean average calculation. Further research would have to be undertaken to make the algorithm more efficient as a significant amount of processing time is currently required. A comparison between the arithmetic and harmonic mean method of calculating the solar protection angles indicated that the latter is less sensitive to outlier values and therefore gives a more appropriate mean.

For the first time an early design stage platform is now able to correctly draw solar shading charts for any bearing and location within the tropics even close to the equator.

## ACKNOWLEDGEMENTS

The financial support of CSIR, Built Environment Unit and the support of CSIR to test the fundamental concepts in two projects, i.e. the Hillside clinic project in Beaufort West (Coralie van Reenen) and a proposed science centre in Cofimvaba (Llewellyn van Wyk and Jan-Hendrik Grobler)

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## Sanitation options for sustainable housing: A decision making tool

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### ABSTRACT

There is increasing pressure on water and sanitation systems in South African human settlements. Droughts have reduced water availability in many areas. Ageing infrastructure and a lack of maintenance have contributed to water supplies being unreliable in some regions. Water and sewage disposal costs have also escalated over the last five years particularly in water scarce areas such as Cape Town. Scarce, expensive and unreliable water supplies make waterborne sanitation problematic. There are also problems associated other widely applied sanitation types such as pit toilets which can contaminate ground water and cause diseases like cholera. It is therefore important to re-evaluate water and sanitation systems in human settlements to ascertain whether these are responsive to changing local conditions related to water supply, climate change and social and economic dynamics. The Sanitation Options for Sustainable Housing (SOSH) is a tool that assesses alignment between local environmental, economic and social characteristics of a human settlement and sanitation options. The paper presents the SOSH and applies it in case studies in order to critically evaluate the tool. The study concludes that the SOSH shows potential as a support tool for making decisions about sanitation options in human settlements and recommends further development.

Keywords: Sanitation, sustainable housing, Decision making tool, SOSH

### 1 INTRODUCTION

Water and sanitation systems in South African human settlements are under stress. Municipalities are finding it difficult to adequately service rapidly growing urban areas such as new townships and informal settlements and infrastructure backlogs are increasing. In addition, existing water and sanitation infrastructure is ageing and limited resources and capacity have affected maintenance and upgrade programmes.

Climate change is making this situation worse by increasing the occurrence of droughts and extreme weather events such as flooding. In addressing backlogs it is therefore important to identify water and sanitation systems that address current and emerging needs in human settlements. These needs include a requirement for systems that are a) more water efficient, b) sustainable and c) can be implemented and maintained within the existing capacity and resource restraints of local councils and communities.

This study investigates sanitation options within this context and consists of the following steps. Firstly, it undertakes a literature review to define key criteria which can be used to evaluate human settlements in relation to sanitation in South Africa. Secondly, it describes the main sanitation types available in South Africa, as well as less commonly applied solutions. Thirdly, criteria identified for human settlements (above), are used to evaluate the sanitation types identified (above). Fourthly the results of this evaluation are discussed and conclusions and recommendations developed. The study therefore addresses the following questions:

- What are the key characteristics of human settlements that should be taken into account in selecting sanitation solutions for sustainable housing in South Africa?
- What sanitation options can be applied to human settlements in South Africa? What are the characteristics of these sanitation options?
- Can a framework be developed that assesses alignment between human settlement characteristics and sanitation requirements in order to ensure there is a good 'fit' between these two?

## 2 CHARACTERISTICS OF HUMAN SETTLEMENTS AND SANITATION

Identifying characteristics of human settlements that are important for the selection of sanitation systems is undertaken through a review of sanitation in relation to health and human development goals, such as the Sustainable Development Goals. This is followed by a review of housing and informal settlements in order to identify key characteristics. Finally, climate change impacts which will affect sanitation in South Africa are reviewed.

### 2.1 HEALTH AND SANITATION

Poor sanitation has been linked to ill-health and the outbreak of disease (Jasper *et al.*, 2012; Cheng and Hong, 2004). Cholera outbreaks have been linked to poor sanitation and 90% of diarrheal disease has been attributed to unsafe sanitation, water and hygiene (Gundry *et al.*, 2004; Isunju *et al.*, 2011). The Global Burden of Disease study by the World Bank indicates that 15% of children's death in low and middle income countries are due to diarrheal disease (Isunju *et al.*, 2011). Cholera outbreaks have a devastating impact on health and local economies and have been recorded recently in Zimbabwe (September, 2018), the Congo (March, 2018), Mozambique (February, 2018), Tanzania (January, 2018), Kenya (December, 2017) and Zambia (December, 2017) (WHO, 2018).

### 2.2 HOUSING, WATER AND SANITATION GOALS

The Sustainable Development Goals include goals which aim to improve health and living conditions through the elimination of people living in slums and universal access to safe drinking water and sanitation by 2030. A review of progress in terms of these goals however indicates that these goals may not be achieved in African countries. The number of people living in slums is projected to double in Africa and access to safe sanitation is only projected to improve marginally from 68% in 2015 to 75% in 2030 (Nicolai *et al.*, 2015).

South Africa has made significant progress in terms of a number of SDG targets but rapid urbanization has meant that backlogs are growing. Housing backlogs in 1994 were estimated to be 1.5 million, by 2011 these were 1.9 million and in 2017 these were estimated to be 2.3 million (Wilkinson, 2014; Msindo, 2018).

In 2017, the proportion of the population living in slums (referred to as informal settlements in South Africa) was 13.7% (Statistics South Africa, 2018). About 1,755,000 households (about 3% of the population) did not have access to a water supply in 2017, 14% of households did not have an electricity connection and about 17% had substandard sanitation (Statistics South Africa, 2018).

### 2.3 HUMAN SETTLEMENTS

Sanitation backlogs are predominantly in rapidly developing urban areas and in particular in informal settlements. It is therefore important to understand the nature of these settlements in order to identify key characteristics that may be used to select sanitation systems. The UN defines informal settlement households as:

*A group of individuals living under the same roof lacking one or more of the following conditions: access to improved water, access to improved sanitation, sufficient living area, and durability of housing* (SDG Tracker, 2018)

Local definitions tend to emphasize illegal, unplanned and makeshift characteristics. For instance, definitions by Statistics South Africa distinguish between informal settlements and informal dwellings, as follows:

*(Informal settlement is)... an unplanned settlement on land which has not been surveyed or proclaimed as residential. Consisting of mainly informal dwellings (shacks). Informal dwelling is a makeshift structure not approved by a local authority and not intended as a permanent dwelling* (Statistics South Africa, 2004)

This distinction is important as Statistics South Africa point out that although there has been a decrease in the proportion of the urban population living in informal settlements from 17% in 2002 to 11% in 2014, the number of people living in informal dwellings decreased slightly from 13.6% to 13.1%. This is

attributed to increases in the number of people erecting and living in informal dwellings in the backyards of existing dwellings (Statistics South Africa, 2018a)

The definition of informal settlement in the South Africa's National Housing Code's Informal Settlement Upgrading Programme emphasizes issues related to investment and stress by referring to the following characteristics:

- Illegality and informality;
- Inappropriate locations;
- Restricted public and private sector investment;
- Poverty and vulnerability;
- Social stress (National Department of Housing, 2004)

International literature characterize slum settlements as areas with high poverty, a lack of space, services and infrastructure, no tenure and a predominately informal economy. Slum settlements are attributed to a failure by government to enforce building regulations and provide services such as water and sanitation resulting in placing occupants at a higher risk of "disease, mortality and misfortune" (Isunju *et al.*, 2018).

## 2.4 CLIMATE CHANGE

Climate change will have significant impacts on human settlements and sanitation in South Africa. Climate change projections have been developed for a range of scenarios. Projections for a low mitigation scenario (RCP 8.5) are outlined below. Representative Concentration Pathways (RCPs) are defined according to their contribution to atmospheric radiative forcing in the year 2100 relative to pre-industrial values. A RCP 8.5 therefore represents the addition to the earth's radiation budget as a result of an increase in GHGs of  $+8.5 \text{ W/m}^2$  (Gibberd, 2018). Under this scenario the following projected changes include:

- **Higher temperatures:** Temperature increases of 1 to 3°C are projected for the period 2021 to 2050, relative to temperatures in the period 1961 – 1990.
- **Very hot days:** An increase in very hot days is predicted for the period 2021 – 2050, relative to 1961 – 1990.
- **Changes in rainfall:** Annual rainfall increases are projected in the central interior and east coast, while reductions are expected in the western interior and the north-eastern parts of South Africa during the period 2021-2050, relative to 1971 – 2000.
- **Extreme rainfall events:** Extreme rainfall events are predicted to increase in frequency in the central interior and east coast for the period 2021-2050, relative to 1961 – 2000. Extreme rainfall events are likely to result in increased risk of flooding (Engelbrecht, 2017).

Of particular relevance to sanitation, are the projected increases in the severity and frequency of droughts (Makki *et al.*, 2015). Drought has already contributed to water shortages in many towns and in 2014 the National Water Resource strategy estimated that that 30% of South Africa's towns were in water deficit. The strategy also projected an additional 25% of towns would also be in water deficit within the in the next 10 years (Department of Water Affairs, 2013). Water shortages have led to rapid tariff increases. Cape Town, for instance, has increased the cost of water by more than 50% over the period 2016 to 2018 as a result of drought conditions (Groundup, 2018). This can significantly increase the financial burden on poor households that are reliant on water-borne sanitation.

The conservation of water has, therefore, become a key objective of many municipalities (Dolnicar *et al.*, 2012). This has led to an increasing emphasis on reducing water consumption in human settlements and housing (Willis *et al.*, 2013). Lower water consumption also has a range of benefits including:

- Deferment or avoidance of supply expansion options such as dams and desalination plants
- Deferment or avoidance of wastewater treatments plants
- Reduce energy requirements to power water supply and wastewater treatment infrastructure
- Reduce energy requirements to heat water, as less water is used, within domestic situations (Willis *et al.*, 2013)

## 2.5 IDENTIFIED CRITERIA

The above review can be used to identify criteria which can be applied to help select the most appropriate sanitation type for a particular human settlement. These criteria are outlined in table 1. Questions and indicators are outlined against each criteria, in order to provide greater clarity and detail on the criteria.

Table 1 Key settlement characteristics, questions and indicators for the selection of sanitation

| <b>Criteria</b>                                                                | <b>Questions</b>                                                                                                                                                                     | <b>Indicators</b>                                                                                                                                                              |
|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Permanence                                                                     | Will the settlement be there in the long term?                                                                                                                                       | Formal right to occupy the land<br>Formal approved development plans for the settlement<br>Commitment by the municipality to provide services / some services already in place |
| Density                                                                        | How dense is the settlement?<br>How does the density restrict the type of sanitation that can be used?                                                                               | People per ha<br>Dwellings per ha                                                                                                                                              |
| Water supply                                                                   | Is there access to water?<br>How may the characteristics of the local water supply affect sanitation choices?<br>Will climate change, or other factors, affect local water supplies? | Type of water supply<br>Reliability of water supply<br>Water and sanitation costs (R/kl)<br>Climate change projections                                                         |
| Availability of organic material                                               | Is waste organic material available locally?                                                                                                                                         | Availability of organic material                                                                                                                                               |
| Ground water and flooding                                                      | Is the area prone to flooding?<br>Will the characteristics of groundwater and flooding affect sanitation choices?                                                                    | Flood diagrams and studies<br>Groundwater studies<br>Climate change projections                                                                                                |
| Cultural and social mores of occupants                                         | Are there cultural and social issues that will affect the type of sanitation that can be used?                                                                                       | Cultural and social mores related to sanitation                                                                                                                                |
| Municipal / local management capacity to develop and manage sanitation systems | Is there capacity and resources within the local municipality or within local community structures to develop and manage local sanitation systems?                                   | Capacity within the municipality or within a local organizational structure that is dedicated to the development and management of the sanitation system                       |
| Capital available for sanitation systems                                       | What level of funding is available for the construction of sanitation?<br>Are there alternative development methods that can                                                         | Household / user funding available for the development of the sanitation system<br>Municipal / organizational funding available for the                                        |

|                                                        |                                                                     |                                                                               |
|--------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------------------------------|
|                                                        | be used to achieve the sanitation, such as self-build?              | development of the sanitation system                                          |
| Ongoing funding available to operate sanitation system | What level of funding is available for the operation of sanitation? | Household / user funding available for the operation of the sanitation system |

### 3 SANITATION TYPES

Sanitation systems currently found in housing in South Africa include flush toilets connected to mains sewage, flush toilets linked to septic tanks, flush toilets linked to conservancy tanks, pit latrines and ventilated pit latrines. Internationally, a range of other toilet and sanitation systems have been applied which may be suitable for South Africa. A selection of these sanitation types with their requirements are outlined in table 2.

#### 3.1 SANITATION TYPE DESCRIPTION AND REQUIREMENTS

Table 2 Sanitation types

| Sanitation types                                                     | Description                                                                                                                                                                                                                                                                                                                                  | Requirements                                                                                                                                                                                           |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Flush toilet and mains sewage                                        | This sanitation system consists of a toilet where water is used to flush excreta into a sewer system. Sewage is then treated in a central sewage plant.                                                                                                                                                                                      | Piped water supply<br>Connection to mains sewage<br>Capacity within local sewage plant to take additional load                                                                                         |
| Flush toilet and onsite septic tanks                                 | Water in this system is used to flush excreta into an onsite septic tank instead of a mains sewer. Within the tanks, settling and anaerobic processes reduce solids and organic material and treated liquid effluent then flows to a septic drain field. Faecal sludge accumulates in the septic tank and must also be removed periodically. | Piped water supply<br>Space onsite for septic tank<br>Faecal sludge must be cleared periodically<br>Care must be taken that treated liquid flowing from septic tanks does not contaminate ground water |
| Flush toilet and onsite conservancy tank                             | Water in this system is used to flush excreta into an onsite conservancy tank. This is a watertight tank that is emptied when full. This is usually done by a municipal or private tanker or "honey sucker".                                                                                                                                 | Piped water supply<br>Space onsite for conservancy tank<br>Access for tank to be emptied must be possible                                                                                              |
| Flush toilet and neighbourhood biological wastewater treatment plant | Excreta is flushed into sewer that flows to a local biological wastewater treatment plant. This local treatment plant uses trickle filters, microorganisms, anaerobic digestion and a disinfection process to produce water that can be reused. This                                                                                         | Piped water supply<br>Capacity to maintain and manage local plant<br>Space for local treatment plant                                                                                                   |

|                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | water can be used for irrigation.                                                                                                                                                                                                                                                                                                       |
| Aqua Privy                           | Aqua-privies consist of a latrine connected with a vertical pipe to a watertight tank immediately under it. Excreta drops down this pipe into the water and as the bottom of the pipe is submerged a water seal is created, preventing smells. Treated effluent from this tank is directed to septic tank or conservancy tank.                                                                                                                                                                      | Sufficient water to maintain water seal<br>Space onsite for conservancy or septic tank<br>Access for tank to be emptied must be possible                                                                                                                                                                                                |
| Pour flush                           | In the pour flush system excreta is flushed by pouring water down a latrine into a pit. A water seal between the latrine and pit avoids smells. From the pit, treated effluent is then directed to a septic or conservancy tank                                                                                                                                                                                                                                                                     | Sufficient water to flush toilet and maintain water seal<br>Space onsite for conservancy or septic tank<br>Access for tank to be emptied must be possible                                                                                                                                                                               |
| Ventilated Pit Latrine               | In this system, excreta drops into a pit directly underneath the latrine. A ventilation pipe into the pit aims to reduce smells and flies. The pit is either emptied and reused when full, or filled in and the latrine and top structure moved and located over a new pit.                                                                                                                                                                                                                         | The area around the toilet cannot have a high water table or be flooded as this results in the risk that the contents of the pit contaminate ground water.<br>Access for pit to be emptied must be possible                                                                                                                             |
| Composting Toilet – Offsite Disposal | In offsite disposal composting toilets excreta drop into a 20-120 l container where it is combined with other organic matter to form compost. The container is located directly under the latrine. Organic matter added can be kitchen waste, sawdust, garden or farm waste. Smaller mobile containers are used which are emptied in an offsite composting location. After the composting period (6-12months) compost at the offsite location can be used as fertilizer on planting beds and trees. | Organic matter, such as kitchen waste, saw dust, garden and farm waste is required for the composting process.<br>Capacity and a transportation system that removes and replaces mobile containers from latrines is required<br>A central composting location is required.<br>Locations, such planting beds, where compost can be used. |
| Composting Toilet – Onsite Disposal  | In onsite composting toilets excreta drop into a 20 – 1,000l container where it is combined with other organic matter to form compost. The container is located directly under the latrine. The organic matter can                                                                                                                                                                                                                                                                                  | Organic matter, such as kitchen waste, saw dust, garden and farm waste required for composting process.                                                                                                                                                                                                                                 |

|                                                                                                                                                                                                                                                        |                                                                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| be kitchen waste, sawdust, garden or farm waste.<br>Composting occurs within the container or at an onsite composting location. After the composting period (6-12months) the composting material can be used as fertilizer on planting beds and trees. | Capacity to empty composting toilet<br>Onsite space for composting process<br>Planting beds that can be fertilized.<br>Locations, such planting beds, where compost can be used. |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

#### 4 SANITATION OPTIONS FOR SUSTAINABLE HOUSING (SOSH)

The data in tables 1 and 2 can be used to develop a simple framework that can be used to evaluate alignment between settlements and sanitation options. The simple framework is called the Sanitation Options for Sustainable Housing (SOSH) and is shown in figure 1 and consists of 4 main parts which are explained below.

- Sanitation types: These are the sanitation types listed and described in table 2.
- Settlement criteria: These are the settlement criteria listed in table 1. For each criteria, such as 'Water availability', sub-criteria are provided, such as 'No water available on site', 'Very limited water available on site' and 'Piped water available on site'. These are used to describe the conditions on site, or at the housing, in relation to that particular criterion.
- Sanitation requirements: This lists sanitation criteria and requirements as well as sub criteria. For instance, criteria 'Water requirements of sanitation' has the following sub criteria 'Suitable for use in area with no water', 'Suitable for use in area with very little water' and 'Suitable for area with plentiful supply of water'. These are used to describe the requirements of the different types of sanitation in relation to the particular criterion.
- Alignment matrix: The alignment matrix is used to establish alignment between the settlement and the sanitation types. Settlements can be assessed using the settlement criteria (2) and the most appropriate sub criteria indicated in brown in the 'settlement' column. The brown square can then be compared with the green shapes in the Alignment matrix (4) to establish alignment. Alignment occurs when both brown and green colours are indicated and this generates a score of '1', which is carried down to the bottom. A lack of alignment is reflected as a score of '0'. The scores at the bottom of the alignment matrix can then be reviewed to ascertain alignment between sanitation types and the settlement.

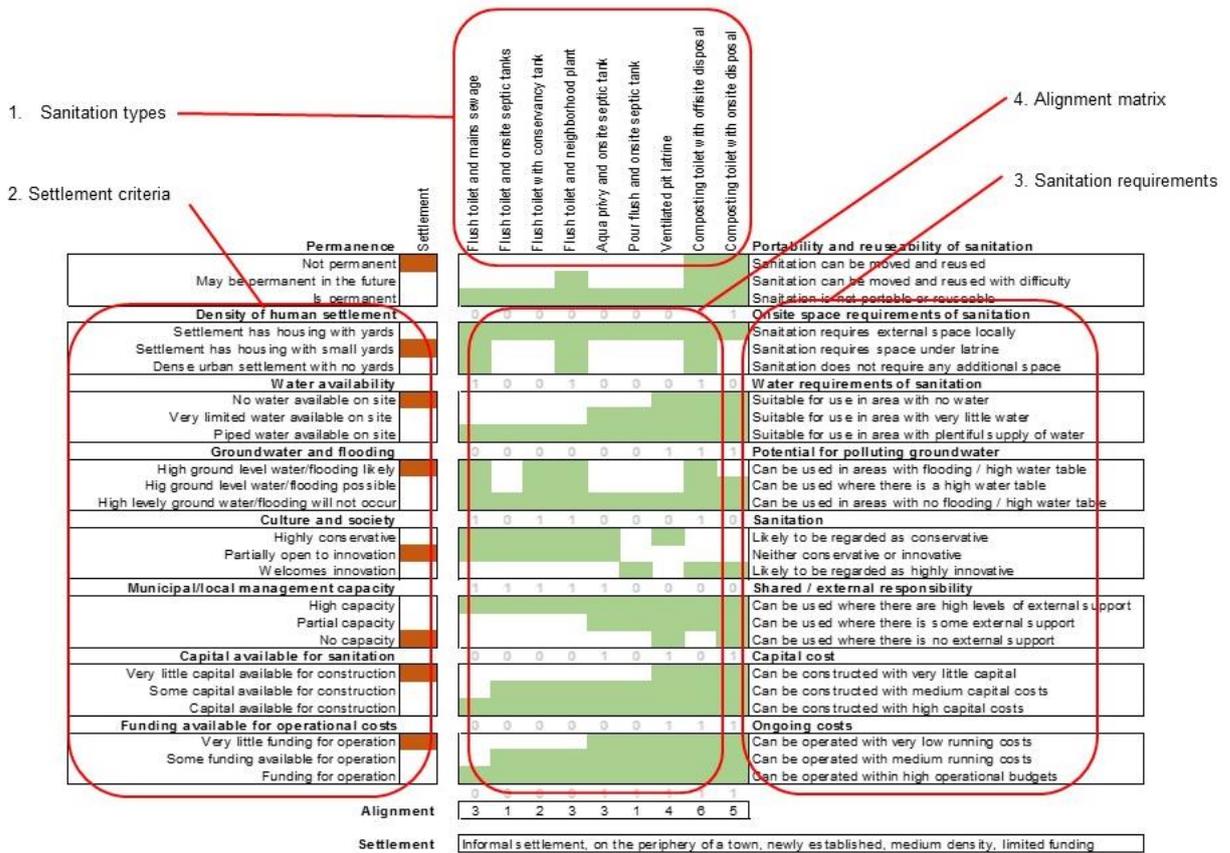


Figure 1 Sanitation Options for Sustainable Housing (Larger diagrams show in figure 2 and 3)

## 5 APPLICATION OF THE SANITATION OPTIONS FOR SUSTAINABLE HOUSING (SOSH)

To test the SOSH, it is applied to two types of human settlement that occur in South Africa towns and cities. The first is a temporary informal settlement on the periphery of the town and the results are shown in figure 2. The second application, is dense student housing on a campus location in a central urban location. The results of this application are shown in figure 3.



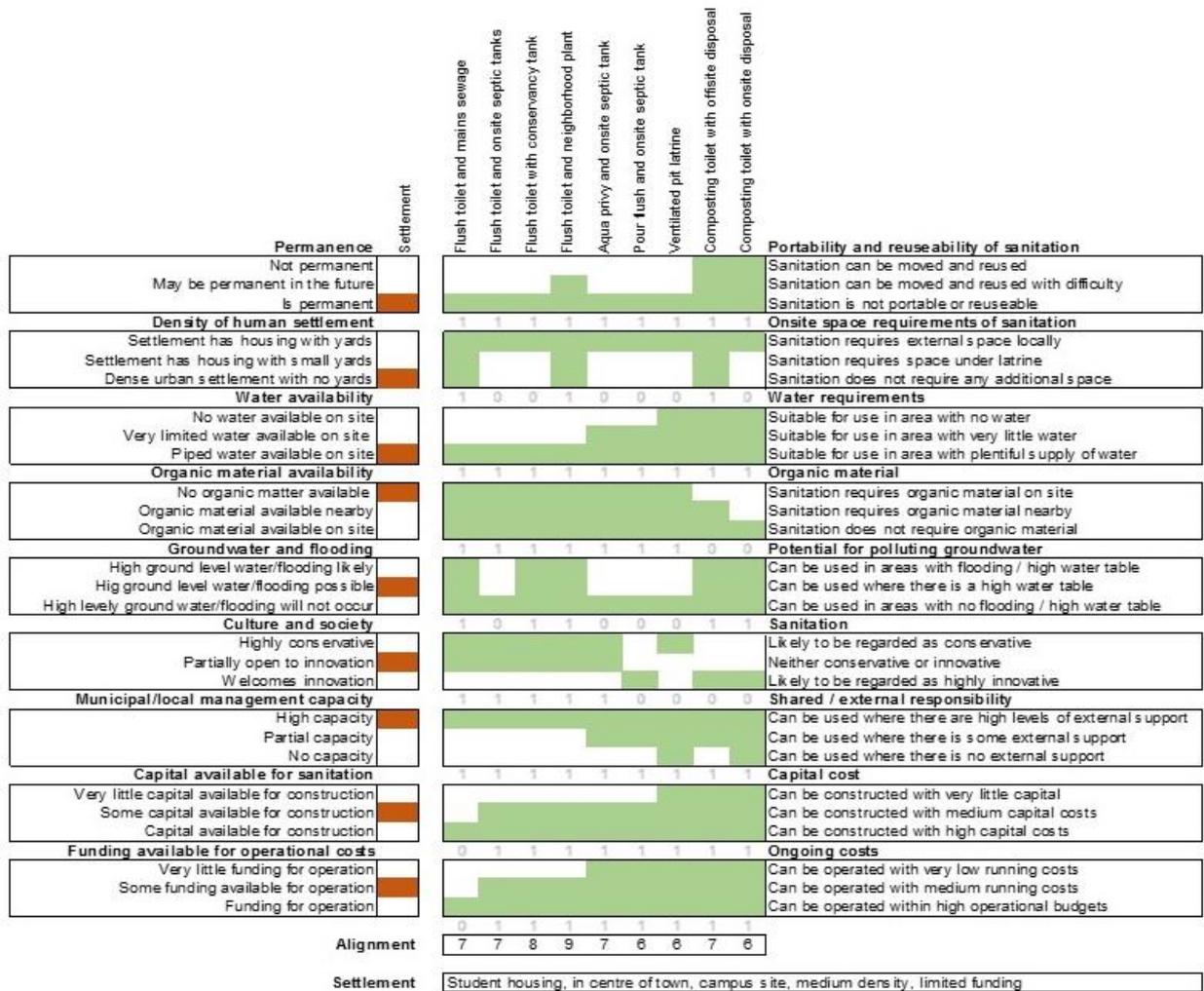


Figure 3 Sanitation Options for Sustainable Housing: Student housing

## 6 RESULTS

The application of the SOSH to the informal settlement indicates that a) composting toilets with offsite disposal and b) composting toilets with onsite disposal have the strongest alignment with the human settlement characteristics and have an alignment score of 7. Other options have a much weaker alignment and a) flush toilet and mains sanitation, b) flush toilets and neighbourhood plant, c) ventilated pit latrines have an alignment score of 4.

The application of the SOSH to the temporary informal settlement captures a number of important characteristics of the settlement including a) the settlement may not be permanent, b) there is very limited capacity to develop and manage sanitation, and c) there is very limited finance for the development and operation of toilets. In this case, the most aligned type, composting toilets, is probably the most appropriate sanitation type. This finding, however assumes that the sanitation type will be acceptable to occupants, which may not be the case.

Application of the SOSH to student housing indicates that a) flush toilets with a neighbourhood treatment plant has the strongest alignment with an alignment score 9. This is followed by b) flush toilets with a conservancy tank with an alignment score of 7.

Here, the SOSH captures important local characteristics of the settlement, such as a) the density b) the capacity to develop and manage sanitation systems and c) the limited availability of operational funding. These characteristics result in the SOSH indicating that the best alignment is with flush toilets with a

neighbourhood plant. This is a surprising result, as one would expect a flush toilet linked to mains sewage to have the strongest alignment. However, further analysis, suggests that flush toilets with a neighbourhood plant could be the most appropriate solution. This is because this system could be managed by strong onsite management (which can be created in a well-run university or higher education institution) and the site benefits from treated water that can be used for irrigation. Operating costs can therefore be reduced by minimizing costs associated with municipal water and sewage charges.

## **7 DISCUSSION**

The results indicate that the SOSH could provide valuable guidance that can be used to determine the most appropriate sanitation systems for human settlements. However, the current framework has a number of deficiencies that should be addressed. These are outlined below.

### **PERMANENCE**

The framework does not provide a specific timeframe in relation to the 'Permanence' criteria. This therefore could result in subjective judgements. However, this can be addressed through reference the 'Permanence' indicators (see table 1) such as formal rights to occupy and develop the land, which can be used to ensure objective measurement of this aspect.

### **DENSITY**

The SOSH density indicators could be improved by providing more detailed quantitative definitions of density. These could help ensure that aspects such as multi-story high-rise development were captured and reflected better in the tool, as the characteristics of these type of developments have significant implications for the choice of sanitation.

### **SOCIAL AND CULTURAL MORES**

Assessment of the culture and society characteristics in the SOSH is likely to be subjective and reference to the indicators in table 1 do not support a rigorous evaluation. This area therefore could be improved. However, it should be noted that assessments in this field are difficult, particular where there are diverse populations. For instance, the acceptability of different sanitation types such as ventilation pit latrines and composting toilets is likely to vary widely depending on the age and background of users.

### **MUNICIPAL AND LOCAL MANAGEMENT CAPACITY**

Greater clarity should be provided on the 'municipal/local management capacity' criteria. Reference here to table 1 is useful as it describes the type of capacity required. However, assessing the capacity within a community or an organization to manage local sanitation is complex. Therefore the value of the SOSH could be to hi-light local management as an option, but not to rigorously measure or assess whether this capacity is sufficient. Local sanitation systems are particularly valuable where their by-products can be used locally. For instance, in the student housing example, treated water that can be used for irrigation may be of considerable value in maintaining sports grounds or planted landscapes on a campus site. In these cases, it may be worth developing local management capacity, if it is not already in existence.

### **CAPITAL AND OPERATING COSTS**

No quantitative definitions of capital and operating costs are provided in the SOSH. This again could lead to subjective assessments. This could be addressed by defining capital and operating costs as a percentage of household expenditure. This could provide a clear cost ceiling that sanitation systems would have to meet.

### **A DECISION SUPPORT TOOL**

Despite these shortcomings, the SOSH appears to be an effective tool for supporting the selection of appropriate sanitation for human settlements for the following reasons.

Firstly, the tool encourages a re-evaluation of flush toilets and pit latrine sanitation. This is important as significant problems are associated with these systems. These include large-scale consumption of water and high operating costs (flush toilets) and groundwater contamination and disease (pit latrines).

These problems are likely to become worse with increasing urbanisation and the intensification of climate change.

Secondly, the tool encourages the evaluation of settlements in terms of characteristics such as permanence and social and cultural mores, as a prerequisite for the selection of sanitation. This evaluation could help avoid large-scale investment on sanitation systems that will not be used or will be rejected.

Thirdly, the tool encourages an evaluation of local sanitation management capacity. This is important in ensuring that sanitation systems operate safely in the long term. Where it is likely that municipal systems will not meet local demands for sanitation, the SOSH indicates that sanitation management could happen at a household level or at a community level through local organisation structures such as a Community-based Water Trusts (Water and Sanitation for the Urban Poor, 2018).

Fourthly, the SOSH, introduces a range of sanitation systems that decision makers may not be aware of. These include flush toilets with local sewage treatment which provide a valuable local supply of water that can be used for irrigation; composting toilets, that do not require water and provide valuable fertiliser; and low-water use systems such as aqua-privies. Given, the increasing pressure on water supply and importance of biodiversity and food security it is important these alternatives are considered.

## **8 CONCLUSION**

The study identifies and develops human settlement criteria that are important for the selection of sanitation types. These criteria include the permanence of the human settlement, the density of the human settlement, the availability of water, the availability of organic material, the likelihood of flooding, the level of the ground water table, cultural and social mores, sanitation management capacity, the availability of funding to develop sanitation systems and the availability of funding to operate sanitation systems. The study also identifies a range of sanitation types, such as flush toilets linked to mains sewage, ventilated pit latrines and composting toilets that may be applied to human settlements. For each sanitation type key requirements and characteristics are ascertained.

The Sanitation Options for Sustainable Housing (SOSH) combines human settlement criteria and sanitation characteristics in a matrix which can be used to assess alignment and identify the most suitable sanitation type. Applying the SOSH to an informal settlement and to student housing indicates that unconventional sanitation types such as composting toilets and flush toilets linked to a local sewage plant may align better with the characteristics of these settlements than conventional sanitation types such as ventilated pit latrines and flush toilets linked to mains sewage.

The results question the current sanitation design paradigm which has a rigid focus on conventional sanitation. The approach indicates that a more flexible approach that responds to local circumstances may be valuable. In particular, this approach can help ensure that sanitation systems supports more sustainable housing by supporting the selection of sanitation that does not entail large-scale consumption of water or lead to groundwater contamination and disease.

## **ACKNOWLEDGEMENTS**

This work is based on the research supported in part by the National Research Foundation of South Africa (Grant Numbers 103996). A critical review of the paper and useful comments by Louiza Duncker are also acknowledged.

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## Pointing innovative building technologies path through learnt experiences for sustainable human settlements development: a case study of Thembelihle Manyano project in the Eastern Cape Province

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### ABSTRACT

Eastern Cape Province continues to embrace the use of Innovative Building Technologies (IBT) in human settlements development. Nevertheless, the knowledge on the implementation process of IBT projects has never been sufficiently extracted and preserved. This paper, utilising both a critical review of documents and validation of data through interview, evaluates Thembelihle Manyano IBT project to determine systemic factors that both enabled and hindered its successful implementation. The paper utilising evaluation theory traces the theory of change in technology transfer and uptake. Therefore, systematically evaluates the selected IBT project to inform policy and procedure review for expedited uptake of IBT in the housing segment of human settlements environment. The paper further recommends policy direction and areas of integration promoting green development agenda through the use of innovative building technologies for sustainable human settlements development.

Keywords: Innovation, building, technologies, green development, infrastructure, policies, regulations, beneficiaries, subsidies, procurement, inspection, skills

### 1 INTRODUCTION

In September 2000, the leaders and representatives of 189 countries met to lay down tangible goals to combat poverty throughout the world. At the summit, the leaders agreed to adopt the Millennium Development Goals (MDGs) which set out eight key areas to be achieved by 2015, using 1990 as the baseline year (UN-HABITAT, 2003; Samari, 2010). The MDG were later improved to Sustainable Development goals (SDG). Goal 11 of the SDG aims to make cities and human settlements inclusive, safe, resilient and sustainable (Hsu, Parnell and Rodriguez, 2014). The SDG according to Hsu *et al.*, (2014), is a huge and complex domain in which states are one of many actors alongside the private sector. Furthermore, 'the current framing of goal 11 is reported broad and speaks to all dimensions of sustainable development. Such an inclusive approach is appropriate as human settlements have been shown to be pathways to social, economic and environmental development. Hsu *et al.* (2014), claims that goal 11 entails much more than the spacial concentration in cities and towns of actions across all other goals. The goal demands multi sectoral, multi scale, and multi actor planning, implementation, enforcement and innovation to ensure that human settlements becomes sustainable development pathways with regional and global impacts. The leaders also pledged to establish a wide-ranging global partnership for development that would engage the private sector and civil society organizations, and make the benefit of new technologies available to everyone so as to achieve these universal objectives (Samari, 2010).

Against this background, South Africa since considered the use of innovative building technologies (IBT) in construction of low cost housing for the poor (Sokopo, 2010). Tshivhasa (2014) defined innovative building technology as any expertise, skill, knowledge, equipment, machinery or tools other than conventional ones meant to accelerate the delivery of housing without compromising quality and durability of any erected structure. According to Agrément SA definition, non-standardised construction products, systems, materials, components and processes which are not fully covered by the South African Bureau of Standards falls under the scope of IBT. This definition was also adopted by the National Home Builders Registration Council (NHBC). The broader aim of introducing IBT was to curb the housing backlog by increasing the number of units delivered per annum.

It is evident that only conventional methods used in housing construction were not sufficient to resolve the backlog facing the country. There are also allegations that IBTs are not only fast methods for housing construction, but also bears environmental benefits which include reduction of carbon emission. The latter is known to contribute to the global concern of climate change. Roets and Ramraj (2010) further recognised the durability, cost effective and a long term economic and environmental benefits of IBT. These authors believe that IBT, with specific focus to polymer products could assist in facilitating enterprise development and associated job creation. This paper reviews project documents with specific focus on what was theory of change underpinning the project, and what were the successes and failures at various stages of the underpinning project theory of change. Some elements of analysis included project inputs, activities, output and outcome. Each element was logically framed and documents were analysed in line with frame reference to trace success and failures, and draw lessons learnt from the implementation of the project. The study identified several grey areas that require attention when projects of this calibre are implemented. The project lacked strong theory of change at design stage, also in the implementation there was a gap that negatively affected the beneficiaries' choice of IBT compared to conventional methods. This clearly confirmed the weakness of the underlying theory of change for the project. The lesson drawn from this paper include that the purpose for each logical stage of the theory of change for a project should be satisfied. All actors at each logical stage should be actively engaged to play their part towards the attainment of the key targets of activities within the project. Lessons learnt in this paper are vital for guidance in the process of project design, policy development and programme design.

## 2 LITERATURE REVIEW

Globally, construction employs more people than any other industrial sector and 98% of construction enterprises are Small, Medium And Micro Enterprises (SMMEs), thus key to economic growth (van Wyk, 2010). The South African construction industry in view of van Wyk (2010), faces significant challenges to enhance its role as a catalyst for growth. Among the main pressure areas, it faces are depletion of resources, increased competition by international enterprises, and the growing demand for increased efficiency. Henceforth, as the world becomes more environmentally aware, the drive towards eco-friendly materials and products has gained momentum. Rajesh (2010) believes that it is essential to rethink the materials used on a daily basis for packaging, building and manufacturing, so that when these materials reach the end of their life cycle, they would simply be absorbed back into the earth in a way that would not harm the environment.

The UN Habitat, (2014) Human Rights Fact Sheet, compiled by the Office of the United Nations High Commissioner for Human Rights spelled out that, '*international human rights law recognises everyone's right to an adequate standard of living, including adequate housing*'. The Fact Sheet further revealed that, 'millions around the world live in life or health threatening conditions, in overcrowded slums and informal settlements, or in other conditions which do not uphold their human rights and their dignity. The United Nation's Committee on Economic, Social and Cultural Rights (UNCESCR) has underlined that the right to adequate housing should not be interpreted narrowly. Rather, it should be seen as the right to live somewhere in security, peace and dignity. Human rights to adequate housing is the right of every woman, man, youth and child to gain and sustain a safe and secure home and community in which to live in peace and dignity (United Nations, 2012).

According to Radebe, (2013), the current government of the African National Congress inherited numerous service delivery challenges from the previous government of the National Party. Amongst the key challenges is the national housing backlog caused by colonialism and aggravated by apartheid policies and laws. One of the results of colonialism and apartheid was to deprive black people of not only access to land, but also access to dignified housing with land tenure. Radebe, (2013) and Hadebe (2010) further stated in agreement that, this had the net result of relegating black people to informal settlements and inadequate buildings all over the country, even after the ushering in of democracy. The informal settlements according to Statistics South Africa Household Survey (2011) cited in Marutlulle (2017), constitute 12.1% (1 789 million households) of South Africa's 14.75 million households lived in informal housing in 2011. In order to reverse this ominous position, the current government has adopted a number of policies and enacted much legislation. Despite these attempts, the challenges posed by

access to adequate housing post-1994 remain, partly because the housing issues facing the poor in South Africa are numerous. These include a housing backlog, corruption in the allocation of houses and problems related to the building of houses.

While manufacturing and other industries have raised productivity steadily in past few decades, in construction it has remained flat or gone down in many countries. Likewise, in many places residential housing is still built in the same way as 50 years ago (Woetzel *et al.*, 2014). Projects costs could be reduced by 30% and completion schedules shortened by about 40% if developers make use of value engineering (standard design) and industrial approaches such as assembling buildings from prefabricated components manufactured offsite. Woetzel *et al.* (2014) suggested that efficient procurement methods and other process improvements would also help.

### 3 RESEARCH METHODOLOGY

The study implements the process evaluation method to systematically evaluate the selected IBT project to inform policy and procedure review for expedited uptake of IBT in the housing segment of human settlements environment. Process evaluation evaluates how an intervention is actually implemented and helps to avoid the error of drawing a conclusion about the effectiveness of a project without knowing whether or not it has been adequately implemented. This study took a qualitative design approach because the volume of collected data was descriptive which rendered the study to be descriptive in nature. Therefore, the method of enquiry used in this paper include both a critical review of documents and validation of data through interviews. Thembelihle Manyano IBT project was evaluated to determine systemic factors that both enabled and hindered its successful implementation. The paper traces the theory of change in technology transfer and uptake utilising evaluation theory. The term '*Theory of change*' originates in the field of program evaluation sometimes also called '*programme theory*' Imus and Rist (2009). It refers to the construction of a model that usually visually specify the underlying logic, assumptions, influences, causal linkages and expected outcome of a development project. Connell and Kubisch (1998) defined theory of change approach to evaluation as a systematic and cumulative study of the links between activities, outcomes and the context of the initiative. The definition suggests that the first step towards evaluating a project is to determine its intended outcomes, the activities it expects to implement to achieve those outcomes, and the contextual factors that may have an effect on implementation of activities and their potential to bring about desired outcomes.

The project documents which include project funding approvals, procurement strategy, minutes of the meetings and other communications were analysed against key systematic factors of project management. In human settlements environment, the distinguished stages that characterised the key systematic factors of project management include project initiation, procurement process, inception, planning and design, implementation and close out. The analysed descriptive data presented in thematic form tracking the project management process was verified through interviews with the relevant respondents that forms the value chain in the project management process of the project under study. There was no major difference from the initial analysis and the verified results of the study. This identified accuracy of the results served to confirm the relevance of the methodology implemented in this study. The next section is devoted to the results and discussion of the research study.

### 4 FINDINGS AND DISCUSSION

#### 4.1 THEORY OF CHANGE EMBEDDED IN THE EVALUATED PROJECT

Table 1 Theory of change for the implementation of innovative building technology project

| IBT PROJECT IMPLEMENTATION DESIGN                                                               |                                                                                       |                                                                                              |                          |
|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------|
| Inputs                                                                                          | Activities                                                                            | Outputs                                                                                      | Outcomes                 |
| <ul style="list-style-type: none"> <li>Human resource: Project managers, inspectors,</li> </ul> | <ul style="list-style-type: none"> <li>Project initiation: Needs analysis,</li> </ul> | <ul style="list-style-type: none"> <li>IBT Houses</li> <li>Completion Certificate</li> </ul> | <p><u>Short term</u></p> |

| <b>IBT PROJECT IMPLEMENTATION DESIGN</b>                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                        |                                                                                                                                                                                                                                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Inputs</b>                                                                                                                                                                                                                                                                                  | <b>Activities</b>                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Outputs</b>                                                         | <b>Outcomes</b>                                                                                                                                                                                                                                                                           |
| engineers, social facilitators, beneficiary administrators<br>• Housing Regulator: NHBRC<br>• Financial Resource: subsidy funding<br>• Technology: machinery, building system and materials<br>• Land zoned for residential purposes<br>• Qualifying beneficiaries to render the project ready | investigation of project information<br>• Social (IBT acceptance) facilitation<br>• Funding application and approval<br>• Procurement process: Procurement Strategy, Terms of References, tendering, appointment and contracting<br>• House plan and designs<br>• Construction and completion of top structures: project level monitoring, inspections<br>• Project close out: clearing snags, compile project report and hand over | • Final Unit Reports<br>• Happy Letters<br>• Completed housing project | • Beneficiaries IBT project acceptance <u>Long Term</u><br>• Improved social and economic conditions of IBT housing beneficiaries and creation of viable communities<br>• Improved construction skills for the beneficiary community<br>• Upscaling the use of IBT in housing development |

Thembelihle Manyano lacked clear theory of change, therefore as part of the process the evaluator had to develop one based on available information and verification with the project proponents. This paper traced the theory of change underlying the project understudy. Attention was given to change dynamics and pathways in the project process, with specific focus to inputs, activities, outputs and outcomes in facilitating the uptake and utilisation of IBT. It also focused on the occurrence of change as opposed to the expectation of the proponents of the project. Unforeseen factors and actors who promoted or constrained change were also taken into cognisance. Obstacles that deadlock and render ineffective theory of change were considered including how those obstacles may be minimised or eliminated.

#### **4.2 PROJECT DESIGN TO ACHIEVE THE SET TARGET OF HOUSING DELIVERY**

The project implementation design in line with the theory of change follows a logical framework that started with inputs streaming through various activities that trigger the flow via output to outcomes. The expected project inputs include human resource, housing regulation, financial resource, and technology. Identified activities were beneficiary administration and social facilitation which covers acceptance of innovative building technology (IBT) by the target beneficiary community. Funding application and procurement process had no exception. House plans and designs, construction and completion of top structures as well as project close out activities were also considered under project implementation design. The project trajectory considering the success and failures tracking the theory of change will be discussed in details in the next sections that unpacks the elements of theory of change underlying the project.

### **4.3 TYPES OF INPUTS AIMING TO THE SUCCESS OF THE PROJECT**

#### **4.3.1 Human resource**

The project had two project managers from both the Eastern Cape Department of Human Settlements and the IBT Contractor which is called Bendolite. The role of the project managers was to ensure that project was implemented according to the planned schedule and within the framework of the implementation design as depicted in the theory of change. It was therefore the responsibility of all project managers to ensure that the expected outcome of the project is met. This was driven through contract management that included project level monitoring and reporting. The project manager's roles also included coordinating both technical site meetings and beneficiaries' meetings including social facilitators of the project.

The inspectors had a responsibility to review structural designs and to ensure that the construction work is done according to the designed quality standards. The responsibilities of the inspectors included monitoring of project site to ensure total compliance by performing inspections. It was also the responsibility of the inspectors to produce an inspection report which specifies the technical satisfaction of inspected aspects such as the foundation, walling systems and insertions such as door and window frames, roof, plumbing and electrical fittings as well as other finishes to render a house completed. The inspector would also issue a non-compliance and order the contractor to rectify or to redesign where necessary. In this project, the inspectors included qualifying personnel from the NHBRC and the Department of Human Settlements. The contractor appointed an engineer to ensure project adherence to quality standards and to address any technical queries that transpired during the implementation process. The Departmental inspector was also responsible to recommend the issuing of completion certificate whilst the NHBRC issued Final Unit Report (FUR) for each completed house.

The Contractor was responsible for ensuring that the project is running according to the contracted schedule and budget. It was the responsibility of the contractor to manage the work on the project site and to ensure that necessary resources are acquired to run the project. This included acquiring necessary machinery, materials and general labour managing the project allocated fund. In case of deviation, it was the responsibility of the contractor to motivate for additional funding also considering the acceptable variation percentage to ensure that any obstacle encountered is taken care of.

The beneficiary administrators were responsible for facilitating beneficiary approval process by identifying qualifying beneficiaries, capture beneficiary information for verification in Housing Subsidy System (HSS). The administrators further communicated the results of beneficiary screening process to both qualifying and non-qualifying beneficiaries informing them of the matters to be addressed on their applications. The social facilitators also served to educate beneficiaries about housing related matters which include change management in the case of IBT. They were responsible for managing the reception of IBT to the beneficiaries by organising platforms where beneficiaries will be empowered with the knowledge about IBT. This included facilitation of the construction of demonstration unit and allowing beneficiaries to make an informed decision about their development project.

#### **4.3.2 Home building regulation**

The National Home Builders Registration Council (NHBRC) is a regulatory body of the home building industry, whose goal is to assist and protect housing consumers who have been exposed to contractors who deliver housing units housing units of substandard design, poor quality material and workmanship. The Housing Consumers Protection Measures Act, 1998 requires all builders and developers to enrol every new home with the NHBRC at least 15 days' prior construction. This had no exception for Thembelihle Manyano project that was enrolled with conventional as well as IBT housing designs. For every house enrolled with NHBRC quality home inspections were conducted at various stages which include foundation, wall plates, roof and finishes and FURs were issued where a unit satisfies the technical requirements of the NHBRC.

The IBT product implemented in Thembelihle Manyano project was Agrément South Africa certified as was a pre-requisite to satisfy technical requirements of IBT. Also, the Eastern Cape Department of Human Settlements took a decision to procure IBT projects using Agrément SA procurement guidelines. The responsibility of Agrément SA as enacted in 2007 is to support the process of integrated socio-economic development in South Africa as it relates to the construction industry by facilitating the introduction, application and utilisation of satisfactory innovation and technology development in a manner which would add value to the process. Agrément SA is responsible for non-standardised

construction products, systems, materials, components and processes which are not fully covered by the South African Bureau of Standards as the case with the product used in Thembelihle Manyano project. For this project, it was not clear whether the Imison 3 building system with Agrément SA Certificate 2008/342 or Imison Building System with Agrément Certificate 2001/289 was used. Therefore, there is no clarity on this specific input, also copy of the relevant certificate was not found in the project file during the review process.

#### **4.3.3 Financial resource**

Subsidy funding application process was done for the project to be adequately funded. Before the regional office of the Department of Human Settlements process funding, the project state of readiness is determined through project pre-planning process. The project was in the Housing Chapter of the Integrated Development plan (IDP) of the Buffalo City Metropolitan (BCM) Municipality. And was therefore eligible to be funded as the beneficiaries were also confirmed through the relevant processes. The project was then incorporated in the business plan of the Department for implementation. The funding was applied through normal process which as when applying for funding for conventional project. Nothing distinguished this project from any other project or rather an indication that this is a mixed design project where the expected outputs include both IBT and conventional housing units.

#### **4.3.4 Construction technology**

The technological requirement is a major input necessary for a project to be rendered a success. Machinery that was required for the project was adequate to deliver according to the expectation of the project managers and the beneficiaries, but the materials were not adequate to cater for the building system that was earmarked for the project. This was instigated by poor planning for material procurement for construction of IBT units for the project.

### **4.4 PLANNED ACTIVITIES FOR THE SUCCESS OF THE PROJECT**

#### **4.4.1 Beneficiary administration and social facilitation**

Beneficiary administration process which include capturing of information and screening using the HSS was conducted to create beneficiary list. Beneficiaries were required to fill in the application forms for housing subsidy applicable to the year 2004 Quantum. The common errors identified include the beneficiaries who did not submit all relevant documentations during capturing and those who already received subsidy in other areas due to various reasons. For instance, a person who moved to East London areas from rural home in search of greener pastures and ended up settling in the area and therefore require a house. Such beneficiary may qualify for subsidy according to the household income but again the system does not allow for double benefits of the same subsidised limited resources. Beneficiaries with outstanding issues were required to address them in order to qualify for the subsidy.

The first step towards the implementation of IBT project is acceptance by the beneficiaries. In Thembelihle Manyano project, the approach used was to put up a demonstration unit by the contractor. One beneficiary who accepted to receive a demonstration IBT house was identified. The house was built in the presence of the beneficiaries and relevant departmental officials so that they may take an informed decision about the product and the proposed approach. List of beneficiaries who opted for IBT was created, and the beneficiaries who opted for conventional bricks and mortar were also listed separately.

#### **4.4.2 Project funding application**

Funding Application titled 'East London-Mdantsane Infill Areas-1459 Subsidies: Funding for the Construction of 1459 Top Structures' was approved by the Member of executive Committee (MEC) for the Department of Human Settlements through Project Assessment Committee (PACOM) of the department. The funding was not clear whether it is specifically for IBT project or conventional bricks and mortar. Only one funding approval was used for both IBT and conventional bricks and mortar technology in the project. The items covered by funding approval include cost for top structures, variances and norms and standards. The top structure is characterised by foundation, wall plates and roof also covered in the same funding application. The variances cover for ground water category, soil sensitivity to erosion, collapsing sands, topography category, location adjustment and additional professional fees. Whilst norms and standards include ceiling installation, glass fibre insulation, plastering of internal walls, plastering of external walls and enhancement.

#### **4.4.3 Procurement process**

Three procurement strategies with different dates were traced for this project. The first procurement strategy was for the construction of 421 units using conventional building method and the construction of 62 units using IBT. At a later stage, another procurement strategy was drafted which introduced a conventional method and this time exclude IBT houses. According to the motivation and information found from meeting report, beneficiaries who chose IBT approach were few and it took the contractor time to order the materials for IBT as it was not at larger scale and may be costly if materials were disjointedly ordered.

There is no trace of Terms of References (TORs) to guide the bidding process in the project file. It is therefore not clear how the documents were interpreted into a contract and it was assumed that GCC and JBCC contracts were used as it is a common practice in the Department. Tendering was done using short limited bidding for both technologies and it was stated that the consideration would be given to the best performing contractors. This was in time where government had not started to deliver IBT at scale and therefore performance on IBT contractors would not be easily justified. It therefore means that the criteria used to evaluate IBT contractors was the same as the criteria used for conventional bricks and mortar contractors. This is one of the identified areas of improvement for projects of this nature.

The contractor was appointment and would be contracted for the period of 12 months' subject to submission of project implementation plan (PIP) which was not traced in this project documents file. HIV Aids Policy, Occupational Health and Safety Plan, priced bill of quantities (BOQ) and workman's compensation certificate were also required to be submitted within the maximum of 14 days of the commencement date for construction works.

#### **4.4.4 House plans and designs**

The house plans and designs traced in the project file had the characteristics of conventional bricks and mortar technology therefore miss the characteristics of IBT implemented in the project. According to Agrément SA certificate of the IBT product, the system is a walling panel whereas the descriptions on the house plan and designs submitted to the NHBRC for enrolment are indicating block work. During design phase, IBT units should consider house plan and designs details as referenced from the Agrément SA quality control manual. The designs and structural diagrams for the project understudy are silent on this notion. This raise a concern about the inspection process that took place in the project as the designs serves as the point of reference during construction.

#### **4.4.5 Construction and completion of top structures**

Project construction process involved project level monitoring and inspections for quality assurance purposes. This project was monitored like any other project ensuring that the project is progressing according to the project implementation plan that was submitted to the Department of Human Settlements by the appointed contractor. The project also experienced variety of dynamics which include among others delays due to weather, payments of milestones. For IBT units there were concerns from the beneficiaries who stated that since the construction works started, beneficiaries who opted for conventional bricks and mortar technologies are receiving their houses whilst the beneficiary who opted for IBT are still waiting. The beneficiaries who chose IBT felt like they are deprived of their rights to housing as enshrined in the constitution which is a supreme law of the country. Delays in the starting of construction of IBT units resulted to the beneficiaries changing their choice to conventional bricks and mortar technology. There was no technical performance aspects or perceptions of IBT associated with the change of choice by the beneficiaries who initially chosen IBT units. When asked, the contractor indicated that it would be better to order materials in bulk, so the pace of acceptance of IBT by the beneficiaries was not favourable for the urgency of the project to be completed on time. However, there are almost 10 units completed using IBT in the project some of which may not easily be singled out from the conventional technology units.

Both IBT and conventional housing units were constructed with the consideration of four milestones namely foundation, wall plates, roof and finishes and those were the stages were inspections took place and payments were processed following value created. The Eastern Cape Department of Human Settlements would issue the completion certificate where the inspector is satisfied by the work done.



Figure 1 conventional house (right) and the IBT house (second from right)

#### 4.4.6 Project close out

Like any other project, this project had retention fee to ensure that the contractor may be held accountable for any technical aspect that need to be rectified with cost bearing, therefore the retention fund would be used to rectify the identified non-compliance. Project contractor was required to clear the snags where there was any identified and to compile project report in preparation for a handover. The project was not closed yet at the time of this assessment but there is no longer an element of IBT due to identified and reported challenges. However, the contractor would continue to compile information relevant to each completed unit for completion and de-commitment of the project from the HSS.

### 4.5 REALISED PROJECT OUTPUT CONTRASTED WITH PLANNED OUTPUT

#### 4.5.1 Completed housing project

With regards to IBT houses, the project was intending to produce a number. According to records from minutes of the meeting, 'it was reported that Thembelihle Manyano had 850 units to be built but it was reduced to 845 units, out of 845 units, 16 sites were not developed, so there were 829 units to be built at the time. These totals refer to both IBT and conventional units simultaneously. At that moment 272 beneficiaries chose IBT, 467 chose conventional bricks and mortar technology and 111 were still undecided. It was captured in the procurement strategy that those numbers changed and the number of beneficiaries who chose IBT declined to only 62. Only ten units were constructed up to finishes and are currently occupied by the beneficiaries. The significant decline in number of units produced as opposed to initially expected units is that the IBT procurement of materials relied much on number of units which is the different case when it comes to conventional bricks and mortar technology. Some critical output that confirms the technical satisfaction are completion certificates issued by the Eastern Cape Department of Human Settlements and final unit reports (FURs) that were issued by the NHBRC to offer a warrant. The signed happy letters portrayed beneficiaries' satisfaction and social acceptance of delivered IBT housing units.

### 4.6 ACTUAL PROJECT OUTCOMES SET AGAINST PLANNED OUTCOMES

#### 4.6.1 Short term outcomes

The beneficiaries' acceptance of IBT project was achieved at reasonable scale for a first project. This project displayed that if beneficiaries are given chance to choose, there might be an equally competing variety of choices especially looking at how Thembelihle Manyano beneficiaries made their choice given the opportunity. This outcome was achieved at planning and design stage and fail or rather decline at implementation stage. The project was completely converted to conventional bricks and mortar technology at its end, and the IBT approach was completely discarded. This may therefore conclude that the short term outcome was partially achieved for the project.

#### 4.6.2 Long term outcomes

The theory of change on upscaling the use of IBT in housing delivery was partially achieved. The lessons learnt are that there is a hope for acceptance and upscaling of IBT provided that a proper SWOT analysis is done to test the strength of the theory of change during project design stage. The theory of change should be developed drawing lessons from the success than failures of the evaluated project. Therefore, there would be a great opportunity and potential to develop a strong theory of change. The reviewed project planning documents and data verification revealed that, in a long term, the Department of Human Settlements intends to build environmental friendly houses to support the community of beneficiaries with improved social and economic conditions. Part of environmental benefits were achieved and confirmed by IBT beneficiaries who already spotted the environmental benefits of IBT units. Whilst doing project site visit, the evaluators communicated with some of the beneficiaries to figure out how they feel about their IBT units. Some IBT units were identified with minor defects like hairline cracks and others with defects that are common with conventional units. What the IBT beneficiaries were happy about was that they don't complain about moisture on the walls as opposed to conventional technologies units. They further indicated that their houses do not grow mould as the case with brick and mortar. Another expected long term outcome is to improve construction skills for the beneficiary community through skills transfer, which is not too clear whether there is any community member who had been empowered to install the IBT technology in question. The socioeconomic benefits were also not identified with specific regards to the IBT, but the community life was improved at the area convenient to access transport, health services, work opportunities, schools and other related services.

## 5 CONCLUSION AND FURTHER RESEARCH

This study was triggered by the consideration of South African government in implementing innovative building technologies (IBT) for housing development projects. The study further aimed at learning experiences benchmarking on one of the IBT project that was implemented in the Eastern Cape. The focus was on project logic model tracking the theory of change through document review and interviews to verify preliminary findings of the document reviews. The step by step analysis gave the helicopter view of the project process exhuming information about success and failures. This served as a blue print for the implementation of new IBT projects by government departments pointing the direction and areas of exploration either through pilot projects, research, policy and programme development as well as monitoring and evaluation. There were grey areas that were identified which include project planning and design and such areas needed special attention. Therefore, it is recommended that design evaluation be conducted for new projects. The area of social acceptance of IBT had proven to be achievable as the acceptance was high, the failure was for the developers to keep up on delivery according to the expectation of the beneficiaries consequently the number of beneficiaries opting for IBT house declined. Research area for further exploration in view of this study include assessing the relationship between acceptance and rejection of innovative technologies in housing delivery and their link to the delivery performance of the appointed developer.

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## Key drivers of resistance to innovative building technologies for low income housing project in the Eastern Cape Province

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### ABSTRACT

Innovative building technology was introduced for a pilot project aiming to speed up housing delivery in the Eastern Cape Province. However, the community where it was piloted rejected the technology at the procurement stage. There was no clear reason for rejection of the technology. This justified conducting a study to explore reasons for the rejection of innovative building technology for housing development. Qualitative research method was used to address the objectives. Purposive sampling method was adopted to source respondents. Focus group discussions were used to collect data that was analysed using content analysis. The key findings of the study provided empirical evidence on the reasons for the community to reject IBT for housing development. It also served as a guide towards an approach to facilitate community buy-in of IBT in low income housing projects.

Keywords: Innovative building technologies, development, housing, public acceptance

### 1 INTRODUCTION

In September 2000, the leaders and representatives of 189 countries met to lay down tangible goals to combat poverty throughout the world. At the summit, the leaders agreed to adopt the Millennium Development Goals (MDGs) which set out eight key areas to be achieved by 2015, using 1990 as the baseline year (UN-HABITAT, 2003; Samari, 2010). The MDG were later improved to Sustainable Development goals (SDG). Goal 11 of the SDG aims to make cities and human settlements inclusive, safe, resilient and sustainable (Hsu, Parnell and Rodriguez, 2014). The SDG according to Hsu *et al.* (2014), is a huge and complex domain in which states are one of many actors alongside the private sector. Furthermore, the current framing of goal 11 is reported broad and speaks to all dimensions of sustainable development. Such an inclusive approach is appropriate as human settlements have been shown to be pathways to social, economic and environmental development. Hsu *et al.*, (2014), claims that goal 11 entails much more than the spacial concentration in cities and towns of actions across all other goals. The goal demands multi sectoral, multi scale, and multi actor planning, implementation, enforcement and innovation to ensure that human settlements becomes sustainable development pathways with regional and global impacts. The leaders also pledged to establish a wide-ranging global partnership for development that would engage the private sector and civil society organizations, and make the benefit of new technologies available to everyone so as to achieve these universal objectives (Samari, 2010).

Against this background, South Africa since considered the use of innovative building technologies (IBT) in construction of low cost housing for the poor. The broader aim of introducing IBT was to curb the housing backlog by increasing the number of units delivered per annum. It is evident that only conventional methods used in housing construction was not sufficient to resolve the backlog facing the country. There are also allegations that IBTs are not only fast for housing construction methods, but also bears environmental benefits which include reduction of carbon emission. The latter is known to contribute to the global concern of climate change. It was further alleged that IBTs are durable, cost effective and has a long term economic and environmental benefits. This paper investigated the key drives of rejection of IBT for government housing project in Ndevana. Ndevana is a congested semi-rural settlement stretching along the N2 road to East London about 10kms south of King William's Town within the Buffalo City Metropolitan Municipality. The area receives about 647 mm average of rain per annum and has maximum temperature of 26.2°C. The shortage of some basic services as well as the rejection of IBT qualifies the Ndevana community to be selected as a case study area.

The Eastern Cape Department of Human Settlements (ECDHS) had a constitutional mandate to ensure that all citizens have rights to adequate shelter. A shelter alone is not enough towards the creation of sustainable human settlements as stipulated in the Housing White Paper of 1994. The Comprehensive Plan towards the creation of sustainable human settlements, also known as Breaking New Ground (BNG), promotes the creation of economically viable communities with access to basic services like education, water, health, safety and others. Housing is the primary need which always comes first among the list of grievances during community strikes. Innovative building technology was introduced for a pilot project aiming to speed up housing delivery in the Eastern Cape Province. It was introduced in a way that the beneficiary administration was done parallel with the procurement of the contractor. However, the Ndevana community where it was piloted rejected the technology at the procurement stage. The technology introduced according to Mkowena and Akinboade (2012), is such that houses are built using pre-cast, insulated concrete panels which are moulded in specifically designed steel moulds. The wall panels are being manufactured in a mobile plant on site and then erected on conventional foundations, joined together by specifically designed joints. The entire process from casting moulds to a completed house can take an average of eight hours and five houses can be built per day as compared to the three months it takes to build a house using conventional methods (Mkownena and Akinboade, 2012). There was no clear reason for rejection of the technology. This justified conducting a study to explore reasons for the rejection of IBT with the aim to contribute to the body of knowledge, policy development and enhance project management activities for the IBT projects in the Eastern Cape Province. The highlight of findings in this paper include that the beneficiaries need to be involved and be educated about the IBT that would need to be implemented in their project. There were various technical and social influences such as perspectives that the IBT unit may not be extended, bank bondable and may not be used as a collateral or an inheritance.

## **2 LITERATURE REVIEW**

According to the “*American Housing Survey*” report (Kaufman, 2012), more than 17.6 million households with children experience at least one major housing problem. This equates to more than one out of every two households with children in the country. In addition, poorer families were more likely to confront housing problems, reflected in almost 87% of poor households with children experiencing at least one such challenge. However, by far the most widespread challenge facing poor families was that housing was not affordable. It affects millions in less tangible ways than other housing challenges because families who pay large parts of their incomes for housing often have little left for food, clothing, health care and other necessities (Kaufman, 2012). Furthermore, Ashley (2013) found that in 2008, the number of households that spend more than half of their income on housing each month rose by a third, to 18.6 million households. If this was translated into the number of Americans, it would equal 44.2 million. Also, more than 9.2 million households that have children pay for housing.

According to Wienecke (2010), the reliance on conventional building approaches had not helped addressing the backlog in housing delivery. The author further alluded attempts that have been made to alleviate some of the constraints. A case in point was the introduction of community-based projects or involvement of emerging contractors in housing construction processes. A slower growth rate in income and a constant increase in the prices for conventional materials and services negatively affected the extent to which many households afforded the technology. Among other initiatives, innovative technologies were often considered in order to lower the costs and overcome the challenge of housing delivery. Also, Donovan (2010) suggested that technologies should be shaped by knowledge, values, skills, and resources of the societies producing them. At the same time, technologies shape that particular society. Although the government made considerable inroads into housing provision, there were still considerable debate relating to innovative ways of making available affordable shelter in livelihoods-accessible locations.

## **3 RESEARCH METHODOLOGY**

The ambition in research methodology is to assist the researcher to anticipate the appropriate decision to maximise the validity of the subsequent results whilst minimizing error. This study focused on designated beneficiaries’ perceptions on the rejection and acceptance of innovative building

technologies. This assisted in achieving the aim of the study which was *'to explore the influencing factors of the rejection of IBT for housing delivery'*. The study adopted a qualitative research procedure where various strategies of enquiry and tools to design a qualitative research were implemented. Qualitative approach the most appropriate in this study that focused on the descriptive analysis of identified themes than their statistical meanings. The study further draws conclusions and craft the recommendations leaning on the themes that were introduced in this paper.

Data collection tool was designed with the basis of designated themes that were structured in a form of questions. Collected data was analysed in thematic forms, and the results were fused with the discussions that were strengthened by other relative literatures. The two main designated themes in this paper include, community understanding of IBT and why community rejected the IBT project introduced to them. A focus group tool was developed based on these designated themes that were converted into open ended questions. These themes were also expanded into sub themes to allow the respondents for wide range and open responses that further give the specifics. The open ended questions driven from the designated themes were administered in an open discussion to focus groups characterised by the beneficiaries' community. Each focus group consisted of 6 individuals to ensure that the group is well managed for maximum participation. The total number of focus groups were 10 which with 6 individuals per each groups that totals to 60 individual participants all together.

Table 1 The framework for data collection tool utilised

| Themes              |                                                                         | Questions              |                                                                                     |
|---------------------|-------------------------------------------------------------------------|------------------------|-------------------------------------------------------------------------------------|
| <b>Main Theme 1</b> | community understanding of IBT                                          | <b>Main Question 1</b> | What is the community understanding of IBT?                                         |
| Sub-theme 1         | community knowledge of IBT                                              | sub-question 1         | Do you know what IBT is?                                                            |
| Sub-theme 2         | community members' perceptions regarding IBT (structural & performance) | sub-question 2         | what do you know/think about IBT? (structural & performance)                        |
| <b>Main Theme 2</b> | why communities reject IBT                                              | <b>Main Question 2</b> | why did the community reject IBT?                                                   |
| Sub-theme 1         | the views of the community towards the rejection of IBT                 | sub-question1          | what do you think where the reasons behind the rejections of IBT?                   |
| Sub-theme 2         | the views of the community on acceptance of IBT                         | sub-question 2         | what do you think could have been done to ensure that IBT is accepted in your area? |

## 4 FINDINGS AND DISCUSSION

This section discusses the results of the study through themes on rejection and acceptance of innovations. It also highlights the influence of the innovative building technologies (IBT) trajectory after its introduction at Ndevana. Furthermore, it reflects on the reception of innovative building technologies for pilot housing development projects in the Eastern Cape Province, where Ndevana was chosen as a pilot site. Community perceptions of IBT, the reasons for rejection and suggestions for its acceptability are also discussed with reference to various practices and available bodies of literatures relevant to each theme understudy.

### 4.1 COMMUNITY UNDERSTANDING OF INNOVATIVE BUILDING TECHNOLOGIES

The results of the current study revealed that, there was lack of knowledge and understanding of innovative building technologies (IBT) by the Ndevana community. This was qualified when the respondents mentioned that they had only seen IBT structures at the neighbouring village but they had no idea how they were constructed. To support these results, Mutagamba (2004) believes that education and acceptance of innovative technologies go together. The Ugandan government gave the go ahead for politicians to carry out advocacy work. Further to this, training and empowerment to sensitise the masses on innovative technologies was also recommended. In addition, Hausler (undated)

in Staadecker (2011) realizes the importance of acting as a role model in order to encourage future inventors and social entrepreneurs. Hausler has a passion for teaching and spends time abroad training the staff and residents in “Build Change” communities on safer building technology. The expert stresses the need to use these skills that work hand-in-hand with creativity and innovation to make real and sustainable change in the developing world.

According to Diacon *et al.* (2011), Gram Vikas, Winner of the 2003 Rural Health and Environment Programme (RHEP) of the Gram Vikas non-governmental organisation (NGO), demonstrated how rural communities could be involved in the sustainable and affordable development of their own village infrastructure and housing. Initiated in 1992, Gram Vikas worked with the entire community to develop sustainable building materials and techniques; promoted a range of training, income generation and other community development projects and to work towards strong self-governing institutions with equal participation of men and women (Diacon *et al.*, 2011). Also, Home Information Packs (HIPs) were then compulsory for almost all homes on the market in England and Wales (Murray, 2010). They contained a set of documents with key information such as property searches, proof of ownership, sustainability information, an Energy Performance Certificate (EPC) or Predicted Energy Assessment (PEA). One of the aims of the HIP, according to Murray (2010), was to improve the sustainability of existing housing stock in England and Wales.

With regards to the need for explanation of IBT, 5 Focus Group (FG) discussions indicated that they would need someone to explain IBT to them what IBT is. This also sustained the theory of Horton and Hunt (1989) which states that the society hesitates to adopt an innovation until they have been shown how it works, hence they could only determine the practical value of the social inventions through adopting them. Horton and Hunt (1989) believe that a dilemma like this slows community acceptance of the innovations.

The community’s concern that IBT were still being tested and that they were not willing to serve as a testing ground tells that they want to see these products being tested somewhere else. In South Africa, the Eric Molobi Innovation Hub (IMI) situated at Soshanguve in Pretoria, part of Gauteng Province, was developed to showcase construction technologies that were cost effective and adoptable in housing programmes. According to Reddy (2009) and Sokopo (2010) the IMI function was similar to Indian Rural Building Centres (IRBC). As Sokopo (2010) confirmed, some provinces in South Africa have considered establishing provincial innovation hubs to showcase various technologies and to train communities on the usefulness of IBT for housing development. In light of this ECDHS might develop a comprehensive programme to facilitate IBT acceptance for housing development. In this case, the beneficiaries may be awarded an opportunity to view and make a choice of IBT systems and products compatible with their local setup; thus they would have been educated on what these IBT is. Educating the beneficiaries on the benefits of IBT may improve their perceptions towards the concept.

Table 2 Focus group responses on knowledge of IBT by the beneficiaries

| Number of focus group participants | Participants                                                                                                            | Males                           | Females | Total Tallies |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------|---------|---------------|
|                                    |                                                                                                                         | 30                              | 30      | 60            |
|                                    | Focus groups                                                                                                            | 6                               | 6       | 12            |
|                                    | Do you know what is IBT?                                                                                                | Number of focus group responses |         |               |
| 1.                                 | a) We know them through seeing a structure from a distance in the neighbouring village but we haven’t experienced them. | 5                               | 5       | 10            |
| 2.                                 | b) We would like to know what IBT is, and would like someone to explain to us.                                          | 3                               | 2       | 5             |
| 3.                                 | c) We know the structure but are not familiar with the name ABT; also we have not seen them being constructed           | 2                               | 2       | 4             |

According to Diacon *et al.* (2011), new technologies for preventing damage from natural disasters have been developed over the years by a range of winning and finalist practices of the International Housing Innovation Competition. Working in collaboration with local communities to identify needs, the Building and Construction Improvement Programme in Pakistan developed a range of new and affordable

technologies for home improvement products for those living in remote mountainous regions. This was meant to intensify community participation for development driven through IBT.

#### 4.2 COMMUNITY MEMBERS' PERCEPTIONS REGARDING INNOVATIVE BUILDING TECHNOLOGIES

The results of the current study were consistent with the study done by Sokopo (2010). The findings revealed that the respondents think that it is not easy to do alterations on an IBT house. They also stated that the house could not be easily extended because the wall panels develop cracks even before they are assembled as a housing unit. This paved way for the respondent communities doubting the strength of the housing structures; for instance, thinking that in cases of heavy rains or wind the roof may be carried away or if a car accidentally crash into the wall, then the structure might collapse. These respondents think that it may cost a fortune or even not be possible to re-assemble the wall panels. They were referring here to the fact that the wall panels are single structures that are prefabricated with windows and door frames. In the sight of the community, this is similar to a house built with one brick that, if it crumbles and falls, it may also affect the whole housing unit. These findings were concurrent with the ones presented by Sokopo (2010) who reported that consumers' perception that houses built with innovative building materials could not be extended presents acceptance challenges. According to Sokopo (2009), these respondents were also deterred by the thought that IBT walls are too hard for wire nails to penetrate in case they want to hang up their pictures or put up curtains.

Even though some members of the Focus Group Discussions (FDG) blamed the thin diameter of the wall as well as the shallow foundations, the results of this study revealed that the conditions of the wall and the foundation had not much influence on people's perceptions about IBT. The respondents believe that IBT houses were not good for thermo-regulation. Their belief drives them to think that IBT units could pose health hazards to its occupants. They supported their argument by indicating that Ndevana was in the Southern Cape Coastal Condensation Allowance (SCCCA) zone. The SCCCA, which was phased out by the revised subsidy quantum, includes areas receiving the winter, all-year and high annual rainfall between 250 and 500 mm per year. According to SCCCA practice, all housing developments within the radius of 60 km away from the sea were entitled to be plastered in and out, with ceilings installed and should be well insulated (Seed, 2011).

Table 3 Focus group responses on structural perception of IBT in housing development

| Number of focus group participants                                                            | Participants                                                                                          | Males                           | Females | Total Tallies |
|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|---------------------------------|---------|---------------|
|                                                                                               |                                                                                                       | 30                              | 30      | 60            |
|                                                                                               | Focus groups                                                                                          | 6                               | 6       | 12            |
| What do you know/think about structural issues relating to alternative building technologies? |                                                                                                       | Number of focus group responses |         |               |
| 1.                                                                                            | The structures could not be extended                                                                  | 5                               | 5       | 10            |
| 2.                                                                                            | The walls are too hard for wire nails to penetrate                                                    | 4                               | 4       | 8             |
| 3.                                                                                            | They develop cracks easily even before they are assembled as a housing unit                           | 2                               | 4       | 6             |
| 4.                                                                                            | They have no proper foundation which seems as if there was no foundation                              | 2                               | 2       | 4             |
| 5.                                                                                            | The foundation is fine                                                                                | 1                               | 0       | 1             |
| 6.                                                                                            | The wall diameter is too thin                                                                         | 1                               | 0       | 1             |
| 7.                                                                                            | The roof may be difficult to re-assemble if it could be taken by wind due to the nature of the panels | 0                               | 1       | 1             |

The community had a fear that IBT may change their living patterns, especially their rural set up as spelled out by Majova (2008). The respondents further mentioned that they do not trust IBT houses. Their lack of trust was also influenced by the lifespan of IBT houses which was unknown to them. The respondents have, therefore, developed a feeling that IBT houses could not be passed on to their

relatives. This was also supported by an idea that each society had many specific attitudes and values which make it cling to its objects and activities (Horton and Hunt, 1989; Donovan, 2010).

Table 4 Focus group responses on attitude and value-based perceptions of IBT house

| Number of focus group participants                        | Participants                                                                                 | Males                           | Females | Total Tallies |
|-----------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------|---------|---------------|
|                                                           |                                                                                              | Focus groups                    | 30      | 30            |
|                                                           |                                                                                              | 6                               | 6       | 12            |
| What do you value do you assign to IBT house performance? |                                                                                              | Number of focus group responses |         |               |
| 1.                                                        | It could pose a health risk                                                                  | 5                               | 5       | 10            |
| 2.                                                        | It are non-inheritable                                                                       | 4                               | 3       | 7             |
| 3.                                                        | It could not be easily extended (cost)                                                       | 3                               | 3       | 6             |
| 4.                                                        | It could not be used for a permanent structure                                               | 2                               | 4       | 6             |
| 5.                                                        | It could be good for fencing a yard and as a storage facility rather than housing people     | 2                               | 3       | 5             |
| 6.                                                        | We call them slabs                                                                           | 2                               | 3       | 5             |
| 7.                                                        | It is not from our background                                                                | 2                               | 1       | 3             |
| 8.                                                        | It could not be a valuable assets to enter the housing market so we compare them with shacks | 2                               | 1       | 3             |

Diacon *et al.* (2011), support the above statement by Horton and Hunt (1989), as well as Donovan (2010), alluded to the point that the technology, skills, knowledge or processes being transferred should not only be adapted to local conditions but should also be appropriated by the 'receiving' community or organisation in order to ensure the long-term sustainability of the initiative. How the message was delivered was key to the success of the development. It was important to have committed individuals or teams who could champion their good practice, communicate effectively and inspire others (Diacon *et al.*, 2011).

### 4.3 WHY COMMUNITIES REJECT INNOVATIVE BUILDING TECHNOLOGIES

Not all technological options and innovative were developed or explored. Although this was often because innovative were either more expensive or less economical, there were often other reasons too (Beder, 1994). The results of this survey revealed that the rejection of IBT houses by the Ndevana community was also related to cost for change. The respondents stated that people may not afford the alterations of an IBT unit because it may need specialised tools to do alterations like changing the positions of the door and windows. The respondents also think that the tools and materials to effect changes may be expensive or not available at the local market.

Table 5 Focus group responses on the reasons for rejection of IBT house by beneficiaries

| Number of focus group participants                                           | Participants                               | Males                           | Females | Total Tallies |
|------------------------------------------------------------------------------|--------------------------------------------|---------------------------------|---------|---------------|
|                                                                              |                                            | Focus groups                    | 30      | 30            |
|                                                                              |                                            | 6                               | 6       | 12            |
| What do you think were the reasons behind the rejection of ABT in your area? |                                            | Number of focus group responses |         |               |
| 1.                                                                           | ABT was rejected because it was not bricks | 5                               | 5       | 10            |
| 2.                                                                           | They have a lot of structural defects      | 3                               | 3       | 6             |

|                                                                      |   |   |   |
|----------------------------------------------------------------------|---|---|---|
| 3. To change the position of the doors may be difficult              | 2 | 1 | 3 |
| 4. ABT materials were not available at local markets                 | 0 | 1 | 1 |
| 5. It could be difficult to re-build in case of a car crash accident | 0 | 1 | 1 |

Arensberg and Niehoff (1971) accentuated that, in general, the very poor often resist all change because they could not afford to take any risk. These authors, supported by Beder (1994), further highlighted that change was nearly always costly. It disrupts the existing culture and might destroy cherished sentiments and values, in addition to being costly at times. For example, a study carried out by the NDoHS revealed a high cost of new technology at ZAR1, 004 – ZAR3, 600/m<sup>2</sup> (US \$118 – US \$424/m<sup>2</sup>; when US \$1=ZAR8.5), excluding land and foundation (Sokopo, 2010). The figures presented before were compared to conventional ways of housing construction. Sokopo (2010) further reveals that the initial cost for innovative building technologies and high levels of maintenance often exceeds the subsidy quantum. Some technologies may need specialised tools to cut the wall panels to prepare for alterations; or else the structure may be faulty if it was done manually. Considering that the beneficiaries qualify for a housing subsidy because they were living below the poverty line, this may also result in them not being able to afford the machinery to process alterations of their housing units.

Staaecker and Martinovich (2011) explain the Build Change's model developed by Hausler and based on simplicity. Beginning with a thorough examination of a region's unsafe housing issues, Hausler's team makes slight adjustments to the original building construction plans rather than overhauling an area's traditional architectural structure. Build Change helps community members work with locally available materials and labour to rebuild. The outcome was a cost-effective, easily modified and, most importantly, a culturally accepted construction method the homeowner adopts and understands.

According to Staaecker and Martinovich (2011), Build Change homes cost anywhere from ZAR25, 000 to ZAR144, 000 (US\$3,000 to US\$17,000 at the exchange rate of ZAR8.5) less than similar structures built in donor-driven environments. Despite the clear benefits, many communities were rooted in custom and were, therefore, resistant to change. As a solution, Build Change educates and trains anyone who would play a role in the rebuilding process, including homeowners themselves, materials vendors, engineers and builders. The non-profit organisation also works with local governments to instruct officials on the technology, helping to enforce the reconstruction model as a new building standard, reducing community resistance and leading to further implementation (Staaecker and Martinovich, 2011). This model could also assist in tabling the recommendations for development practice by the current study.

The findings of the current study also indicated that the beneficiaries were given a chance to choose whether their housing development should adopt the use of IBT or the conventional methods. The results further revealed that respondents had chosen to use conventional methods but IBT were imposed on them. This was the same as Spicer (1952)'s view that there was often resistance when the change was imposed by others, was not well-understood, and was regarded as a threat to people's values. In support of this view, Majova (2008) further accentuates the involvement of people in the choice of the development models and options for their communities through active participation.

Table 6 Focus group responses on the rejection of IBT based on social attitudes and values of the society

| Number of focus group participants                                           | Participants                            | Males                           | Females | Total Tallies |
|------------------------------------------------------------------------------|-----------------------------------------|---------------------------------|---------|---------------|
|                                                                              |                                         | Focus groups                    | 30      | 30            |
|                                                                              |                                         | 6                               | 6       | 12            |
| What do you think were the reasons behind the rejection of ABT in your area? |                                         | Number of focus group responses |         |               |
| 1.                                                                           | They could be a health risk             | 4                               | 5       | 9             |
| 2.                                                                           | People could not afford the alterations | 3                               | 4       | 7             |
| 3.                                                                           | They are unknown to our culture         | 2                               | 4       | 6             |

|                                                                                                                                                                          |   |   |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|
| 4. We do not know the level of risk of ABT houses                                                                                                                        | 3 | 3 | 6 |
| 5. They are inhabitable                                                                                                                                                  | 5 | 3 | 8 |
| 6. They could be life threatening                                                                                                                                        | 2 | 3 | 5 |
| 7. If a serious technical error is experienced, we may not benefit as we have already benefited from the grant                                                           | 2 | 2 | 4 |
| 8. We were given a chance to make a choice and we chose bricks, but ABT were imposed on us                                                                               | 1 | 0 | 1 |
| 9. It was still tested and we were not comfortable when it was tested on us                                                                                              | 0 | 1 | 1 |
| 10. We believe that when one is staying in an ABT house, it is the same as if one had no house at all, yet government would be thinking they had delivered a house to us | 1 | 0 | 1 |

The reasons for the Ndevana community's rejection of IBT for housing development have all been mentioned under the section on IBT perceptions. One of these reasons is that they think the IBT houses are non-habitable and, therefore, could pose a risk to the lives of the inhabitants. Donovan (2010) believes that, if an object had a purely utilitarian value, that is, if it was valued because of what it would do, change may be accepted more readily. This study revealed that ECDHS have seen an IBT development as a solution to the housing backlog sitting at the province. In contrast, if some feature of traditional culture was treasured intrinsically, valued for it aside from what it would do, change was less readily accepted (Donovan, 2010). In this case the Ndevana community have seen IBT as an inferior housing product, hence the rejection. They indicated that, if they accept IBT houses, they would no longer benefit from the housing subsidy scheme because government would record that they had already received a housing grant. The respondents further mentioned that they do not consider IBT house as a solution to their housing problem. They suggested that these IBT materials may be used for other functions like fencing or building storage facilities rather than housing people.

#### 4.4 COMMUNITY VIEWS ON ACCEPTANCE OF INNOVATIVE BUILDING TECHNOLOGIES

Acceptance is the first step to social change; it is the first step in making real and lasting change (Noel, 2011). This was in line with the findings of the current study on the community views of acceptance of IBT. Even though the Ndevana community had generally rejected the IBT housing development project in their area, they still believed that the Government may still succeed in implementing it when certain issues were improved. Among areas of development they listed were that IBT could be acceptable if the house could be extended without structural defects. The respondents further promoted the demonstration of innovation by mentioning that the quality of the houses built should be the same as that of the show houses. They further emphasise that constant inspection should be done during the construction phase.

Table 7 Focus group responses about beneficiary perceptions on what could have been done to ensure IBT houses were accepted

|                                                                                         |              | Males                           | Females | Total Tallies |
|-----------------------------------------------------------------------------------------|--------------|---------------------------------|---------|---------------|
| <b>Number of focus group participants</b>                                               | Participants | 30                              | 30      | 60            |
|                                                                                         | Focus groups | 6                               | 6       | 12            |
| <b>What do you think could have been done to ensure acceptance of IBT in your area?</b> |              | Number of focus group responses |         |               |

|                                                                                            |   |   |    |
|--------------------------------------------------------------------------------------------|---|---|----|
| 1. To be educated and informed how ABT works                                               | 5 | 5 | 10 |
| 2. Improve the quality of the structure                                                    | 3 | 3 | 6  |
| 3. Constructor should have built houses which were of the same quality as the show house   | 0 | 4 | 4  |
| 4. Inspectors must always be on site to ensure quality of structures built                 | 0 | 3 | 3  |
| 5. Nothing best could be done; these houses were just unacceptable                         | 1 | 0 | 1  |
| 6. If it could be extended without the wall panels cracking                                | 1 | 0 | 1  |
| 7. The way to extend must be made available to local markets                               | 0 | 1 | 1  |
| 8. Proper consultations and gaining access with the community leaders for decision making. | 0 | 1 | 1  |

According to Noel (2011), accepting an innovation does not mean passive acquiescence. This was in line with the findings of this study where the respondents accentuated proper consultation to prepare the community for the implementation of IBT for housing developments. Reflecting back to the way the IBT project was introduced at Ndevana, one could understand that the community felt undermined when they were not involved in the “choice making” around their housing development issue. Goldston (2010) suggested that the idea of growth and change often stems from the basis that we were disadvantaged in some way and that we need to improve our lives, hence acceptance of new, improved technologies should also follow proper processes.

In relation to this Miller (2008) argues that Science, Technologies and Sustainability (STS) researchers have called for upstream engagement of the broader public in scientific and technological decision-making, in which citizens become involved in choices of design and implementation, whether as knowledge holders or authoritative decision-makers.

According to Miller (2008), a key challenge was how to enable public participants to understand and make visible the potential technological futures for society that stem from today’s choices about the use of new infra-structure or new technologies. Equally challenging was to continue to advance STS research into effective strategies for encouraging effective deliberation of socio-technological options. A third challenge was to structure decision-making processes that ensure that public inputs were meaningful and were effectively integrated into decisions that also entail substantial technical elements. Such processes need to ensure that choices were revisited as the imagined technological futures become concrete as technologies were constructed and used in society; and, finally, important research was needed into the training necessary for technical, policy, business, and civic participants to ensure these processes viably inform decision-making, rather than rendering decisions impossible (Miller, 2008).

## **5 CONCLUSION AND FURTHER RESEARCH**

There are various concerns which leads to the rejection of new technologies that were explained by various authors reflected by literatures reviewed in this study. This study was meant to exhume the concerns related to the rejection of IBT by the Ndevana community. The causes of the rejection were explored, and some of them include structural defects and performance, as well as cost of alterations. These are the concerns that change management officials should be aware of when introducing innovations for housing development to the communities. It was learnt that social change is a process where innovation is not automatically accepted and adopted even if it may bring positive change. Innovation may be partially accepted or entirely rejected. It may need a very comprehensive programme to facilitate the acceptance of innovation in the community. When given a chance to suggest ways to make IBT acceptable, the respondents indicated that IBT may be accepted if proper consultation is done, alterations may be done without structural defects and constant inspection are done during the construction phase of the project.

In light of the explorations in this study, standards of practice towards IBT implementation should be observed to avoid the recurrence of similar situation like this in housing development projects. It is believed that, accepting an innovation is the first step in making real and lasting change. Therefore, a

clear understanding of IBT is essential. For government to achieve total technological diffusion, this paper suggests policy direction learning from identified key drives of rejection of IBT through descriptive themes. Project initiation should be done in the way that the beneficiary administration is done as part of pre-planning. Qualifying criteria and warrants after the grant is awarded should be well explained to the beneficiaries. Thereafter, the beneficiary community should be informed, educated and guided on what the concept of IBT including the functionality of the houses, without imposing anything on them. After IBT acceptance, beneficiaries should be involved in the process of selecting the IBT model to be used in the development of their community and further studies on IBT reception should be done in the process using the existing projects. The IBT companies should be responsible for erecting a demonstration house on site in the presence of the all value chain stakeholders including the beneficiaries of an earmarked project. The procurement including all contract documents for the IBT project should be drafted in such a way that it would be implementable without compromising the quality of the end product delivered to the beneficiaries.

Innovation villages should be established to demonstrate and educate beneficiary communities about the usefulness of IBT. The likelihood, drawbacks and costs for construction and alterations of IBT structures should be clearly explained to the beneficiary community. The similarities and differences between IBT and conventional methods should also be clearly demonstrated. The innovation village should be integrated in a way that allows a space for non-housing innovative technologies to be tried and tested. The likelihood and drawbacks for repairs of IBT structures in the case of disasters and related incidents should be made clear. Effective options should be made available for IBT beneficiaries to add on decorative features without permanent damage to the wall. The construction process should be constantly inspected by IBT competent inspectors who are trained specifically for IBT products inspection.

A training workshop on IBT house maintenance should be done before the handing over ceremony. In the training workshop the IBT House Maintenance Manual should be handed over to the beneficiaries too. Housing units constructed using the IBT system must allow for the long term investment in property especially for the next generation. Housing units developed using IBT should bear a market value. Its market value should be demonstrated with proof that the IBT unit could be bank-bonded or may be used as collateral. Housing development implemented using IBT should allow for the use of quality materials that are available in the local market. A comprehensive change management programme should be developed to ensure positive reception of IBT for government subsidised housing development programmes and its effectiveness should be tracked through evaluation research.

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## **Un-learning ‘community’: Reflections on socio-technical spatial design support with Slovo Park**

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### **ABSTRACT**

The South African city we experience today did not simply manifest in a vacuum outside of the social injustice of the last 400+ years of colonial and Apartheid ‘development’. The four-hour commute that the average Johannesburg city user experiences, the sense of fractured locality across the metropolitans of Durban and Pretoria and the intact socio-economic segregation of townships to suburbs seen in Cape Town are all the tangible legacies of the Apartheid city design that we complicity accept as our South African city on a daily basis.

The knee-jerk reaction by built environment practitioners to this observation is typically a technocratic response to suggest an addition of infrastructure and implementation and not a reform of the practice of city-making. The fact remains that among the large-scale projects our democratic government has implemented we sit with infrastructure deficits larger today than 1994.

The practice of ‘making city’ in South Africa requires some form of radical change, one that calls on all city makers to re-conceptualise how we see, make and manage our spaces. While technical skills and competencies are vital to this approach, the immediate challenge for built environment practitioners can be seen in the lack of skills or willingness of individuals and institutions to engage with the socio-political complexity of our cities. The misnomer that we are dealing with a homogenous technical challenge for a homogenous social demographic of people (or the ‘community’) that can be solved through a ‘better house/shack/dwelling’, a more efficient toilet system or solar panel array, is damaging and criminally myopic in its lack of imagination, creativity or recognition of the situation.

The paper offers a structured reflection on an eight-year case study conducted by the author and his colleagues. The argument of the paper is centred around a critique on the often-misused terms of ‘informality’, ‘community’, ‘participation’ and ‘development’ in the built environment sector of spatial development. The case study unpacks the approach and methods used within the Socio-Technical Spatial Design practice of ‘Neighbourhood Making’ and offers a reflection on critical skills and lessons gathered from the experience. The intent of this reflexive study is to offer a working reference for private-sector practitioners, government officials and grassroots practitioners who are looking to engage informal neighbourhood upgrading in South Africa.

**Keywords:** Informality, community, grassroots, neighbourhood, city-making, Socio-technical, development, participation

### **1 INTRODUCTION**

Since the end of the Apartheid, South African cities have seen a large growth in urbanisation and spatial development. This condition, combined with over 400 years of colonial and apartheid socio-spatial inequality has resulted in over 2700 recognized informal settlements across South Africa of which, according to the Housing Development Agency (HDA, 2018), around 2 million households are living in ‘informal circumstances’, while other statistics state that over 700 000 households of this number live in backyard dwellings. In total, 1 in 5 South Africans lives in inadequate conditions (Isandla, 2013).

Latest statistics suggest that while government efforts have built over 3 million housing opportunities since 1994 (HDA, 2018), the country’s current backlog of housing is still over 2.1 million (Isandla, 2016). This figure is larger today than since it was at the beginning of South Africa’s democracy in April of 1994 - in other words by building houses we haven’t solved the ‘housing’ challenge nor the issue of

'informality'. These numbers indicate that these patterns of city-making<sup>5</sup> will be with us for the foreseeable future and that as a city we should accept 'informality' as part of urban growth (Pieterse & Simone, 2013).

Contemporary urban scholars guide us to rather work with these conditions to address issues of safety, health, livelihoods and access to economic and civic opportunities at what the Isandla (2013) suggests at a '*Neighbourhood level*' - rather than trying to '*eradicate*' it with formal houses or '*formality*' - a turn or phrase that is heavily critiqued and avoided in contemporary practice (Huchzermeyer, 2011).

While '*informality*' is a broad and often unhelpful term in regards to place-making for people it is unfortunately a lens that users, makers and managers of the city understand their operational landscape through (AlSayyad, 2004; Roy, 2005) and is used in this paper as a means of articulating the content. The hesitation to use 'informal' stems from the author's work in the spatial development sector. The term alludes to a negative stigma being attached to people and systems that exist in 'informal' neighbourhoods and is often euphemism for other bigoted perceptions of people. In this respect, residents of informal neighbourhoods face the systemic effects of unequal spatial development (South African Cities Network, 2016) in terms of their physical access (in the form of four-hour commutes to work, education and civic amenities, service access (in the form of bad service delivery of electricity, water and sanitation from government) and social access (in the form of job opportunities and important social networks).

On the average, those living in informal neighbourhoods pay more for basic services, transport and education than those living in more affluent areas owing to this lack of access to the well located city-based amenities (Pieterse, 2008; United Nations, 2016; Cirolia *et al.*, 2017b).

Despite these immense challenges, informal neighbourhoods are some of the most dynamic and entrepreneurial spaces in cities (Roy, 2005); with grassroots businesses, social groups and advocacy groups demonstrating ground-breaking processes to address livelihood creation, building practice and social cohesion that if supported and scaled up have the potential to change our South African city-making processes to be more equitable, grassroots and representative of a South African city. This observation is tempered with caution from Pieterse (2008), who warns of the danger within the binary perspectives on informal neighbourhoods as '*apocalyptic*' or '*irresponsibly optimistic*'. These perspectives and stigmas around informal neighbourhoods are powerful forces that in the author's experience often remain unchallenged and not addressed in the built environment practice space.



Figure 1 Socio-Spatial Mapping of 'informal Urbanism' conducted by the author demonstrating the dynamic of 'informality' (1to1, 2018)

These uncritical views on informal neighbourhoods are a key part of the challenge that government officials, NGO's and other grassroots practitioners in city making face when in working with this sector (Isandla, 2013). These city-making practitioners have very few best-case examples of successful neighbourhood making processes to draw from (NUSP, 2013; Cirolia *et al.*, 2017b) which is compounded by a lack of skilled practitioners (both grassroots and 'professional') or as what Van Donk

<sup>5</sup> City-making is a term drawn from Isandla's 2011 Right to the City document that outlines the principles of city making through a rights-based approach developed with a range of local stakeholder on 11 core principles of inclusive city making (Isandla, 2011).

refers to as 'Design Activists' (Marjam Van Donk & Edgar Pieterse, 2014) and builders - who the author believes are a missing sector of practice in South African city-making.

## 2 SETTING THE CHALLENGE

### 2.1 CHALLENGING DEVELOPMENT

Interwoven in the fundamental views on South Africa's version of urbanisation lie deep (unanswered) questions of resource re-distribution or spatial justice as outlined by De Souza (2011). Spatial Justice is an often difficult concept to articulate in South African cities, and even De Souza writes about the difficulty in identifying what a spatially just city-making practice is, with the provocation: "*What does spatial justice look like?*" The National Planning Commission (NPC) (2010) offers the people of South Africa a vision for our future '*just*' or '*developed*' city:

*By 2050, South Africa will no longer have: poverty traps in ... townships; workers isolated on the periphery of cities; inner cities controlled by slumlords and crime; sterile suburbs with homes surrounded by high walls and electric fences; households spending 30 percent or more of their time, energy and money on daily commuting; decaying infrastructure with power blackouts, undrinkable water, potholes and blocked sewers; violent protests; gridlocked roads and unreliable public transport; new public housing in barren urban landscapes; new private investment creating exclusive enclaves for the rich; fearful immigrant communities living in confined spaces .... (National Planning Commission, 2010)*

While this offering from the NPC sums up the ills of what many city users experience on a daily basis, there are many urban voices who would argue that these are not what makes South African cities difficult to thrive in (Charlton, 2009; Matsipa, 2014), but rather are symptoms of the larger injustices of our city's historically unequal development. These hidden interpersonal intricacies around what is meant by development<sup>6</sup> or upgrading (Abbott, 2002) in South Africa lies at the heart of many disagreements' between practitioners, government and the academy on the topic of city-making.



Figure 2 Explorations of 'development practice' as suggestion of De Souza's provocation - by the author (1to1, 2018)

Development itself is a heavily challenged term, as Hamdi (2004) anecdotally critiques in his description of an exercise that he employs with Development Studies students at Oxford Brookes. In the exercise he allows students to use the Robertson Lexicon to create a list of development terms. From this list he makes students re-organise the terms in to different sentences in different columns to randomly generate statements for development – that all make sense as statements of intent. The point of Hamdi's 'jargon generator' demonstrates his argument: "...*Development is whatever you want it to be*

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<sup>6</sup> Or 're-development' a term employed by the author to recognise the uneven development of South African cities since the geo-political formation of South Africa in 1652.

depending on your politics and ideology: economic growth, rights, freedom, livelihoods, good governance, knowledge, power...” (Hamdi, 2004: xv).

This precludes an important observation that the concepts around development are so interchangeable in the minds of those it affects that to agree on what a ‘re-developed’ city, just city-making or ‘spatially equal’ process is, becomes an impossible and sometimes quite violent task. This observation belies the point that if the understanding of development is contested and abstract, what does the practice of technical or social support towards ‘development’ look like?

Hand in hand with contestation around ‘development’ comes an established history in the use and practice of ‘participation’, a term employed in contemporary development practice since the 1970’s (Cooke & Kothari, 2001) that has seen volumes of critique and exploration amongst scholars and practitioners. The use of participatory practice in South Africa around spatial development and the built environment efforts remains difficult to articulate (Ballard, 2008) as what encompasses the practice seems to conflate consultation, discussion, capacitation, empowerment and other nuances of engagement that the term conflates. Arnstein’s ladder of participation (Arnstein, 1969) offers a global perspective on a structuring of this term, but in the practice of city-making in South Africa the author has more often witnessed the only rungs 1-5 of Arnstein’s ladder (Osman & Bennett, 2013).

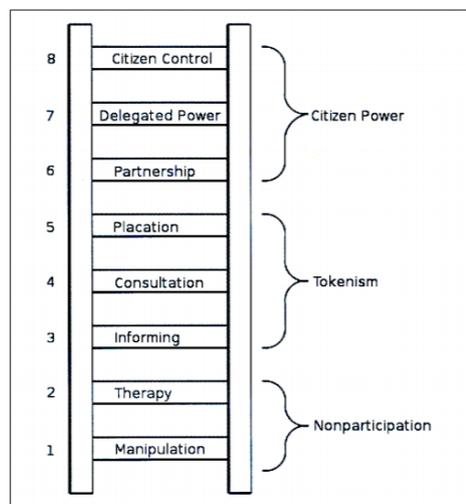


Figure 3 Eight Rungs on the Ladder of Citizen Participation (Arnstein, 1969)

The absence of the citizen power elements of the ladder is an observation is echoed by practice bodies such as DAG and Planact (Isandla, 2013) in their annual roundtables and scholars such as Ballard (2008) who describes how; even though government tenders call for participation in the project structuring of the upgrading of informal neighbourhoods, and even under the UISP has a fiscal allocation of 3% (NUSP, 2013) of project budget to this role, this role in the sector still remains fundamentally missing from built environment projects as a whole.

*“Participation does not necessarily imply self-help home building by undernourished and over-worked people without credit, with inadequate tools and poor materials . . . The central issue is that of control and power to decide”* (Turner & Ward, 1991).

Turner offers a critical observation on the underlying reasons for participation, but locally these practices of participation in the built environment and upgrading space require nuanced local critique in the South African context. Isandla (2013) offers 3 important framing questions on the various forms of citizen participation:

- Who participates?
- How do they communicate and make decisions?
- What is the connection between their conclusions and opinions, on one hand, and public policy and action, on the other?

In other words, participation does not mean much if there is not a space for the actions be implemented or if there is no meaningful feedback structures to those in power or the actions are understood.

## 2.2 CHALLENGING COMMUNITY

The following critique of the term 'community' does not exclude the valid existence of organised groups of people who share vision and the author offers Nick Wates's definition of the term 'community' from *The Community Planning Handbook* as '...a group of people sharing common interests and living within a geographically defined area' (Wates, 2000: 184).

While it often supports a personal (or naïve) optimistic view on dire circumstance, the romantic notions of 'community' only being a well organised, self-propelled cohesive social entity, are not 'fair' to the groups of people who make up the social and spatial networks of informal neighbourhoods. This unbalanced view is clearly seen when projects 'fail' or are halted these groups of people who are held to blame – often against this idealistic view (Winkler, 2013). Again, Hamdi offers a counter perspective and in his written work often describes how 'communities' are not necessarily always organized and cohesive and sometimes lack the 'sense of community' and 'social identity' (Hamdi & Goethert, 1997: 67). He qualifies this by explaining that for participatory processes to work, it is not a requirement to have an already well-organized community from the start of a project. But that a sense of community can be achieved during the course of the work - which he states "...can also be one of the objectives of including community participation in development projects..." (Hamdi & Goethert, 1997).

Guijt and Shah(1999) challenge the term '*community*', arguing that the simplistic understanding of 'community' as a homogenous static and harmonious entity where all involved share the same interests and value are short sighted and often hide important power relations and biases of practitioners and residents. These hidden biases are very dangerous when the line between life and death around development is determined by these understandings. Challenging the use of the term '*community*' is echoed by leading scholars in the field (Cooke & Kothari, 2001; Hamdi, 2010; Chambers, 2017) and remains an unchallenged point in this sector of spatial development in South Africa.

The term 'community' is particularly unhelpful to practitioners in the spatial development sector around housing delivery and urban upgrading as it is often code for 'poor non-white South Africans' and limits the scope of what development projects allow for. The use of the term often implicitly excludes non-qualifiers for support and ignores cultural, gender, nationality and religious dynamics of South African informal neighbourhoods as described in the images below.



Figure 4 An example of complex 'community'<sup>7</sup> engagement in Killarney Neighbourhood, Johannesburg (1to1, 2018)

The use of the term by built environment practitioners often results in myopic perspectives on the needs of complex groups of people who share space into simplistic interventions such as 'community centres' or 'skills centres' that offer generic and often reductive support as pointed out by Hamdi (2010) in his reflection to site visits of similar centres "We have learnt that belonging is not just about location but about meaning and association – the kinds that offer a multiplicity of opportunity for social exchange..." (Hamdi, 2010) and witnessed by the author his in own teaching and praxis in this sector.

These reductive views on people and place have the unaccounted cost of limiting creativity and innovation for strategies of development and reducing the inherent agency that often exists at grassroots level in South African informal neighbourhoods (Bidwell *et al.*, 2010; Marjam Van Donk &

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7 1to1 students who have worked and working on a process of socio-spatial mapping

Edgar Pieterse, 2014). The critique offered here does not deny that communities exist in South African neighbourhoods, but rather that the use of the term is often not questioned or challenged – more often than not there are many ‘communities’ that make up neighbourhood structures.

Hidden in the immensity of the challenge faced by built environment practitioners in the housing delivery sector, but mentioned often in the rhetoric around South African Development processes, is the description of people and place as *Neighbourhood*. The Western Cape Human Settlements’ *Living Cape* framework for Human Settlements makes specific mention of developing ‘resilient neighbourhoods’ and ‘neighbourhood typologies’ and has already begun working with groups of people through this scale of engagement as was demonstrated in earlier work by the author in the figure below.



Figure 5 Alternative means of Digital Tools for Neighborhood level Socio-Technical Support (1to1, 2018)

The right to the city is the right to be ‘messy’ as stated by Simone (Simone, 2013), and the author’s offered term of ‘Neighbourhood’ as a scale of engagement is not intended to be a clinical definition, but rather a more nuanced and flexible understanding of place and the relationship the people who see, manage and make such place have to it.

A ‘neighbourhood view’ on the larger issues of ‘re-development’ removes the specialisation of informal settlement development which should be seen as city development and has the potential to normalise the processes of in-situ development for any form of marginalised area in South Africa. The technocratic approach to these challenges in both the physical and digital space has already shifted away from the sciences (Sambuli, 2016; Berridge, 2017) and is looking to incorporate the humanities and embody the principles of social sciences and development studies in the technical approach. The missing piece remains models, examples and a skilled individuals who can take up the call.

*“A proactive approach to community involvement is not common amongst local councils, yet the reforms to the planning system and to local government generally increasingly require necessitate, both proactivity and systematisation of involvement as well as an implied need to build and sustain a widened network of stakeholder interests in local governance” (Masiko-Kambala, Görgens & van Donk, 2012).*

The term ‘Neighbourhood’ in South Africa has the potential to realistically humanise the complexity of the challenges and offers a spatial delineation to describe a set shareable values and markers for at least a nationally agreed set of ‘development’ standards and ethos in practice.

The following case study unpacks a narrative of what such a role would look like. The case study has been structured to describe lessons, skill sets discovered along the way. The case study reflects on eight years of socio-technical spatial design support for the Slovo Park Development Forum (SPCDF) and offers a reflective case study for practitioners, students and government officials to learn from and critique.

### 3 RESEARCH METHODOLOGY

#### 3.1 SLOVO PARK: SOCIO-TECHNICAL SPATIAL DESIGN SUPPORT, ADVISORY AND BUILDING

##### 3.1.1 Student Phase: 2010 - 2011

In July 2010 the FIFA 2010 World Cup took place in South Africa. The global event brought with it hundreds of thousands of visitors to South Africa and generated a public space through the fan-parks that have never been seen in South Africa since. Charged with this spirit of connectivity and a recent university field trip to Maputo, a small group of students from the University of Pretoria's Masters programme accepted the third quarter elective of working in Slovo Park<sup>8</sup> (Slovo Park Support Team, 2010). The project was structured under Carin Combrinck who at the time had begun her own doctoral inquiry into informal settlement upgrading in South Africa and after establishing a connection with Max Rambau at a departmental conference had arranged for a small student group to conduct an architectural research project with the Slovo Park Development Forum (SPCDF).

The students arrived in Slovo and were introduced to the SPCDF through the Chairman at the time, Mohau Melani, who over the eight-week period of research and design the university offered, worked with the students and the various groups who made up the Slovo Park 'community'. These included the Policing Forum, the Water Forum, the Electricity Forum, the Business Forum, the Church groups, Stokvel's, block committees and sports teams who made up the 4000 people neighbourhood of Slovo Park as indicated below.

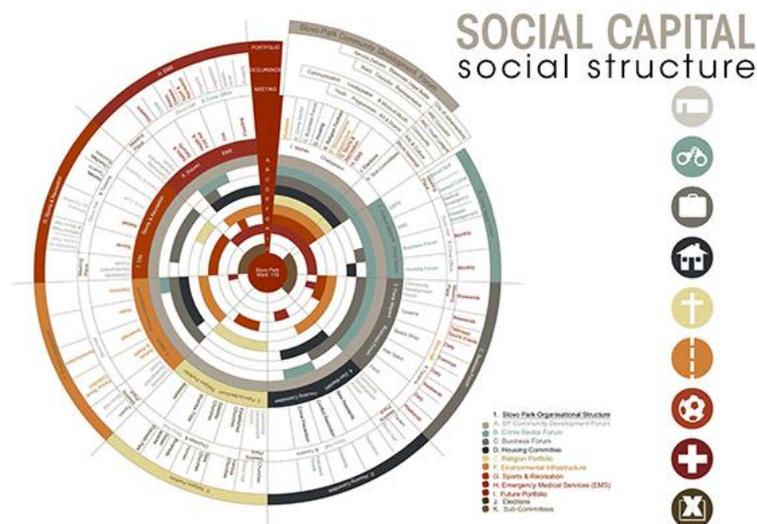


Figure 6 Slovo Park Social Structures that explain the complexity of the term 'community' (Omar Horzook, 2012)

The students realised quickly that the issues at hand were not around the technical design of a house or a shack, but rather the issues were tied into much more complex political, socioeconomic and cultural issues that were halting the development of Slovo Park. The SPCDF had been working towards this goal since 1986 (Tissington, 2012) when the original founders of Slovo Park, Baba Mthembu worked with various elders to block out the settlement (based on the grid of El Derado Park adjacent to Slovo Park) and was now being managed by the SPCDF established in the 1990's (Zondo & Royston, 2016.). The SPCDF had at this point been working with various institutes and universities including the Socio-Economic Rights Institute (SERI) (Tissington, 2012). The proposal by the students, based on this understanding, sought to break away from traditional architectural responses and incorporated ideas of

<sup>8</sup> Slovo Park is an informal settlement comprising about 5000 households, totaling about 25,000 people. Slovo Park is situated in a politically and socially sensitive stretch of land south of Soweto. The community has been known by national government as Nancefield, by local council as Olifantsvlei and in the last five years as Slovo Park – named in honour of South Africa's first minister of housing and former Umkhonto we Sizwe General, Joe Slovo. The forced changing of identity reflects an on-going struggle faced by the leadership of Slovo Park to gain recognition as a legitimate settlement to access governmental support. This battle has been fought through constant shifts in governmental policy, power and promises for the community of Slovo Park. Their only tactics comprising of service delivery protest, painstaking formal requests for upgrade and currently a lawsuit against the City of Johannesburg. (Yolande Hendler, 2012)

incrementalism, livelihoods and cultural infrastructure as a means of working off the inherent energies in Slovo Park (Bennett *et al.*, 2010). These included a housing clinic, a funeral pathway and infrastructure, a public park and a rental housing scheme that employed open-building principles.

Upon presenting this work to the leadership and the community after the academic portion, the students attempted to share the ideas through the drawings in architectural form. This presentation took place in the intersection of the streets in Slovo Park and was later revealed to be a tactical move by the SPCDF to bring on board the local ward councillors and various grassroots groups. The event was an important moment for the students because they dismally failed in communicating their ideas (due to language and visual format) but after the work was discussed intimately with residents in a 1-on-1, or 1to1, manner did the ideas proposed by the students find traction and the students were able to get useful critique on their proposals (Combrinck & Carin, 2015).



Figure 7 Slovo Park Students speaking with Slovo Park residents in a 1to1 manner (Slovo Park Support Team, 2010)

At this moment, the lecturer (Carin Combrinck) in charge offered the students an opportunity to build part of their design idea as part of the final quarter's technical submission. At this point, the students undertook the building of a portion of the design idea as the output for a technical module in their course. The students spoke with the SPCDF who agreed to the idea and after several discussions agreed that a meeting hall (adjacent to the original meeting at the intersection) would be a valuable resource for the leadership. The students then worked with the Business Forum and designed an incremental, multi-use space (Bennett *et al.*, 2010) that could be built in eight weeks with minimal resources and become a larger project later on.

This period of co-design, co-build and co-manage was a challenging period as there was no budget for the project and the team worked with locally sourced recycled bricks, reeds, tyres, steel donated from nearby factories, lunches sponsored by residents and local businesses and eventually a small donation of bricks from an NGO in the final week of the project. The project exceeded the initial proposal and merged into phase 2 as residents gathered resources from employers to propel the build.

Upon the completion of the initial hall, the students realised they had stumbled upon another way of practising architecture (1to1, 2018) and sought to take these lessons further in their studies and practice. The university responded by dissuading the students from this work as they were '*emotionally compromised*' and did not feel the social aspects of this work were vital for architectural training.

### 3.1.2 Key Lessons from being students:

The student phase of the Slovo Park project revealed a key set of lessons:

- The disciplinary boundaries set by the Universities and Institutional bodies are one of the many hindrances holding back the holistic training of practitioners in training and implementation spaces.
- Residents and stakeholders should always be placed at the center of development processes, with practitioners and supporters trusting and following the decisions of local leadership.
- There are many ways to support from a technical space, and many ways to negotiate and barter what that support means and how it is remunerated. It is vital to be upfront and open to be 'turned away' from projects if these are not accepted.

- Expectation management is an important part of this work, but not a factor to stop projects – these expectations must just be negotiated and managed.

### 3.1.3 Skill sets for students:

The skill sets identified in the Student Phase of the Slovo Park Project were:

- Co-productive means of conceptualising, understanding and developing ideas and strategies for spatial development
- Collaborative or Participatory means of practice, work sharing and resource procurement
- Visual Translation and Spatial Literacy towards tactical spatial development.

## 3.2 TEACHING AND TRAINING PHASE: 2012 – 2015

The student group stepped away from the Slovo Park Project in 2012 in order to complete their post-graduate studies. They each engaged with the same topic of architectural response to 'informality' but chose to explore it elsewhere while the lecturer in charge continued an engagement with the SPCDF alongside her doctoral research (Combrinck, 2015). During this stepping-back period the students gathered their perspectives and decided to form a student group named 1to1. This name emerged in response to the moment the drawings made sense to residents in Slovo Park in 2010 (1to1, 2018) . The group intended to carry the questions and actions of making socially engaged architectural work accessible to more students and lobbying the academy to allow this work to be considered part of the training.

On completion of their masters course the original student group returned as studio assistants and took another group of students through the same project in 2012 (Combrinck, 2015), but this time in response to a new set of challenges that a two-year period of reflection had revealed. This included the management of the hall, maintenance issues, internal conflicts between local groups and safety. The 2012 student group worked closely with the Youth Forum in Slovo and completed a new version of the hall in July of that year. This project outlined the need for a formal vehicle to carry the costs, indemnity and support structures of this work and the 1to1 - Agency of Engagement was legally registered.

The need to register the NPC came from the lack of professional opportunities for this type of work and almost no built environment definition for the role that the students had developed with the SPCDF. At the same time, there were almost no precedents in how to structure professional offering for this work and no means of articulating the scope of work or accountability.



Figure 8 2012 students working in Slovo Park on the first 1to1 project (1to1, 2018)

1to1 now managed several tactical neighbourhood interventions in Slovo Park that responded to the needs of the SPCDF and the various groups in Slovo Park (Business forum and Youth Forum in particular) while also creating a mutually beneficial learning relationship between universities and the groups. The intervention built in this period included the playgrounds, hall upgrades, Mandela Day projects, hosted school visits and other tactical interventions.

During this period 1to1 also assisted the leadership in their ongoing court case (Zondo & Royston, 2016.) against the city of Johannesburg while assisting the local NGO, Shack Dwellers International (Yolande Hendler, 2012) with the socio-technical support across Gauteng which Slovo Park leadership played a crucial role in building network of social mobilisation support around their learnings in the project .

The organisation developed several tools and methods (The Blue file, Tools of Engagement) and employed them in the projects they managed (1to1, 2018). The group also sought to build network of engaged students, the 1to1 student league, through this and grow the field of practitioners. 1to1 directors also worked in other professional disciplines (planning, engineering and other related disciplines) to embed themselves and bring in other disciplines in this work.

### 3.2.1 Lesson from Teaching and Training:

- The lack of definition of Socio-Technical Spatial Design allows for existing professional bodies to absorb the work and continue *'business as usual'*.
- Saleability of this type of work was difficult to conceive while developing the practice – an entrepreneurial mindset was crucial to balance research, impact and value translation.
- Sustainability of energies, expectations, resources of all stakeholders (technical and social) is a crucial and often forgotten aspect of this work.
- Maintenance of infrastructures and strategies is a vital aspect of Socio-Technical Spatial Design.

### 3.2.2 Skill Set for Teaching and Training:

- Due to the long-time frames of engagement and stakeholder management, the skills developed around Teaching and Training were a useful skill set to mitigate the role of the university and other outside practitioners involvement as a translation of this time into research and data gathering.
- Learning as a means of generating support from educational facilitates and grant bodies was an effective approach to securing support for indeterminate project outcomes.
- Network and Collaboration building were employed around tactical engagements between government, university and grassroots entities. This proved invaluable in the early stages of this practice.

## 3.3 PRACTITIONERS PHASE: 2016 - ONWARDS

The SPCDF won a landmark case in 2016 (Zondo & Royston, 2016; SERI, 2016), when the City of Johannesburg was ordered by the high court to deliver development promised to Slovo Park through the Upgrading Informal Settlement Programme (UISP). The city had a limited time to deliver this judgement and forced them to work closely with the SPCDF through the pro-bono entity SERI.



Figure 9 Johannesburg Mayor, Herman Mashaba, breaking ground in Slovo; SPCDF member after victory (SABC Digital News, 2016; The Star, 2018)

In the early stages of this process the SPCDF worked with the city processes who followed traditional processes of upgrading, which effectively ignored the requirements of participation outlined in the UISP process. 1to1 alongside representative from the University of the Witwatersrand's (Wit's) Center for Urban Built Environment (CUBES) who were asked to assist, and a technical support team was developed. This role outlined the spatial and technical translation of the city's plans into an cross-visual (Rose, 2016) understandable form. This role also was crucial to support the SPCDF in attending various stakeholder meetings and workshops with departments from the city as seen below.

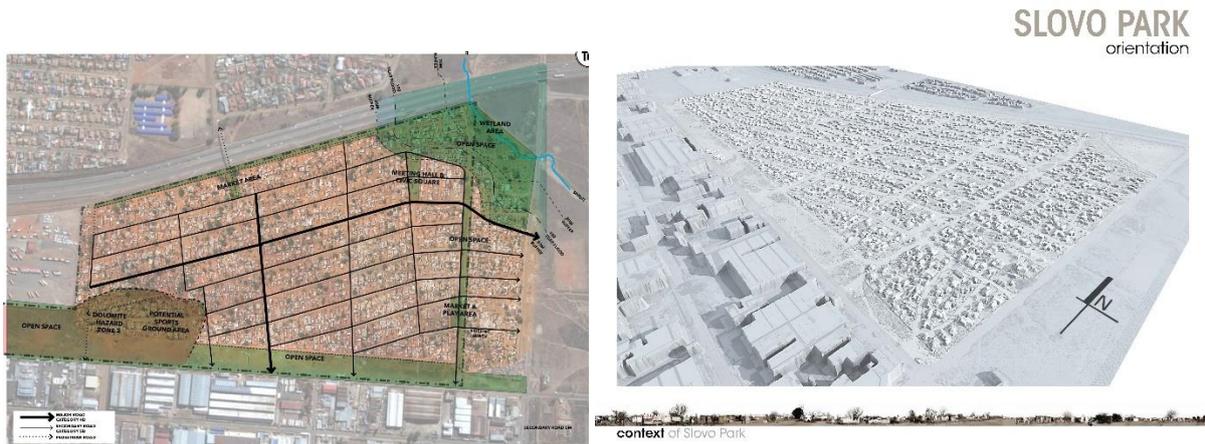


Figure 10 Translated Neighbourhood Diagrams and Models (2012 Students) used in key city departmental meetings with the SPCDF and 1to1 (1to1, 2017)

This role saw 1to1 gearing up and attempting to expand the offering outside of Slovo Park and formalise an approach to Neighbourhood Making that exoriated cross-disciplinary means of supporting development. Eventually, this process broke down and 1to1 offered a tactical workshop to pilot a mini-UISP workshop that would have tested and prototyped the UISP process to demonstrate to all involved. Tragically, the chairperson of SPCDF (and co-founder of 1to1) passed away and the project was stopped during the mourning period and December holidays.

This shifted the nature of the prophecy as the city's mandate change with yet another round of position changes but was saved by the electrification of the settlement (The Star, 2018) but a crucial landmark of development promise for the SPCDF. Today, the role of Socio-technical Spatial Design Support and Advisory continues to be one of translation, ideation and support of visions of local people into action plans, but an additional role of 'strategic facilitator' has been introduced and attempted to fit into the offering.

### 3.3.1 Lesson from Practice:

- Institutional knowledge of the sector was a difficult and hard-won experience set for the organisation. To watch several versions of government support shift and appear was a tricky and process to support within.
- Trust-building and positioning the organisation to be supportive when and if the SPCDF needed socio-technical support was an important takeaway.
- Capacity Building, both internally and externally of the organisation, is an important process that should take place. 1to1 had been working for five years at this point and drawing in much support from supporters to support the work.

### 3.3.2 Skill Sets for Practice:

- Visual translation across different education backgrounds and technical experience
- Spatial Design as means of place-making – not technical upgrading
- Facilitation between different actors, stakeholders and supporters.

## 4 CHALLENGE ACCEPTED

### 4.1 CHALLENGING PRACTICE

The National Upgrade Support Programme (NUSP) was tasked to support in building technical capacity and provide support to local governments across south Africa to meet Outcome 8 of the former NDP (NUSP, 2013) which aimed to develop 400 000 well located informal settlement houses in South Africa by 2014. The instrument of national government has worked across the country in this regard and worked towards the 2014 goal and now the their new targets with a substantial support from National Treasury (Cirolia *et al.*, 2017b).

The position of NUSP in the housing and development sector indicates the nationwide need for socio-technical capacity in the built environment sector to address the issues of housing in South Africa. This need for practitioners is highlighted by Cirolia et al (2017), who describes this capacity in his call for 'intermediaries' between government, residents of informal neighbourhoods and other stakeholders in informal neighbourhood upgrading. The role of the intermediaries should be one of '*...mediator and conflict resolver...'* and need to combine technical knowledge with a sophisticated process that navigate the local context and negotiate communally acceptable options' (Cirolia et al., 2017).

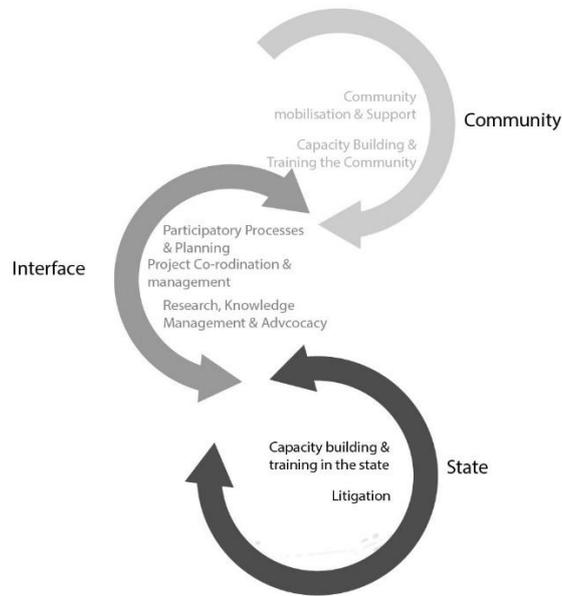


Figure 11 The role of intermediary function in establishing and maintaining state-community interface (Cirolia et al., 2017)

Isandla's work through the GGLN has focussed on framing the issues around building capacity for participative and technical supporting through their project building capacity for the development and use of meaningful collaborative planning tools in South Africa. The project was initiated from the organisation's assessment of the current development approaches and methodologies in South Africa are '*...flawed as they lack meaningful and real public participation...*' (Van Donk & Gorgens, 2012). This work has been extensively documented and the concepts of supporting a 'community of practice' and practitioners are recurring themes at conference and network events on the informal neighbourhood upgrading.

The intimate nature of this work remains largely un-developed, with Van Donk and Pieterse's (2014) call for Design Activism describing this type of practice and the real need for creative and innovative solutions to address these issues with case studies from Latin America to showcase the role that innovation plays in systemic place making. This type of work should not only be 'social', but somehow blend aspects of the technical, creative and spatial into the scope while at the same time building capacity for those who are most affected by these conditions; the residents of these areas (Wilson, 2006). An example of such a practice is offered below.



Figure 12 A neighbourhood making exercise employing digital tools and socio-technical spatial facilitation (Backstory Collective, 2018)

The skills, approaches and embedded methods to meet the demand of practitioner capacity required to address the spatial inequality of cities, particularly in the area of informal settlement upgrading, are in need in the built environment (Cirolia *et al.*, 2017a). The author believes that a difficult part of this individual capacity to articulate, but vital to the practice of equal city making, is set of institutionalised ethos and morals to guide this type of work. This set of moral and ethical guides should recognise the intersectional privileges inherent in the south African post-apartheid Spatial Development built environment (Oldfield *et al.*, 2004; Watson, 2014). These skill sets are present, but currently are not seen as valuable in the discourse around addressing spatial inequality. Private practices are not willing to take the risks, government entities are trapped by their institutional arrangements, residents have too many other problems to worry about and universities do not see a reason to engage other than producing fodder for research. These two together are a vital piece missing in the 'development' sector in South Africa (Combrinck & Bennett, 2017).

While this paper reflects on the case study of Slovo Park and 1to1 – Agency of Engagement, it aims to outline a scale of engagement: the Neighbourhood Scale and an institutional role for the built environment: Socio-Technical Spatial Design. The scale and approach should not be seen only around housing issues but address the systemic legacy of spatial inequality by being used as a means of spatial development that co-produces equitable public and common spaces, a right articulated by Van Donk and Gorgens: '...that is, it should be produced in such a way as to enable the "full and complete use" of urban space by inhabitants in their everyday lives. It therefore includes the "right to live in, play in, work in, represent, characterize and occupy urban space...' (Van Donk & Gorgens, 2012).

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## **The influence of mortar mix design on resistance to damage in light structures built on expansive clay**

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### **ABSTRACT**

Research shows that while the South African government spends millions of Rands building houses for lower income residents, many of these government subsidy houses are failing structurally. As a result, the South African government is now spending millions of Rands in rectifying poorly built light structure homes built on expansive clay. The failure of these low cost housing is attributed to many factors, such as foundation design, quality of material and workmanship. However, there is an inspection element that most home inspectors are failing to pay attention to that is the mortar mix.

This paper investigates, whether the flexible mortar mix used in these houses meet the requirements of the South African National Standards. Brick piers were constructed according to the SANS10164 and tested to determine the bond strength. . It was found that the current construction methods are not adequate to produce proper mortar mixes and that the material used for mortar mixes commonly do not comply with South African National Standards.

Keywords: Bond strength of mortar, fineness modulus, flexibility of mortar, housing

## **1 INTRODUCTION**

Historical buildings are often better able to deal with movements than modern rigid structures, because of the lime mortars which were used in their construction. Modern structures with slender walls set in hard cement mortar with brittle plaster are more vulnerable to cracks (Van Wyk, 2016).

For load-bearing brickwork to be structurally sound, a good mortar mix and the quality of brickwork plays an important role. The difference between good and bad workmanship may make a difference of 25 to 35% in the strength of the brickwork (Van Wyk, 2016). Mortars are classified in 3 categories namely, Class I is mainly used in multi-storey buildings, Class II is mainly used in normal load bearings and Class III is mainly used in lightly stressed buildings (SANS 10164-1; 1980). The study aims to evaluate the influence of mortar mix on damage to light houses built on expansive soil.

The aim of this research is to find a mortar mix which will allow a structure to accommodate considerable heave from expansive clay without cracking and illustrate the importance of mortar design to the construction industry. The objectives of the study are to determine the most economical and flexible mortar mix suitable for light structure houses, demonstrate the importance of bond test and improve serviceability of all types of brickwork.

This preliminary paper documents the preliminary testing to assess the suitability of material currently being used in the construction of masonry structures such as government subsidy housing.

## **2 LITERATURE REVIEW**

### **2.1 EXPANSIVE CLAY**

Expansive clay is the most widespread problem facing housing construction in South Africa. The damage to buildings caused by expansive clay is often expensive to repair. Countries such as United Kingdom and USA have also lost millions per annum in repair of light structures. In South Africa a house built in Queenswood, Pretoria for R60,000 required R24,000 for the repair of the structure, a multi-housing project compromising hundreds of houses, 50% of the houses required to be repaired

(Williams, Pidgeon and Day, 1985). It simply shows that a massive 30-40% of the house cost will be spent on repairing cracks and foundations due to expansive clay.

One of the difficulties arises in the failure to predict soil movement in the early stages of the project.

Figure 1 indicates the areas where expansive clay is common in South Africa. They are classified as either Residual Soils which are developed from basic igneous or argillaceous rocks or Transported soils which are developed from Alluvial, Lacustrine, Gulleywash and Hillwash which contain active clay (Byrne and Berry, 2008).

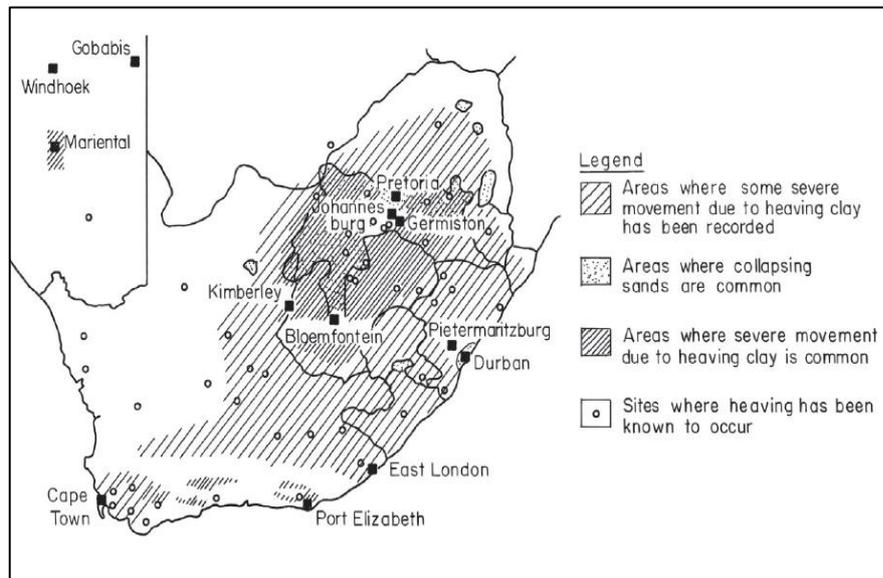


Figure 1 Areas where expansive clays are common (Byrne and Berry, 2008)

## 2.2 FOUNDATION PROBLEM

The major cause for foundation failures on expansive soil is water from rainfall and domestic sources as well as the redistribution of soil moisture from wetter to drier soils or subsurface water, irrespective of the quantity (Brown, 2000). The variation of water results in settlement in non-expansive and expansive soils and upheaval for expansive soil.

In expansive soils the rate of moisture loss due to evaporation is limited because it has a very low permeability properties. A study in the United States indicates that over 80% of total moisture loss occurs within the top 1.5m (Brown, 2000). Evaporation in expansive soils results in the soil becoming drier, the cracks growing wider and deeper, until the soil moisture content approach the shrinkage limit. The soil remains in this state until water is available, which results in the soil then absorbing water and swelling. These changes in soil conditions affect the foundation as it moves up and down, resulting in house cracks. The upheaval due to moisture increase is by far the most serious concern for slabs on the ground.

## 2.3 MORTAR

Lime-based cement mortars have been used in building construction for decades and by adjusting the content of lime and cement in mortars flexibility and strength of mortar could be modified (Tate, 2005). Lime mortar is one of the binding materials that hold together the material of historical structures like stones and bricks and it is obtained by mixing lime and aggregates (Solak, 2016).

This research focused on mortar mixes which include cement, sand, water and lime as ingredients. Mortars are complex composite building materials. "The relative proportions of the various components should offer suitable workability and appropriate physical, mechanical and aesthetic characteristics to the finished product" (Montana et al., 2016).

The primary function of mortar in a wall is to distribute the load evenly on the wall, over the whole bearing area of the structural units. The mortar assists the structural units to resist lateral forces and also to seal the joints for lateral rain (SANS 10164-1; 1980).

The 3 mortar classes are classified according to their compressive strength as tabulated in Table 1:

Table 1 Requirements for mortar (SANS 10164-1; 1980)

| Mortar Class | Min. Compressive strength at 28 days, MPa | Min. Compressive strength at 28 days, MPa |
|--------------|-------------------------------------------|-------------------------------------------|
|              | Laboratory tests                          | Works tests                               |
| I            | 14.5                                      | 10                                        |
| II           | 7                                         | 5                                         |
| III          | 2                                         | 1.5                                       |

## 2.4 MORTAR PROPERTIES

The following properties of mortar, which are briefly discussed below, are of importance in any masonry work:

- workability
- water retention
- tensile strength
- bond strength
- ability to accommodate movement
- rate of strength development.

Workability is the property which allows mortar to be spread easily over the structural unit and affects the satisfactory performance of the mortar and the productivity of the artisan.

Good water retention properties are important to ensure that bleeding and absorption of water from the mortar by the structural units are restricted. Good water retention also ensures that the mortar does not stiffen to the extent that it becomes non-flexible before the structural units can be placed in position. Furthermore, it ensures that sufficient water is retained in the mortar to permit proper hydration of the cement (SANS 0164:1980). The use of lime is a very efficient means of providing water retention and workability

The compressive strength of mortars increases with the increased cement content. The compressive strength becomes significant when high strength bricks are used but it should be emphasized that the tensile and bond strengths of the mortar are more important as compared to compressive strength. No reliable relationship exists between compressive and tensile strength of mortar, while bond strength bears even less relation to compressive strength unless suction and the plastic properties of the mortar are at or near the optimum conditions (SANS 0164.1980)

Bond strength is important not only in relation to compressive or shear strength of the masonry, but also in relation to the passage of moisture. Rain usually penetrates a wall through fine cracks between the structural units and mortar, and only rarely through the body of the structural units or the mortar. The greater the tensile strength of the bond, the greater the possibility of reduced leakage (SANS 0164.1980)

The two most important factors affecting the tensile bond strength are the mortar mix type and the type of brick particularly its suction characteristics. Previous studies have shown that low to moderate suction bricks, have an increased bond strength with the Portland cement content and decrease with the lime content; however, for high suction bricks the bond strength of the straight cement mortar is lower than that of the medium to high lime mortar (Boynton & Gutschick, 1975).

## 2.5 BRICKWORK FAILURE

Cracking is not usually directly attributed to applied loads, but is generally caused by differential movements between the various parts of a building, as a result of thermal or shrinkage effects or foundation settlement. When a strong mortar is used, fine cracks develop between the mortar and the structural units which, as well as looking unsightly, may pass right through the walling and permit the

passage of water. A weak mortar, on the other hand, permits the walling some freedom to absorb movements without obvious cracking and where cracks occur, they will tend to be distributed through the joints (where they are comparatively easy to repair) rather than through the structural units themselves (SANS 10164-1; 1980).

From the above paragraph it is well outlined in the SANS that the mortar mix plays an important role (SANS 10164-1; 1980). The Construction industry should pay serious attention to the importance of mortar mix and apply all the tests necessary for mortar mixes.

### 3 RESEARCH METHODOLOGY

The influence of mortar mix on light structures was investigated experimentally in a preliminary investigation described here. The aim was to establish whether the commonly used materials in current practice are complying to the SANS standards and can deal with expansive clay.

The constituent ingredients of mortar are: Lime, sand, cement and water. The approximate limiting proportions for mortar are shown in table 2 (SANS 10164-1: 1980). The trial mix for this experimental research is shown in table 3. The sand used for mortar mixes shall when 2.5kg of common cement is mixed with 12.5kg of air dry sand, the mixture does not require more than 3 litres of water to reach a suitable consistency (Home building manual, 1993).

Table 2 Trial Mix Propositions (SANS 10164-1: 1980)

| Portland Cement | Lime (l) | Sand (kg) | Water (l) |
|-----------------|----------|-----------|-----------|
| 2.5kg           | 0.5-4    | 12.5      | 3         |

Table 3: Adjusted Mix Propositions

| Portland Cement | Lime    | Sand (kg) | Water (l) |
|-----------------|---------|-----------|-----------|
| 1.67kg          | 0.835kg | 835kg     | 2         |

#### 3.1 SAND

A visit to various suppliers was made to determine which sands are used in housing construction and these were tested for compliance with the requirements of table 4.

Table 4 Requirements for mortar sand (SANS1090:2009)

| Property                                                                                          | Mortar requirements       |
|---------------------------------------------------------------------------------------------------|---------------------------|
| Grading, mass percentage passing sieves that have square apertures of nominal size, $\mu\text{m}$ | Fine aggregate for mortar |
| 4750                                                                                              | 100                       |
| 2360                                                                                              | 90-100                    |
| 1180                                                                                              | 70-100                    |
| 600                                                                                               | 40-100                    |
| 300                                                                                               | 5-85                      |
| 150                                                                                               | 5-35                      |

### 3.2 MATERIAL USED

- Lime: Builders lime complied with the requirements of SABS 523.
- Water: Potable drinking water was used. The water requirement of a sand-cement mix is the volume of water required per cubic metre of the mix to bring it to the required consistency. It influences the water: cement ratio and determines the drying shrinkage of the mix (Addis, 1998).
- Cement: CEM II/B-L 32.5R and CEM I 52.5R Portland cement were used for this research.
- Brickwork: The most economical stock bricks available complying with SANS 227 (Burnt clay masonry units) and normal cement bricks were used for the tests conducted.
- Plasticizers: Plasticizers are allowed but not recommended and were not used for the purpose of this research.
- Bond test: The bond strength of the brickwork was determined by means of a bending test carried out on piers tested as beams supported at the two ends and loaded at the centre. The test was done by checking the bond strength between bricks and mortar by means of a bending test carried out on piers tested as beams supported at the two ends and loaded at the centre (see figure 2), (SANS 10164-1,1980)

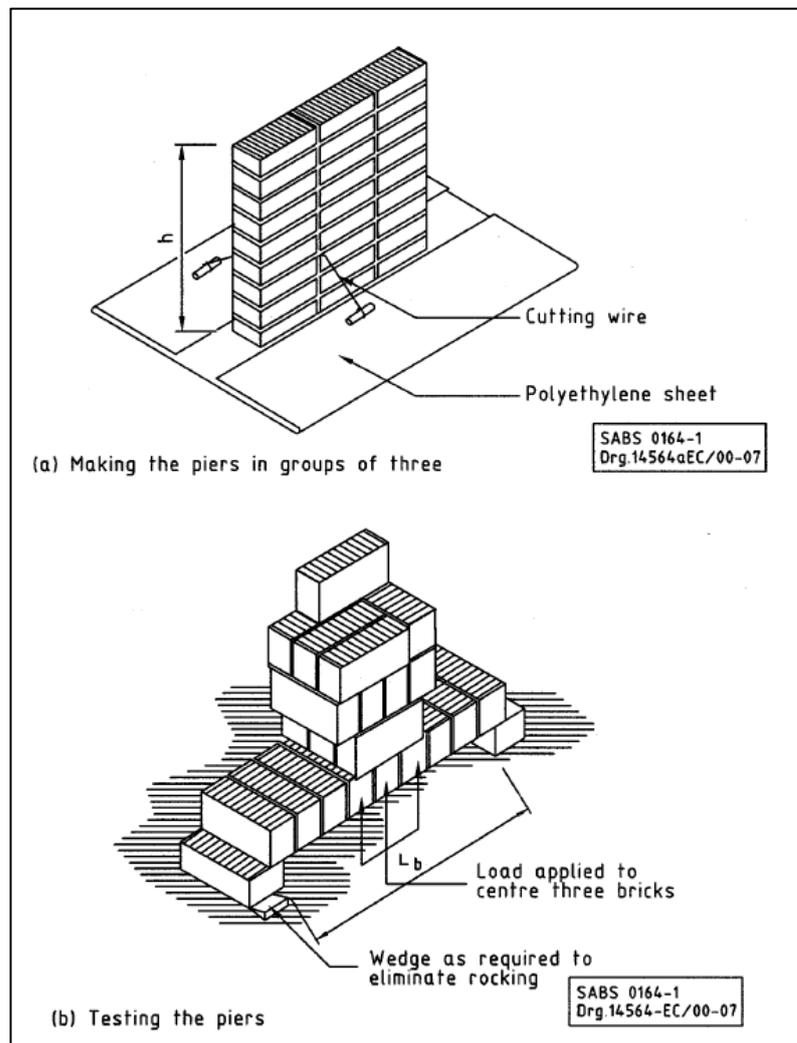


Figure 2 Bending test for mortar bond (SANS. 0164,1980)

### 3.3 CONSTRUCTION OF PIERS

The following steps were followed in the construction of piers:

- Set out three bricks on a firm, flat surface, without the use of mortar, but leaving 6-10 mm between heads.

- Place a mortar bed on all three bricks from, as nearly as possible, a single trowel-full of mortar.
- Wait 30 seconds before placing three bricks on the mortar bed, to produce three stack-bonded couplets. Cut off surplus mortar but do not strike off or tool the joints.
- Two minutes after placing the first mortar bed, place a second bed as in (2) and (3) above.
- Repeat steps (2), (3), and (4) above until the piers are nine bricks high.
- On completion of the bricklaying, cut down perpend with a wire, without disturbing the piers. Wrap the three piers in a single polyethylene sheet and leave undisturbed until the testing date.

### 3.4 CURING TIME AND TESTING OF PIERS

The testing of piers was carried out 7 days after making the piers. This testing period would be prolonged if chemically retarded mortar has been used to construct the piers. Then piers testing would be extended by the full amount of any time, where the air temperature during curing remains below 5 °C plus half the amount of any time in which the air temperature is between 5 and 10 °C.

Carry out the test using the following procedure (see figure 2):

- Weigh the pier to the nearest 0,1 kg.
- Lay the pier on its side, so that the stretcher faces of the bricks are uppermost.
- Support the pier on a clear span of  $L_b$  mm using bricks symmetrically placed at each end for supports.
- Load the pier by placing bricks carefully and without shock on the centre three bricks in the beam, until it breaks.
- Weigh the bricks used to load the beam and calculate the bending stress.

Bending stress is calculated according to the formula:

$$\text{Bending stress (kPa)} = \frac{M}{Z} \quad (1)$$

$$M = \frac{W_1 L_b}{8} + \frac{5W_2 L_b}{24} \quad (2)$$

$M$  = Bending moment (kNm)

$W_1$  = Self mass of beam between supports (kN)

$W_2$  = Applied load (kN)

$L_b$  = Clean span (m)

$Z$  = the section modulus of the pier ( $m^3$ )

In order to allow for the supported ends of the beam  $W_1$  will be multiplied by the ratio of  $L_b$  to  $h$ , where

$L_b$  = clear span of beam (mm)

$H$  = Overall height of pier (mm)

## 4 FINDINGS AND DISCUSSION

### 4.1 SAND

The sand obtained from different suppliers did not meet the SANS recommendations, the fineness modulus obtained for the available sand from different suppliers was either too high or too low as indicated in Table 5. The sand commonly sold for building contained unacceptable clay and silt content. Commercial building sand was washed to remove the clay particles and thereafter graded to obtain the fineness modulus, which was below recommended levels. Crusher dust was blended with plaster sand to obtain a fineness modulus close to that recommended in SABS01064 clause 6.1.2 Quality of materials “*fineness modulus in excess of 2.5 used with the maximum amount of lime indicated in table C-1*”.

Table 5 Fineness Modulus

| Sample Number | Building sand | Washed sand | Crusher dust | Blend Plaster sand and crusher sand |
|---------------|---------------|-------------|--------------|-------------------------------------|
| 1             | 3.57          | -           | 3.71         | 2.6                                 |
| 2             | 3.34          | -           | 3.6          | 2.59                                |
| 3             | 1.85          | 0.64        | -            | -                                   |
| 4             | 1.74          | 0.71        | -            | -                                   |
| 5             | 1.58          | -           | -            | -                                   |

### 4.2 MORTAR

To meet the required water/cement ratio for mortar, 2.5kg of cement mixed with 12.5 litres of dry sand must require no more than 3 litres of water to make a workable mix. Building sand obtained from a commercial supplier required 75% more water than allowable (5.25 litres). When this sand was washed to remove much of the silt and clay the excess water required to produce a workable mix was 50% more than allowable (4.5 litres). Building sand was obtained from a site where government subsidy houses were being built, it appears to be typical of such houses in the Free State. The water demand was similar to that of the commercial supplier, requiring 75% more water than allowable to make a workable mix.

SANS 10164 allows the use of Portland cement (generally known as CEM1), or specific mortar cement only. It is, however quite usual on human settlement housing projects to find other grades of cement containing significant quantities of blast furnace slag or silica fume being used for mortar.

Tests were performed using sand produced by mixing commercial plaster sand and crusher sand in a suitable ratio to give fineness modulus of 2.6. Lime was added in ratio 1:2 by weight.

### 4.3 BOND TEST WALLS

Clay bricks were soaked a day before for building of piers while cement brick were not soaked. The piers were built to conform to SABS 0164 clause 6.7.2 Construction of piers, and tested after 7 days.

### 4.4 TEST RESULTS

- Test walls built with commercial building sand could not be tested since they failed while being prepared for testing. The bond was too weak to support the self-weight of the piers.
- Test walls built with clay bricks and the mixture of plaster and crusher sands described above and CEMII cement either failed while being prepared for testing or gave bond strengths of the order 100 kPa.
- Test walls built with cement bricks and the mixture of plaster and crusher sands described above and CEMII failed while being prepared for testing.
- Test walls built with clay bricks and the mixture of plaster and crusher sands described above and CEMI cement average bond strengths of the order 250 kPa.
- Test walls built with cement bricks and the mixture of plaster and crusher sands described above and CEMI cement gave bond strengths of the order 100 kPa.

## 5 CONCLUSION AND FURTHER RESEARCH

The mortar trial mixes, and the tests on bond-strength piers done in this preliminary investigation, reveal that materials currently being used on many construction sites, including those on government subsidy houses, do not meet the requirements of SANS 1090 and 10164. The bond test walls show the structural inadequacy of these materials. Using mortar mixed with both sand and cement commonly being used on government subsidy houses produced walls which failed even before they could be tested. It is therefore not surprising that many houses are not performing as they should.

This preliminary study has shown that it is essential to extend this study to a detailed research program into efficient and effective masonry production. A detailed investigation into the effect of choice of sand, cement and lime, as well as on cost and quality of resulting masonry will be conducted. The results suggest the superiority of bond to clay bricks to cement bricks also need investigating, to find out how dependent this discrepancy is on the pre-wetting of the bricks, and to establish what is the best method of pre-treatment in both cases.

The research project will also examine resistance to distortion similar to that produced by expansive clay. Mortar mixes will be sought which give masonry flexibility and resilience which will enable them to sustain as much distortion as possible without cracking.

It is proposed that enough tests will be done to ensure a high confidence level in the results. Test panels will be made with original commonly used mortar and research design mortar and will be compared numerically and graphically. Mean and standard deviation calculations will be done to justify that the findings are significant. It is expected that it will be possible to find mortar mixes which will significantly improve the life expectancy of light houses built on expansive clay.

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## **A Framework for Distributed Grids for Municipal Solid Waste Management in South Africa**

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### **ABSTRACT**

A framework for the structural reform of solid waste management is proposed based on the use of distributed grids which encompass a collection of microgrids operating together as a system within distribution networks. The paper explores the concept with regard to municipal solid waste management. A systematic literature review of an electricity distributed grid system is conducted. The components are used to produce a systems diagram. Municipal solid waste (MSW) management is then analysed at a structural level and the component parts for a distributed grid system for MSW management are identified. The paper is limited to exploring a framework where a framework is a basic structure underlying a system for distributed municipal solid waste management. The paper finds that many of the required component parts are already in place albeit operating with a centralised system. The paper finds that waste loads at designated municipal waste sites can be significantly reduced, while also creating a new economic sector that supports job creation. The paper finds that a public/private partnership is a prerequisite for distributed grids. An enabling policy and regulatory environment is required to ensure effective management.

Keywords: Infrastructure, municipal service delivery, municipal solid waste management, distributed grids

### **1 INTRODUCTION**

Despite trillions of Dollars in annual investment in global infrastructure many foundational systems are deteriorating (MGI, 2016). Infrastructure commentators claim that investment in infrastructure is insufficient and the investment needs are only growing steeper: an estimated average annual investment of \$3.3 trillion through to 2030 is required just to support current economic growth projections (excluding maintenance backlogs) (MGI, 2016). It is not surprising therefore that critical infrastructure systems are eroding (MGI, 2016). The poor condition of infrastructure not only undermines the quality of life of communities, but also undermines the performance of companies and their ability to grow the economy (KPMG, 2009). KPMG found that 77 percent of global executives surveyed fear there will not be enough infrastructure investment to support the long-term growth of their organisations (KPMG, 2009).

There are at least two primary causes of public sector under-funding: first, the finance model is dependent on borrowing to fund infrastructure development and the cumulative impact of successive borrowing has negatively affected countries debt-to-GDP ratio, especially so for developing countries (Williams, 2017); and secondly, the urban growth model is based on continuous expansion – known as urban sprawl – requiring continuous extensions to and upgrading of infrastructure megagrids. This perfect storm of challenges has, as Beske and Dixon (2018) note, broken apart a 70-year-old suburban growth model shaped around car-focused, relatively affluent, and dispersed development. They argue that demographic and economic trends suggest that these dynamics will grow more disruptive over the next two decades.

The circumstance regarding infrastructure in South Africa is no different: municipal infrastructure was rated as 'D+' overall in the SAICE 2017 Infrastructure Report Card for South Africa largely due to the increased demand placed on infrastructure from a growing urban population, the ageing condition of infrastructure, under-investment, and lack of proper maintenance (SAICE, 2017). Yet the 2017/18 budget for capital spending and transfers of R173.5 billion (11 percent of total spending) is only marginally more than the budget for interest payments of R169.3 billion (National Treasury, 2017).

Solid waste management, one of the infrastructure systems covered in the SAICE Report Card, is assessed in four categories namely: waste collection in the major urban areas (rated 'C'); waste

collection in other areas (rated 'D'); waste disposal in metro areas (rated 'C+'); and waste disposal in other areas (rated 'D-') where 'C' is satisfactory for now and 'D' is at risk of failure (SAICE, 2017).

The focus of this paper is the management of municipal solid waste (MSW) which typically consists of all solid waste generated within the municipal area although household waste is the dominant contribution. Household waste comprises of an organic fraction (food and garden waste) and a non-organic fraction (paper, plastic, glass, metal, builders rubble, ash, sand, grit, batteries, e-waste, paint, thinners, etc.). About 108 million tonnes of waste was generated in South Africa in 2011 of which 98 million tonnes were disposed of at landfill sites (SAICE 2017). These resources are valued at about R25.2 billion per year (DEA, 2016). However, landfill sites are under pressure in South Africa with some areas having exhausted their landfill capacity (DEA, 2011). In addition, many of the landfill sites are not licensed (estimated at 64 percent for general waste) although this improves to 100 percent for hazardous waste, health care risk waste storage, recycling facilities and transfer stations (SAICE, 2017; DEA, 2011).

This pressure on disposal has supported an increased focus on alternative disposal methods away from landfilling to recycling and waste-to-energy initiatives. Whereas only 10 percent of all waste was recycled in 2011, mainstream recycling has increased to 54 percent currently with scrap metal the best performer (at 80 percent) and eWaste the worst (at 14 percent) (SAICE, 2017). A number of benefits arise from recycling including an improvement in recovery rates from between 3-5 percent for hand pickers at landfill sites to 75 percent for kerbside collections, and an increase in jobs from 6 jobs per 10 000 tons of waste in landfill to 36 jobs per 10 000 tons for recycling (WasteGroup, 2018).

The internationally accepted waste management hierarchy comprises a number of options for waste management namely (in order of preference): waste avoidance and reduction; re-use; recycling; recovery; and treatment and disposal as the last resort (SAICE, 2017). Although recycling is legislated in South Africa, recycling activities are largely executed by the private sector with notable results for tyres, paper and packaging.

## 2 LITERATURE REVIEW

Commentators and economists generally share the view that a substantial boost over current investment is required to overcome infrastructure backlogs, and interventions are therefore primarily focused on developing a range of funding models and instruments (World Bank, 2018; MGI, 2016; KPMG, 2009). Other interventions include improving the productivity performance of the construction industry itself, and improving the planning, project management, and operational capabilities of government agencies and other stakeholders that are charged with carrying out infrastructure builds (MGI 2016). Technology interventions seldom feature as a potential solution and when it does, it is limited to the greater use of Information and Communication Technologies (ICT) (MGI 2016).

The development of microgrids and distributed grids however is highlighting a potential alternative approach to the provision of some municipal infrastructure services most notably electricity generation and reticulation. A distributed grid is not a single technology, but rather, a system of systems – or an ecosystem – that can be applied by multiple stakeholders over a range of spatial scales. This development has prompted interest within the CSIR to evaluate the extent to which distributed grids could be applied conceptually to other bulk municipal services including potable water treatment and reticulation, waste water treatment and reticulation, and municipal waste management and disposal.

Microgrids have rapidly emerged as a viable alternative to a centralised grid in electricity generation and reticulation. In the electricity sector a microgrid is a localised group of electricity sources and loads (sinks) that typically operates connected to and synchronous with the traditional centralised electrical grid (macrogrid), but can disconnect and maintain operation autonomously as physical and/or economic conditions dictate (Berkeley Lab, 2018). Microgrid definitions focus primarily on two features: as a locally controlled system; and as a function both connected to the traditional grid (megagrid) or as an electrical island (Berkeley Lab, 2018).

There are two major types of microgrids namely '*customer grids*' or true grids which are wholly on one site, and '*milligrids*' which involve a segment of the legacy regulated grid (Berkeley, 2018).

There are cogent benefits to be derived from microgrids, i.e. improved energy efficiency, minimisation of overall energy consumption, reduced environmental impact, improvement of reliability of supply,

network operational benefits such as loss reduction, congestion relief, voltage control, or security of supply and more cost efficient electricity replacement (Berkeley Lab, 2018). More critically, microgrids can coordinate all these assets and present them to the megagrid in a manner and at a scale that is consistent with current grid operations, thereby avoiding major new investments that are needed to integrate emerging decentralised resources (Berkeley Lab, 2018).

Electricity microgrids comprise of four basic components as shown in Figure 1, i.e. local generation (solar, wind turbines, small hydro, biomass, and thermal energy sources); consumption (users); energy storage (electrical, pressure, gravitational, flywheel, batteries, and heat storage technologies); and point of common coupling (connection between microgrid and macrogrid) (Berkeley Lab, 2018).

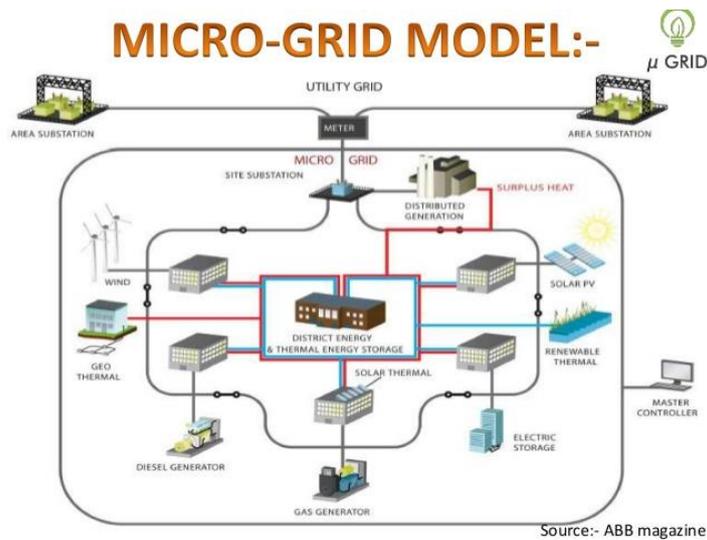


Figure 1 Electricity Microgrid Model (Windpower, 2015)

Electricity microgrids have been made possible by the rapid development of renewable energy (RE) equipment, reducing costs of RE equipment over time, and a reduction in electricity prices. As a consequence global microgrid capacity had reached 20,766.2 MW in the fourth quarter of 2017 (Navigant Research, 2017). Due to the structure of the grid most of the investment for this capacity came from institutional and private sector investors (Navigant Research, 2017).

### 3 RESEARCH METHODOLOGY

In determining an appropriate research methodology for the paper, consideration was given to the key characteristic of the research problem i.e. assessing the replicability of an electricity microgrid system for other municipal bulk services, in the case of this paper, municipal solid waste management.

This study makes use of a systematic literature review (SLR). This research methodology has been used by other researchers working in comparable fields with a similar desired outcome (Walter *et al.*, 2009; Kitchenham *et al.*, 2009).

Siddaway (2014) defines a SLR as a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review. Kitchenham (2007) describes a SLR as a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest. Reasons for undertaking a SLR include (Kitchenham, 2007):

- To summarise the existing evidence concerning a topic area of phenomenon of interest;
  - To identify any gaps in current research in order to suggest areas for further investigation;
- and

- To provide a framework/background in order to appropriately position new research activities.

The literature review appraises the critical points of current domain knowledge and methodological approaches adopted in this domain with a view to summarizing the current body of knowledge on microgrids and developing generally accepted microgrid systems. A list of keywords is used such as 'microgrids', 'distributed grids', and 'infrastructure'.

The research design relies on empirical studies using data obtained from case studies and technical assessments. In this sense the empirical design is archival, making use of recorded facts but without direct observation of the facts, which may come from primary and secondary sources.

Having established the electricity microgrid system requirements the study is able to assess the replicability of microgrids for municipal solid waste management.

## **4 FINDINGS AND DISCUSSION**

Waste is defined in the National Waste Management Strategy (NWMS) as any substance, whether or not that substance can be reduced, re-used, recycled and recovered that is surplus, unwanted, rejected, discarded, abandoned or disposed of; which the generator has no further use of; that must be treated or disposed of; or that is identified by the Minister as a waste (DEA, 2011). The NWMS acknowledges that one of the challenges of waste management is the absence of a recycling infrastructure which will enable the separation of waste at source and diversion of waste streams to material recovery and buy back facilities (DEA, 2011). The NWMS further notes that only a few waste treatment options are available to manage waste and are therefore more expensive than landfill costs (DEA, 2011).

Two of the NWMS's goals directly enable a distributed grid (although it is unlikely that this was in the authors' mind when it was drafted): the first is the promotion of waste minimisation, re-use, recycling and recovery of waste; and the second is to grow the contribution of the waste sector to the green economy (DEA, 2011).

These two goals form the foundation of a distributed grid: firstly, converting waste into an economic resource; and secondly enlarging the waste management sector to include a network of public/private partnerships. Distributed grids depend on an intermediate structure between the producer (generator) and the municipality (collector) for its operation.

There is sufficient evidence to indicate that this layer already exists in certain waste streams. Data by Plastics South Africa indicates that there were 204 active recyclers in South Africa towards the end of 2016, up from 176 in 2009 (PlasticsSA, 2017). The results from their 2016 survey confirmed that there is a growing awareness of recycling and public pressure to recycle resulting in more post-consumer and post-industrial plastics being made available for reuse (PlasticsSA, 2017). They note that recycled tonnages have grown by 35 percent since 2011 with a growing number of organisations and consumer groups becoming actively involved in upstream collection efforts (PlasticsSA, 2017). They note further that the recyclers provided formal, permanent employment to 6 140 staff and supported the informal employment of 51 500 waste pickers and collectors (PlasticsSA, 2017).

The South African Waste Sector 2012 report (DST, 2013) found that the private sector was already engaged in the handling of a wide range of waste which would suggest that a key component for distributed waste grids is already in place.

The NWMS constructs a waste management hierarchy which is useful to consider when conceptualising a distributed grid for municipal waste management (Figure 2).

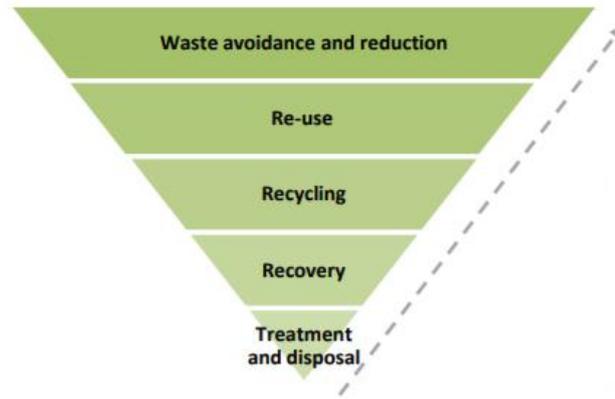


Figure 2 Waste Hierarchy (NWMS 2011:18)

A distributed grid would essentially construct a network of private sector capacity – the country wide infrastructure to enable re-use and recycling referred to in the NWMS (2011) – across and within each of the steps in the hierarchy. The grid would operate at a number of scales similar to the electricity microgrid from individual households to (sub) urban blocks, precincts, and to the city. This new operational network will amend the role of the municipality by shifting more of the management functions to the private sector with the public sector exercising an oversight and governance role.

Using the electricity microgrid model as shown in Figure 1, a modified distributed grid flow diagram based on a typical municipal solid waste management system as depicted in the Municipal Solid Waste Tariff Strategy (DEA, 2012) can be constructed where the red box indicates the area of operation of distributed grids (Figure 3). As is the case with electricity microgrids, MSW distributed grids also comprise of four basic components as shown in Figure 3, i.e. local generation; on-site sorting, separation and storage; collection by various stakeholders including informal waste pickers; reclamation, recycling, reuse, and sale. As indicated in Figure 2, it is the remainder that is finally disposed of for either waste-to-energy conversion, or to landfill.

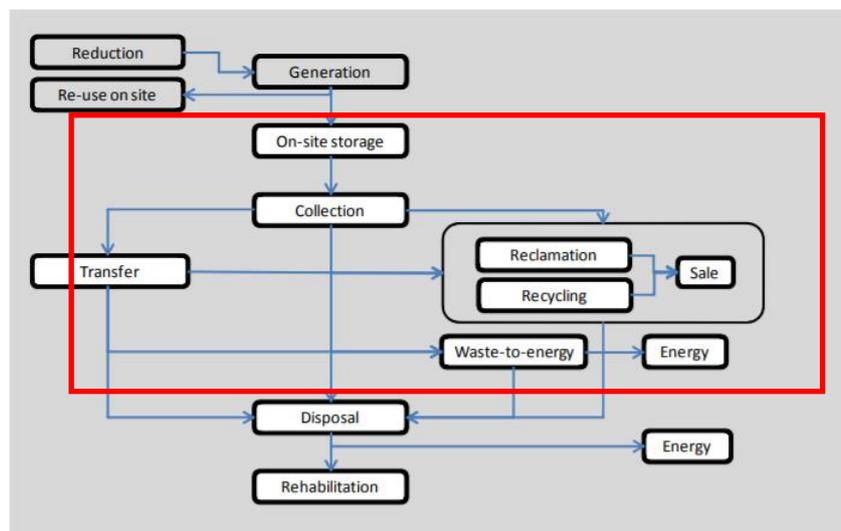


Figure 3 Distributed Municipal Waste Grid Framework (DEA 2012:6)

Growing the role and responsibilities of the private sector will stimulate job creation and broaden participation by SMEs and marginalised communities as indicated in Goal 3 of the NWMS (2011). A distributed grid gives greater effect to 'Goal 5: Achieving integrated waste management planning' (NWMS, 2011): whereas Goal 5 envisages the function to be solely that of municipalities, a distributed grid will assume many of those functions. This will in turn have an impact on 'Goal 6: Ensure sound

budgeting and financial management for waste services' (NWMS, 2011). Experience with microgrids in the electricity sector has demonstrated that creating additional capacity through the private sector has reduced public sector expenditure on electricity generation and distribution.

A significant difference between an electricity distributed grid and a municipal solid waste distributed grid is the value proposition to the household: whereas investing in private RE generation offers cost savings over time (payback period) to the investor, a similar incentive is not immediately obvious in the solid waste distributed grid. This could alter if disposal tariffs increased and/or households received payment for the waste.

## **5 CONCLUSION AND FURTHER RESEARCH**

The paper finds a strong conceptual correlation between the structure of electricity microgrids/distributed grids, and a possible distributed structure for municipal solid waste management. The paper finds that an enabling environment already exists: the South African policy environment is strongly supportive of the foundational elements of distributed grids for municipal solid waste management while a robust private sector waste management capacity already exists suggesting that the economic opportunity has been identified.

The paper finds that sufficient evidence exists to demonstrate both the economic and job creation contribution potential of distributed grids for municipal solid waste management. However, financial incentives will need to be put in place to encourage households to participate in a distributed grid. This may be a combination of increased municipal waste disposal tariffs and potential income from waste collectors. The paper finds that electricity microgrids have added additional resource capacity to the national grids at no expense to the public sector. The paper expects that a similar outcome can be expected for the municipal solid waste service.

The paper finds that institutional arrangements will need to be remodelled to facilitate the establishment of new and extensive public/private partnership arrangements. These arrangements will be based on greater private sector management with municipalities exercising an oversight and governance role.

Electricity microgrids and distributed grids have demonstrated a viable alternative service delivery model, one in which greater responsibility for the provision and management of electricity services is placed in the hands of consumers and private sector service providers. Providing consumers realise benefits from such a model – and there is every reason to believe that solid waste distributed grids will deliver similar benefits as the electricity microgrids – distributed grids for municipal solid waste should be equally viable. If this is the case, distributed grids hold the promise of creating a new infrastructure delivery paradigm that can contribute towards the reduction in service backlogs and future infrastructure development.

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This paper constructs a conceptual framework for the application of distributed grids for municipal solid waste management. The model will need to be further expanded and tested for viability. This will require engagement with all the role players in the waste management sector, and the undertaking of case studies to examine where, and how, this might be working in South Africa and abroad. The value proposition to both individual households and recyclers requires further research.

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## The need for re-thinking national standards for human settlements

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### ABSTRACT

Construction in South Africa is regulated by national standards. At the beginning of the present millennium South Africa moved away from SABS 1200, a standard which assigns overall responsibility and accountability for an engineering construction project to the engineer. It has been replaced by SANS 2001, which does not specifically assign responsibility and accountability to any party involved in a construction project. The philosophy behind this change may have been attractive, but the results in practice have been very unsatisfactory for many construction projects, including those for human settlements. Engineering decisions are now being taken by officials with little or no engineering knowledge, contactors are answerable to officials with little or no engineering knowledge or experience to provide guidance or to assess the work. Engineers have little or no power to enforce sound engineering practice. Approach and assessment procedures are being specified by administrators with little understanding of their relevance or value, and with no knowledge of advances in testing techniques or methods of analysis. Quality of construction has suffered, and failures have become commonplace. A re-evaluation of construction standards needs to be considered.

Keywords: SABS 1200, SANS 2001, SANS 3001, National Standards for Engineering Construction

### 1 INTRODUCTION

It is a universal principle that responsibility goes hand in hand with authority. According to this universally accepted principle SABS 1200 assigned overall responsibility and overall authority for any engineering construction project to the engineer. SABS 1200 also made very clear the responsibilities and privileges of the other parties to an engineering project - the owner and the contractor. Every person responsible for each aspect of a construction project was in no doubt about the chain of authority and responsibility on the site. About twenty years ago this situation came to be deemed politically incorrect. Political correctness demands that all men are equal, and SABS 1200 was considered to give the engineer an unacceptably privileged "master" status (Watermayer *et al.*, 2012). It was therefore replaced by SANS 2001, which gives nobody in particular overall responsibility for an engineering construction project. The high level of unsatisfactory performance experienced in a large number of projects over the past decade raises the question of how wise was the move to replace SABS 1200 by SANS 2001.

The overall result of the move towards SANS 2001 has been the removal of the engineer from the position of general oversight of engineering projects. The engineer is now a service provider who can be brought in where required to deal with technical aspects. The "owner" is often a government department, usually ill-equipped to deal with engineering decisions and whose main concerns are political objectives and budget allocations. Where the owner is a private business enterprise it is common practice to give control to a quantity surveyor, whose expertise is in costing, not in engineering. He is instructed to make sure that the budget for the construction is not overspent. One of many weaknesses of this situation is that the body with overall authority for the construction is not concerned with, or aware of, new developments in engineering. Specifications are written without any consideration for new developments, and engineers who do keep abreast of progress are only called in as contractors to perform certain tasks with already predefined specifications.

## 2 SABS 1200 VERSUS SANS 2001

SABS 1200, the normative standard for engineering construction in South Africa until gradually phased out over the last decade, was very specific about a number of items and procedures which must be the responsibility of the parties involved in construction– the owner, the engineer and the contractor. It was very specific about the fact that the engineer carries overall responsibility and authority. Typical examples of this are found in its “General Scope” section where we find a set of definitions including: “Acceptable: acceptable to the engineer. Approved: approved by the engineer. Adequate: adequate in the opinion of the engineer. Authorised: authorised by the engineer. Rejected: rejected by the engineer (SABS 1200 1986 (A) General Scope, Definitions).

A change in philosophy concerning authority swept through not only South Africa, but much of the world around the beginning of the 21<sup>st</sup> century. Authority came to be seen as an unwelcome entity connected with a “master – servant” relationship. Watermayer et al.(2012) commenting on the demise of SABS 1200 repeatedly refer to it as being a product of an outdated “master-servant” mentality and give the impression that SANS 2001 represents progress by moving away from this. SANS 2001 (2008), in total agreement, specifically states: “These standards do not make reference to the actions of those responsible for executing the works or the parties to a contract”. This may give the politically correct impression that the “master-servant” relationship has been banished from the construction industry, and presumably construction will follow a committee-style process where nobody is in total control and all involved can agree on the best way forward. This has not happened. The owner has discovered that he is free to do as he pleases. And what pleases the owner is getting more for his money than sound engineering practice can buy. It is now common, both in public service and private practice to divide an engineering project into individual sections and put each out to tender. The owner is not usually in a position to assess the capabilities of tenderers to accomplish the job and usually chooses the cheapest tender for each stage. The cheapest is not necessarily the most competent tenderer – competent tenderers have a far better understanding of the difficulties and costs involved and may give a realistic quote which is not the cheapest and is not accepted. The tender price accepted leaves the tenderer with little option but to cut corners whenever the owner is not looking, or to go bankrupt. The next stage of the work is built on the foundations which the first tenderer laid – by the cheapest tenderer for the next stage. So when the job is completed, and the work starts to crumble within a few years, who is responsible? Each contractor can claim either that they could only build on the inferior work of contractors who’s work went before theirs, or that they cannot accept responsibility for inferior work which others did after them.

But this is not the only problem. The contractor knows that the person who can judge the adequacy of his work – the engineer – has little or no authority. He may go to the owner and say “the engineer’s specification is unreasonable, it would be much cheaper to do this instead and it will work just as well. And all too often the quantity surveyor, who is worried that the job is getting ahead of his over-optimistic promises to the owner, sees this as a way to get back to the budget; or the appointed inspector agrees to the change for a donation of cash or services in return; the cheaper alternative is installed. The engineer may be neither consulted nor informed.

Replacement of SABS 1200 by SANS 2001 has not led to the elimination of a “*master-servant*” relationship in construction projects, it has only changed the nature of the leader of the team from a person skilled in sound engineering practice to one skilled in some other discipline - typically cost or political necessity. Engineering decisions are consequently being taken without consultation with the engineer.

## 3 METHODOLOGY FOR THIS STUDY

Justification for the above contentions does not follow the normal research pattern of putting forward a hypothesis and testing it by laboratory experiments. The nature of the problem does not lend itself to such an approach. The propositions of this paper are supported by personal experience in the practice of Civil Engineering. The author has been a professional consulting engineer since 1984 and has experience of practice under both SABS 1200 and SANS 2001. A number of mini case studies from the author’s personal experience are presented to demonstrate the arguments put forward. Many more could have been added, but those presented illustrate most of the relevant points raised.

## **4 FOUR CASE STUDIES**

### **4.1 HOUSING PROJECT IN NORTH WEST PROVINCE**

A contractor, engaged to construct a government subsidy housing project in North West Province, ran into difficulties in 2017. He invited another contractor to take over the project. The second contractor asked an engineer for his opinion on the viability of taking over the contract. Site inspection showed that many of the proposed houses were in areas with expansive soil conditions. Inspection of the drawings showed that the foundation design was unsound. One corner of the house was founded on a pad footing, the remainder on a stiffened raft. The contractor was advised that this would lead to differential movement between the raft and the pad footing which would lead to cracking between the corner involved and the rest of the house. Inspection of the houses built earlier in the project showed cracking exactly as predicted. The engineer advised that the pad footing must be incorporated into the raft foundation. The extra expense would be far less than the cost of returning to site during the 5-year maintenance period to repair the inevitable damage. The contractor was prepared to shoulder the extra cost of expanding the raft but the Human Settlements representative refused to allow this alteration. He pointed out that if the corner of the building were joined to the rest of the foundation, the house would be considered by the department to have a greater area than they were committed to build. A representative from the NHBRC was consulted. He acceded that the design was unsound and would lead to cracking of the house, but claimed that this was no concern of the NHBRC; the NHBRC only checks that the construction complies with the drawings. Such a situation, where administrators lacking in elementary engineering knowledge take engineering decisions, is most unfortunate. Any contractor undertaking to construct such houses - on any but the most favourable foundation conditions - is condemned to building structures which have no chance of delivering satisfactory performance.

### **4.2 HOUSING PROJECT IN CENTRAL FREE STATE**

An engineer was engaged to design foundations for houses in a government subsidy housing scheme in the central Free State. The geotechnical investigation indicated high heave potential in the underlying soils. Foundations using waffle raft construction were chosen by the engineer as most suitable, and designed accordingly. A contractor with considerable experience in waffle raft construction was engaged to build the foundations. Inspections by the engineer showed that the foundations were correctly excavated, correctly water-proofed, and correctly supplied with reinforcing steel. Permission was given to cast the concrete. The engineer arrived on site just as concrete was about to be poured to find that the foundations were in chaos. The contractor informed the engineer that the project manager had instructed him to change the waterproofing to an arrangement which is impracticable for a waffle raft. The engineer went to the client's project manager, a young graduate with virtually no experience in construction and asked why he had interfered with the foundations. He said he thought it would be a better idea to do the waterproofing the way he had ordered the contractor to do it. The engineer explained why such a scheme cannot work for a waffle raft. By this time, however, it was too late to return to the correct method since concrete had been cast. The engineer refused to accept responsibility for the foundations as cast. The project manager had no professional qualifications to allow him to certify the foundations. Such situations, which were unthinkable under SABS 1200 are commonplace under SANS 2001.

### **4.3 WAREHOUSE PROJECT IN CENTRAL FREE STATE**

A contract for a warehouse in the central Free State stipulated a maximum value for Plasticity Index (PI) for material which could be used as fill material under the parking areas. This is common practice in many construction projects. Samples of material from the site were sent for testing at an accredited laboratory. The engineer declared the PI to be too high and rejected the material for fill on the project. The contractor persuaded the Quantity Surveyor that the laboratory where the samples had been tested was well known to give unreasonable results and suggested sending samples to a different laboratory, since using the material from the site would lead to significant cost saving. The second laboratory gave an acceptable PI and the Quantity Surveyor in charge of the project accepted the material as suitable for construction. A soils testing laboratory manager was questioned about this situation. He stated that it is common to find a contractor asking for results which indicate a low PI. He typically points out that he often has samples for testing and he will give the work to the lab which gives him the lowest PI. Under SABS 1200 this situation could not occur since the acceptability of the material would have been at the sole discretion of the engineer.

#### 4.4 HOUSING PROJECT IN BLOEMFONTEIN

An affordable housing project in Bloemfontein was begun in 2014. The first phase of the project consisted of multi-storey apartments. The project was split into two contracts, the first involving earthworks to form the platforms on which the buildings would be erected, together with the infrastructure for the site – water supply, sewers, storm water drainage, fire-mains, electricity conduits etc. The second contract involved the construction of the buildings. If the project had been constructed under SABS 1200, one of the engineer's first responsibilities would have been to provide reference pegs from which the project would be controlled and the contractor would have been required to protect and reference those pegs for use throughout the life of the project (SABS 1200 AH General 5.2 Setting out). Under SANS 2001 nobody is responsible for setting out, so setting out for stage one was given to the cheapest-tendering surveyor. Nobody is responsible for protecting setting out pegs, so they were not protected.

The cheapest, quickest method of surveying uses GPS equipment - in a "*cheap and dirty*" way (the only way to tender and stand any chance of being awarded the job). GPS equipment can give accuracy of about 20-30 mm if strict procedures are followed. This requires that a base station must be set up on a point with established co-ordinates. A probe must communicate with this base station and the same satellites as the base station throughout the time that the probe is used to set out positions. All readings from both station and probe must be recorded with time stamps. After the survey is completed the satellites' actual positions at the times of the recorded readings must be obtained from the satellite tracking system and all field co-ordinates must be corrected. The surveyor must then return to site and adjust all the pegs to their correct positions. This is time consuming, expensive, and inconvenient. It is not done in practice on a typical engineering site. Instead the positions set out by the surveyor are usually set out without accurately coordinating the base station and without any checking of the true satellite positions. The surveyor typically believes his points to be within about 300mm of the true position. In fact they are often far less accurate than this. In this contract the infrastructure was set out approximately 600mm to the North of the correct position. After the infrastructure contractor had left site and the project had been handed over to the building contractor, another cheapest-tendering surveyor set out the buildings 600mm to the South of their correct positions. Since the design had placed the services 1200mm South of the buildings, the foundation excavations were exactly over the pipes installed by the first contractor and wholesale destruction of the infrastructure occurred. Under SANS 2001 it is not clear who, if anyone, is responsible. The project was delayed for a long time and construction was suspended. Everybody involved lost a great deal of money and housing delivery commitments were not honoured.

## 5 LOSS OF ENGINEERING SKILLS

Another consequence of the change from SABS 1200 to SANS 2001 has been loss of engineering expertise. A tertiary qualification in engineering has traditionally been an indication that a student has gained sufficient grasp of the basic principles of engineering to start learning to become an engineer under the guidance of an experienced mentor. Without competent engineers to act as mentors new competent engineers will not be trained, no matter how many students receive degrees. The reduction of civil engineering practice to piecemeal sub projects, with each being given to the lowest tenderer, and under the overall management of someone with little or no understanding of engineering, has been a contributing factor to thousands of South Africa's competent engineers leaving the country. Many are now in Canada and very many are in Australia. This has led to major consequences for both the public and private sectors. In the public sector, there are few competent engineers to serve as mentors to graduates. In the private sector some of the most experienced and successful civil engineering consulting firms have been taken over by Australian companies. Design work may be done in Australia with consequently little mentoring of South African graduates in the design process. Shortage of engineers has probably been one of the factors in the lowering of standards for admission to tertiary engineering institutions and the lowering of standards for obtaining engineering qualifications. Engineering firms are now faced with the fact that many graduates have an inadequate grasp of basic engineering principles. In order to mentor such an unprepared pupil engineer a competent engineer needs to spend an uneconomically large amount of his time attempting to fill gaps in basic understanding. This would be a problem even if there were still enough competent engineers to serve as mentors to the growing number of graduates needing to be trained.

## 6 LACK OF TRANSFER OF NEW KNOWLEDGE INTO ENGINEERING PRACTICE

Research is being conducted into many aspects of improving engineering techniques. For several years work at the Central University of Technology has been examining the suitability of current methods of assessing the heave potential of swelling soils, and looking into alternative, more effective, procedures. This has largely been aimed at solving the problem of large numbers of government subsidy houses becoming structurally unsound within a few years of construction. This research has revealed that deficiencies in the standard testing methods are responsible for a large number of government subsidy houses having been demolished in less than one tenth of their design life-span. The findings have been published in the Journal of the South African Institution of Civil Engineering, and in international journals (Stott & Theron, 2015, 2016, 2017; they have been presented at conferences in South Africa and abroad (Badenhorst *et al.*, 2015, Stott & Theron 2015, 2016, 2018, Monje *et al.*, 2016, 2017, Bester *et al.* 2016, Theron *et al.* 2018); they have been presented in lectures and workshops for engineers at which representatives from the department of public works, the NHBRC, and consulting engineers have been present. There has been general recognition that the current testing standards (in particular SANS 3001) are deficient and need to be changed. But all concede that there is a major stumbling block to putting new techniques into practice. Under SANS 2001, control of engineering projects is not in the hands of engineers. It is in the hands of people who do not read engineering journals, do not attend engineering conferences, do not keep abreast of advances in engineering research, and do not appear to see much necessity to seek the advice of engineers, who are, after all, only appointed as secondary service providers. Sadly this appears to ensure that there is little likelihood of the relevant standards being changed before many more projects suffer extensive and expensive failures.

## 7 CONCLUSION

The adoption of SANS 2001 in place of SABS 1200 was largely based on philosophical grounds (Watermayer, *et al.* 2012), and deliberately abandoned the accumulated experience of two centuries of engineering experience, apparently in favour of a desire to transform construction into a platform for egalitarian ideals. It was specifically aimed at removing the engineer from a position of overall authority and responsibility which was seen as a manifestation of a “master-servant” mentality. By removing any statutory allocation of responsibility it was presumably intended to lead to a consensus type of leadership for engineering projects. While this may be philosophically attractive, it has not proved successful in practice, as can be seen in the typical case studies outlined in section 4. The situation which has developed is that the owner of a project either retains command of the project and delegates specific responsibilities for various aspects of the project to the lowest tenderer, or the owner gives overall responsibility to someone, often a quantity surveyor, who is instructed to accomplish the project as quickly and cheaply as possible. The person in charge is therefore unlikely to be competent in engineering, and unlikely to take decisions guided by sound engineering principles. It has become common for a construction project to be founded on unrealistic expectations incompatible with sound engineering principles. Rapid deterioration of the resulting structures has become common and several almost universal features of SANS 2001 projects have led to a general lowering of standards: Examination of alternative engineering solutions to identify the best and most economical approach is now rarely undertaken. Geotechnical investigation is often cursory, inadequate, and performed by inexperienced personnel. Surveying and setting out is not done by engineers using suitable equipment for the degree of accuracy required for good quality construction, but by land surveyors using the cheapest techniques to allow a tender to be attractive to the owner – accuracy of setting out is rarely even considered. Materials on site are usually chosen on price alone. The quality of such items as sand and cement is usually disregarded even when materials do not come close to meeting SABS requirements (Sehume *et al.*, 2018). Testing is rarely done to check compliance with standards. Many of the competent engineers who gained their engineering experience and competence under SABS 1200 have left the country. Many young engineers being trained in South Africa at the moment are gaining experience not in the engineering excellence encouraged by SABS 1200, but in cut-price accommodations to second-rate solutions dictated by leaders with little or no engineering expertise, as is the situation under SANS 2001. If this situation continues, engineering excellence is likely to become a lost art in South Africa.

To solve these problems will not be easy. A decision needs to be taken that South Africa needs to pursue engineering excellence, rather than the false economy of demanding more for available finances than can be provided by sound engineering practice. One prerequisite for this is returning to the principle

- which has proved successful for two centuries of engineering construction – that an engineering project must be under the authority and responsibility of a competent engineer. Until this happens it is unlikely that the unsustainable situation of many Government subsidy houses becoming unfit for habitation within only 10% of their design life will be solved.

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## **Village economic development through water supply**

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### **ABSTRACT**

Millennium Development Goal 7 seeks to provide full access to basic services and the service allocation caters for all households irrespective of affordability. However, it is assumed that service delivery processes come up short, especially rural areas. This, in most cases is usually caused by limited budget allocations for post-implementation maintenance of water supply infrastructure. It is usually very expensive to formally reticulate water in disperse settlements and in such situations, communities develop innovative ways to get water at convenient points. The community-developed systems are often initially developed to serve as interim solutions have proved to be highly sustainable with an efficient management system. Such circumstances instil high sense of responsibility within the community as they ensure that the system is running at all times. However, the disadvantage is that the original infrastructure rarely gets upgraded once it is installed. Time that is purely allocated to the collection of water from distant sources and maintenance of water supply infrastructure has a potential to economically and extramurally benefit the community when the existing water supply infrastructure gets reticulated to more convenient points such as yard taps. This indirectly means less spending by the government on the maintenance of water supply infrastructure and more time for other revenue generating activities.

This paper looks at two rural South African case studies that have used two different approaches towards the sustainability of water supply infrastructure of which one succeeded and the other one did not. The successful case has a potential to further enhance the village economy and further introduction of Village Development Economic Model (VEDM) will guide the revenue generating processes within the community through water supply security.

Keywords: Village economy, self-supply, Collaboration, communities and government

### **1 INTRODUCTION**

One in six people worldwide do not have access to safe drinking water (UN, 2013). The Water services Act 108 of 1997 of South Africa states that “everyone has a right of access to basic water supply and basic sanitation” and approximately forty percent (19,640,951 people ) of the South African population live in rural areas face serious challenges regarding access to water services (World Bank, 2013). In addition, South Africa is classified as a water scarce country that has a high potential for experiencing even more droughts. Water has been highlighted in the national economic development blueprint as a key service required for sustainable development and economic growth in South Africa (NDP, 2012). In addition, one of the indicators under millennium development goal 7C focused on halving the number of people without sustainable access to water and sanitation by 2015 (MDG, 2012). This prompted planning for water supply by South African government that has managed to increase the access to water by 21% between 2001 and 2011 (Moore & Kenyon, 2013). However, it is also projected that the success in water supply goals will be short-lived as water demand is predicted to outstrip water supply by 2030 (Treasury, 2013).

The SA water policies and regulatory frameworks address the key issues that are critical in delivering water services to all the citizens of the country. Some of these frameworks and programmes include Municipal Water Infrastructure Grant (MWIG) that ensures the provision of water infrastructure in municipalities, Medium Term Expenditure Framework (MTEF) that focuses on the medium term progress on government expenditure and Accelerated Growth Initiative of South Africa (ASGISA) which focuses on fast tracking the service delivery. The issues of sustainability linked to protection, management and development of water resources are clearly defined in chapter 3 of the National Water Act of South Africa. The institutional framework clearly defines the roles and responsibilities of each

institution in the water value chain. These policies have contributed towards increased access to water services. However, the focus has been more on infrastructure which has been misinterpreted as access to water and the misconception is that places that have infrastructure are regarded as having access to water (Majuru *et al.*, 2012).

It is estimated that 34% of installed boreholes in Africa are dysfunctional and most never make it past the first year without breakages (Mac Mahon, Gill 2018). Infrastructure failure is rarely reported because it is feared that the municipality's reputation may be jeopardised and further funding may be lost because donors become sceptical about investing in areas where there are high levels of failure (Barde, 2017). Such challenges have led to the conceptualisation of village economic development model (VEDM) that seeks to narrow the gap between service delivery and sustainability. The unreliability of delivered services results in community unrests because of frustrations which cause the community to destroy what is already available and therefore setting the project implementers back in terms of the service delivery. On the other hand, services are claimed to be delivered because of infrastructure that has been put in place but this is not usually the truth because reticulation systems have been put in place before but taps remain dry in some places. Methods to bridge the service delivery gap focused on the potential formalisation of existing mountain water systems in Mukutung, Limpopo and learn lessons from the unsuccessful management of water supply infrastructure in Thambonkulu, Mpumalanga. The aim was to reduce the inconvenience that is result of technology breakdown.

The introduction of VEDM allows the community to take charge of their technologies, be it indigenous hand-dug wells, mountain water reticulation, boreholes or household based technologies in a manner that will generate revenue for them. The VEDM has a potential for generating revenue from community based management (CBM) that is practiced around the world.

## **2 LITERATURE REVIEW**

Not much has been documented on community participation regarding rural water supply initiatives by aid agencies but data availability slowly is increasing as it has been observed that there are higher levels of infrastructure sustainability when the community participates in decision making positions. For the project to be successful from the planning stage all the way to implementation stages, the community must be genuinely motivated and interested in the project in order to ensure the sustainability. Most methods of instilling psychological ownership revolve around involving the community in all the project processes (Mac Maho & Gill, 2018; Kativhu *et al.*, 2018; Ducrot, 2017).

Different approaches towards community water supply infrastructure management have different influences on the level of community participation. A series of approaches have been applied when dealing with communities. The top down approach is regarded as least productive because the donors decide on which technology and the type of assistance they are willing to offer the community. This approach focuses on the deciding what the ideal technology for the community should be, implement it without any consultation with the users. This approach has a very high failure rate because it lacks community engagement during the implementation processes and consequently, lack of psychological ownership is inevitable (Mac Mahon & Gill 2018; Kativhu *et al.*, 2018). This has proved to be the source of failure in most South African villages (Moriarty *et al.*, 2013). After the realisation that this approach results in failure, project funders were forced to engage with communities where a midlevel lateral approach was taken into consideration (Barde, 2017). The lateral approach is characterised by lateral communication which advocates cooperation between the donor and the community. The approach is known to have both possibilities, of which could be success or failure depending on the project administration. The Accelerated Sustainable Water Service Delivery (ASWSD) project that was conducted in Limpopo and Mpumalanga provinces can be regarded as midlevel approach because of the communication between the donors and the communities. The project focused on providing household based water treatment technology to villages and augmenting existing water supply infrastructure of which was done by engaging all relevant stakeholders from the beginning up until the end of the projects. The level of participation in this approach depends on the initial agreement between the project implementer and the users of technology. A proper agreement includes project monitoring and evaluation as part of the post-project implementation process. Further involvement of day to day system users as decision makers ensures the sustainability of water supply systems (Kativhu *et al.*, 2018; Gill & Flachenburg, 2015).

## **2.1 OPERATIONS, MAINTENANCE AND RELIABILITY OF WATER SUPPLY INFRASTRUCTURE**

A third of water supply infrastructure is non-functional in sub Saharan Africa (Gill & Flachenburg 2015, Behnke *et al.*, 2017) . In South Africa, massive investments by government and donor agencies have been made towards water infrastructure and much more money (R 75 billion) has to be utilised before 2025 (Treasury, 2012).

Most water supply infrastructure is not sustainable because of improper financial allocations for post-implementation O&M and such challenges are perpetuated by the project implementers' implementation strategy for water services that overlooks the importance of budgeting for O&M resources and this usually results in disputes among the community regarding the responsibility of O&M (Kativhu *et al.*, 2018). In addition, current approaches towards infrastructure maintenance increase the amount of non-functional infrastructure because most municipalities wait until the infrastructure reaches its breaking point before it could be fixed. This is because in most municipalities, water services are bundled together with other services and often overlooked but only attended to when people have no access to water (DST, 2014; Hutchings *et al.*, 2016). On the other hand, communities take the initiative to service their own water supply systems by using money they have contributed as well as other resources such as manual labour for those who cannot afford monetary contributions (Kativhu *et al.*, 2018, Behnke *et al.*, 2017). This approach can also be regarded as the perpetuator of "it is ours" attitude by the communities.

## **3 CASE STUDIES**

The article takes two separate community cases into consideration and assesses different approaches they apply towards the management of water supply infrastructure. Both cases are community based management (CBM) practices whereby one is mountain water harvesting and the other is the use of boreholes. The mountain water harvesting is a rudimentary system that was developed by the community in Mukutung, Limpopo while the boreholes were drilled by the municipality for the Thambonkulu community in Mpumalanga. The analysis of CBM approaches that resulted in the fully functional mountain water harvesting system against the non-functional boreholes will determine the potential for the VEDM.

### **3.1 NON-FUNCTIONAL BOREHOLES**

The community of Thambonkulu has always had access to water of which is shared with livestock and is not safe for human consumption. The municipality installed borehole pumps to help improve access to water. However, the management of such infrastructure has left the community without access to available water. This is because of lack of knowledge as well as responsibility towards the infrastructure. This can be seen in figure 1 below where a borehole that has not been working for months because of one replaceable component that could have been replaced by the community if they had the right knowledge.



Figure 1 A non-functional borehole in Thambonkulu village, Mpumalanga

Lack of “ownership” is a challenge in this community since boreholes were regarded as the product of the municipality. Such cases result in maintenance that is based on emergency rather than scheduled. This case portrays a classic example of infrastructure negligence because a non-functional borehole had minor problems that could easily be addressed but were declared broken by the community, leaving them with no access to available water. This is because they had alternative water sources (unsafe water wells) with reliable quantity even though the quality did not meet the South African drinking water quality standards. Lack of communication is another challenge that was observed from this case because implementers of such systems did not involve the community during the planning and implementation phases. According to the community, post implementation strategies were not discussed with them because the boreholes were thought to last for a very long time without experiencing challenges. Lack of unity within the Thambonkulu village in Mpumalanga was also observed because only a few men within the community had the power to make decisions therefore leaving the community members uninterested on what is happening. Further investigation discovered that one or more replaceable components that could be fixed were missing from these boreholes. Lack of information regarding borehole maintenance and willingness by the community to address such issues resulted in longer down periods. The community then resorted to unsafe wells of which they regarded as most convenient. Such challenges could have been avoided if the CBM approach was properly applied.

### 3.2 MOUNTAIN WATER HARVESTING

The Lephephane and Mukuting villages of Limpopo have taken the initiative to create their own water supply system. Such systems are mostly rudimentary but highly sustainable. In one of the village, a system was developed to harvest water from the mountain and store it in containers (Figure 2). A reticulation system was installed to further reticulate water to standpoints on the streets. Such systems have been operational for many years but the community has no intentions to upgrade it. This may be because the infrastructure is governed by a select few which are the owners that benefit from charging a connection fee (i.e. R300) to new members. Consequently, this jeopardise potential improvements to the system by ordinary community members as they regard the system as being owned by the select few.



Figure 2 Community based initiative (Mountain water harvesting)

Men dominate water management committees in these villages and this adds to the challenge since the primary users (women) do not have much to say regarding the O&M of water supply systems. Despite these challenges in management styles, most of these systems stay functional because mountain water sources are regarded as most convenient and reliable for these communities.

Different challenges that were outlined in both case studies can be addressed and be taken a step further by means of developing the economy within the community. The approach takes into consideration the second case study that is shown in Figure 2 where there is a high level of sustainability and responsibility, but no potential for the infrastructure upgrades because only a few people have power over the entire water supply system. Formalising such system and decentralising the decision making process has a potential to enhance psychological ownership of such infrastructure while allowing the community to focus more on activities that will help sustain such systems and even more. VEDM is a concept that aims at addressing water supply infrastructure challenges while indirectly enhancing the village economy.

#### 4 THE VEDM CONCEPT

The VEDM seeks modify and enhance the practices that are currently in place in villages. Communities have demonstrated a willingness to pool resources together to address a common objective such as water services. Such practices have been partially practiced in other countries such as Tanzania, Ghana Kenya and Zambia where the sustainability of water systems increased as more users depended on them as well as having formal management practices being put in place (Gill & Flachenburg, 2015, Behnke *et al.*, 2017). Such approaches are ideal for the community but the level of focus is usually limited to spares for water supply infrastructure.

VEDM focuses on the potential use of “*stockvel mentality*” to enhance similar operations as the Mukutung people have done. Furthermore, introducing the VEDM that focuses on allowing the community to take the lead role in decision making processes and ensure that they, over and above the collective saving approach, partake in income generating activities. The anticipated potential outcomes from the VEDM have also been endorsed by the studies that were conducted in Tanzania and other countries where giving the community a decision making role proved to be more fruitful than giving them a technology without their approval. It is also a cycle that generates income for the community as well as reduces the burden on the government with regards to budget for the maintenance of available water supply infrastructure. The VEDM concept is outlined in Figure 3 below.

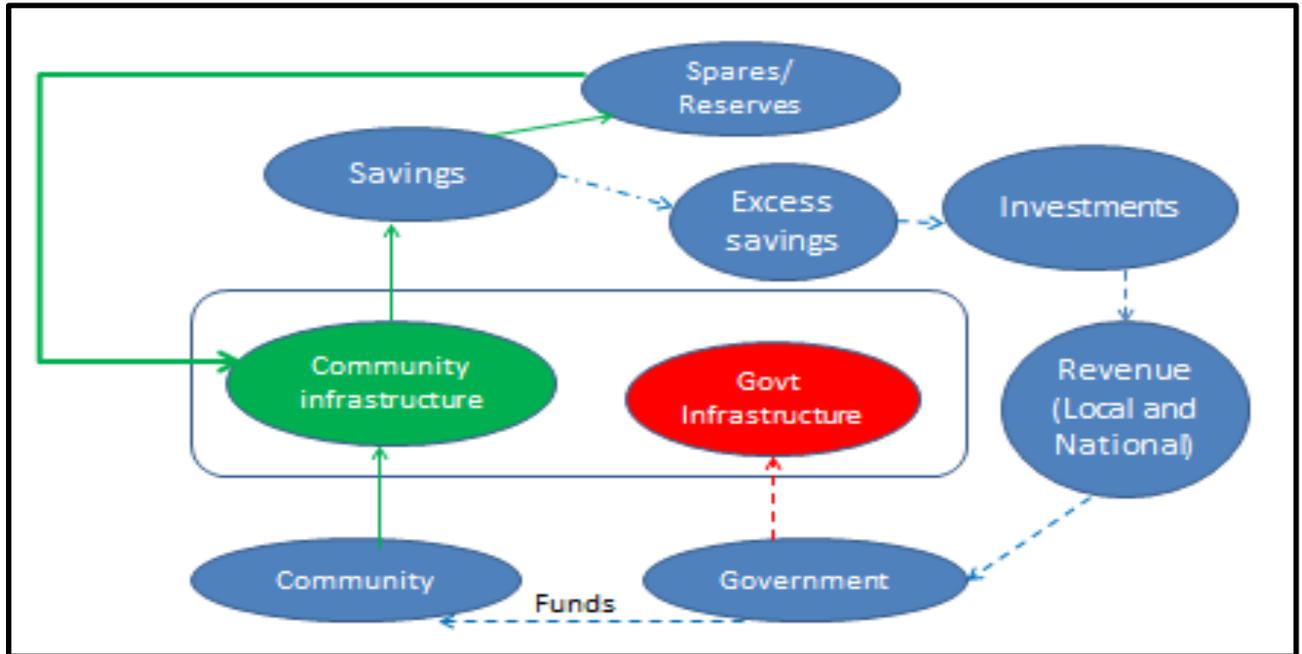


Figure 3 Village Economic and Development Model

The concept seeks to address the “it’s theirs attitude” by the community and promote social cohesion (it’s ours attitude) in communities. Furthermore, VEDM allows external institutions to assistance to village through local authorities such as the Tribal authority by means of funding and advice on decision-making regarding the O&M of water supply infrastructure. The community is then allowed to utilise these funds, and the advice provided by the investors to enhance existing systems (Infrastructure) and formalise their traditional water resources management structures so that the infrastructure can reach its full operational potential in order to meet country’s free basic service standards while supplying water for longer periods.

Alternatively, the community can collectively save money for spares after financing the infrastructure. Once the community has saved money for spares, the excess savings can be used to ensure that water supply infrastructure is upgraded (e.g. water that is gravitated to a stand point can now be reticulated into the yards). This therefore results in high levels of convenience which indirectly allows the community to invest their time to money generating activities rather than water collection (Barde,2017). The revenue generated from such activities can allow the community to appoint a dedicated person that will ensure that the water is of good quality and the infrastructure is operational at all times. The excess funds can then be invested in other non-water related activities that have a potential to bring in more income. However, the process can only be fully functional if there is goodwill between the community and external institutions as this will drastically reduce levels of inconvenience when it comes to the operations, scheduled maintenance and upgrades of water supply infrastructure. This includes informing the community about the performance status of the water supply infrastructure on a regular basis and the community informing the donors about their concerns regarding water supply infrastructure. The whole process can potentially allow the government/ investors to get their returns if the capital was loaned to the community. Furthermore, financial stability within the community will allow exploration of other business ventures that will help expand the economy within the village.

The VEDM can also increase the level of cohesion within the community because everyone will be striving towards achieving the same goal of having to have sustainable water supply infrastructure and eradication of poverty. VEDM has direct and indirect benefits for rural communities and the country at large. The model has a potential to address a region wide problem of non-functional water supply infrastructure and give power back to the users regarding water resources management. In addition, such model can drastically reduce the level of dependency on foreign financial aid and this means that the investors can now focus on other developments rather than water supply infrastructure that rarely meet its design lifespan when improperly maintained.

## 5 CONCLUSION

The VEDM can prove to be a short to long term solution in rural water supply sector of South Africa and the even the world at large. However, the applicability of the model is not standard to all villages because the dynamics are different. The case studies revealed different challenges, namely: lack of communication that causes infrastructure negligence and lack of continuous collective saving contribute to stagnant infrastructure growth within the community. Such scenarios contribute to lack of sustainability of services. However, VEDM focuses on the approach of collective saving by the community and it also takes it a step further by introducing potential ventures that can alleviate poverty. This will allow the villages to formalise their structures, involve more people in decision-making processes and generate more income. The VEDM has the ability to reduce the level of conflict between stakeholders because it enhances private public partnership that indirectly encourages psychological ownership of water supply infrastructure. Furthermore, an increase in the level of independence on external funding by villages can reduce the government's level of spending towards water supply infrastructure. Application of VEDM in rural villages is highly recommended.

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## **Housing subsidy quantum and innovative building systems-a critical literature review output**

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### **ABSTRACT**

The purpose of the research was to provide a comprehensive identification of all the possible factors that influence the housing subsidy quantum cost with time, and the inter-relationships that exist between these factors, including the dynamic changes due to the new innovative technologies. Special focus was directed to how four (4) of some innovative technologies could be infused into the different types of low income housing subsidy programs. The design was based on reviewing of existing literature that is relevant to housing subsidy quantum determination and the innovative building systems in South Africa. A limited analysis of the affordability of the technologies at various construction stages had to be done in order for their infusion into the housing subsidy programs to be practical. The technologies were ranked in terms of their affordability both for credit linked and non-credit linked subsidies. The results for the year 2018 showed that combination of the progressive build methods with the building technologies generally improves affordability. The Disabled Wheel Chair and Military Veterans Subsidy grant levels can generally afford the complete application of the technologies to deliver the completed housing units, while maintaining affordability. An accurate affordability-based infusion of these technologies into the low income programs, will greatly improve affordability for the low income housing beneficiaries for some time into the future.

Keywords: Affordability, Credit, Subsidy

## **1 INTRODUCTION**

### **1.1 BACKGROUND**

Many countries the world over have adopted low income subsidy programs or their hybrid variants in an effort help low income groups acquire decent shelters through low income housing subsidies. South Africa is not exempt. This has partly solved the problem of homelessness, reduced urban crime, and improved the quality of life among these low income groups especially in urban areas.

However the actual housing subsidy quantum costs should be dependent upon the household characteristics and the costs of the housing unit itself with time.

In South Africa, the amount of housing subsidies to be given to each household are usually benchmarked based on the costs of materials and labor, which has been based on brick and mortar. Because of the innovative building systems that have crept into the construction industry, there has been a mismatch between the quantum cost structure and different housing typologies or classifications which have themselves arisen due to these new building systems. The construction process too has as a result been affected, with different stages of site construction varying between brick and mortar and these other technologies. Convention housing construction procurement and payment schedules (and hence construction contracts) have also been impacted upon. All this has an impact on the construction cost of the housing unit, which itself is the final output. This in turn has an impact on the affordability of different low income households of the particular housing unit typology.

The criteria that are used to determine affordability standard of a household is also worth taking note of. Usually the "percentage of income" methods are employed by governments and financial institutions as a basis to establish affordability status. However, household profiles (incomes and household sizes) vary. This means that the "percentage of income method" would not be accurate enough in assessing housing affordability.

Thus the aims and objectives of this research were:

- To identify all the factors that affect housing affordability and the relationships that exists among them.
- To identify at least 2 Innovative Building Technologies and carry out an effective analysis of these technologies so as to infuse them into the low income subsidy programs in South Africa.

## **1.2 SATISFYING THE AIMS AND OBJECTIVES**

In order to meet the aims of the research, relevant literature that dealt with factors influencing housing affordability and their relationships was reviewed. Of particular concern also was finding an alternative way of determining affordability standards for different households depending upon their profiles.

Some Four (4) innovative building technologies approved by Agreement South Africa and the National Home Builder's Registration Council (NHBRC) were also identified, and relevant literature dealing with them was reviewed. These technologies included the Moladi, Robust, Abod, and the National & overseas Modular Construction Technologies. Their current costs per square meter figures (which were obtained from the respective construction technology companies) were then used as a basis of analyzing their effectiveness at different construction levels in providing affordable housing units either separately or with the help progressive building ideas borrowed from the Enhanced People's Housing Program (EPHP). Ranking methods based on income constraint criterion figures (for credit linked subsidies) were used to determine the effectiveness of these technologies at different levels of construction. Ranking methods based on the difference between subsidy grant levels and technology building costs were again used to determine the effectiveness of these technologies at different levels of construction for non-credit linked subsidies.

A mapping was then done of these technologies over the low income subsidy programs as defined in the National Housing Code of South Africa of 2009.

The results obtained were limited or valid for South Africa, and the affordability statuses applied to the year 2018. Because of the complex but very possible and time consuming process of modeling the household profile changes with respect to time, the affordability standard used here was based on the "percentage of income" method. Therefore the results had the inherent weaknesses of the "percentage of income" method.

## **1.3 OUTLINE OF THE FINDINGS**

The findings show that most of the innovative Building technologies are only effective in reducing costs for the foundation and building structure phases of construction. The costs of building finishes are hard to control or reduce because they are based on market prices or market forces. The building finishes often cost more than the cost of building up to the structure level. So the cost reductions due to innovative building technologies can easily be undone by escalating costs of building finishes with time.

Therefore in situations where the subsidy grant levels were lower than the cost of setting up a complete house (including finishes and labor), if the construction technology was applied up to the structure level and combined with progressive building techniques borrowed from the EPHP, it was found in many cases that this would make the housing units affordable in the year 2018. This would be helpful to the Government especially if it does not have the extra funds to increase the subsidy grant levels in order to increase affordability levels of households.

The findings also showed that for the year 2018, if the quantum grant levels of the subsidies were at the levels of Military veterans' quantum grant levels, affordability would be achieved across most of the technologies without even employing credit linked subsidies or progressive building schemes from EPHP. Thus the Military Veterans' subsidy quantum grant levels can be seen as the ideal grant levels across the technologies for the year 2018. This would help the Government in its Budget process in an effort to find out how much more funds it would need to set aside to meet this desired grant level that helps most of the households to achieve affordability status.

## 1.4 HOUSING AFFORDABILITY

Housing affordability as the ability of a household to secure some given standard of housing (or different standards) at a price or rent which does not impose, in the eyes of some third party (The third party being taken as, but not always the Government) an unreasonable burden on household incomes (MacLennan & Williams 1990). The standard could be a figure set by the Government or Financial institution. For example, if it is decided that for a household to remain in an affordable condition it must spend 40% or less of its monthly income on housing expenses, then the affordability standard here is the 40% figure.

### 1.4.1 Methods of measuring Housing Affordability

#### 1.4.1.1 Percentage of Income method

This method is one of the most common methods used to measure housing affordability. It is applicable both to owner occupancy and renter occupancy affordability analyses (Jewkess & Delgadillo, 2010). A fixed percentage is taken as a standard that is multiplied by the household income to determine how much of the income is available for the household to spend on housing. However, it has some shortcomings.

The method gives no consideration to the unfair effects of the income constraints that arise due to the application of the standard percentage figure to all households, irrespective of their differing income levels and household sizes; it fails to consider the different household preferences on the neighbourhood that arise due to differences in income levels and household sizes; it does not specify whether permanent or transitory incomes should be used for comparing with the housing costs; it fails to set preferences (expressed as percentages of income) for other commodities which are non-housing in nature; it is not applicable over the entire household lifecycle but is mostly applied when a household wishes to acquire a house, which implies that it not sensitive to changes in affordability which arise due to house value appreciation (capital gains and inflation effects) and house value depreciation (Bogdon & Can, 1997; Thalmann, 2003; Chen, 2007).

The method also fails to consider the opportunity cost of non-housing consumption. Housing expenses must not crowd out non-housing expenses beyond a certain limit (for example, the poverty datum line limit of non-housing expenses). This limit cannot just be set as a percentage of income since it varies from household to household due to differences in household sizes and age profiles (Chen, 2007).

For house owners or house buyers, Bourassa (1996) provides a modified version of the percentage of income method of measuring housing affordability called the 'borrowing constraints method' It takes into consideration the constraints on liquid wealth due to down payment, in addition to constraints on income due to periodic mortgage payments. A house is affordable subject to the following two (2) criteria:

#### 1.4.1.2 Mortgage underwriting criterion

The mortgage underwriting criterion for housing affordability states that:

$$W \geq D ; D \geq iV \quad (1a)$$

Where W refers to the household's liquid wealth, D is the deposit on a house of value V, and i is the minimum deposit ratio.

#### 1.4.1.3 Income constraints criterion

The following equation summarises the income constraint criterion:

$$PY \geq (V - D) \left( \frac{r}{1 - \frac{1}{(1+r)^n}} \right) \quad (1b)$$

Where  $Y$  refers to the income from other sources other than liquid investments;  $P$  is the maximum portion that can be spent on mortgage payments,  $r$  is the mortgage interest rate,  $n$  is the term of the loan.

#### 1.4.1.4 Household based lifecycle measurements

A more accurate measurement of housing affordability which considers a household's life cycle (as opposed to looking at affordability only in terms of a household's ability to buy a housing unit initially) , must also consider other housing expenses, irrespective of the mode of tenure. These include maintenance expenses for repairs, maintenance expenses for improvements, insurance expenses, property taxes, capital gains, tax rates, tax treatments of incomes and expenses, savings or saving culture, economic depreciation, accelerated depreciation, purchase price per unit, inflation or mortgage interest rate, down payment, property abuse, uncertainty and risk (Brueckner 2011; Diaz & Luengoprado 2008; Quigley & Raphael 2003; O'Sullivan & Gibb 2006; Rosen *et al.*, 1984; Chambers *et al.*, 2007).

Generally the household's consumption is divided into both housing and non-housing expenses. The non-housing expenses are computed using either the percentage of income method (which has identified flaws as previously pointed out), or they can be computed using the poverty datum line method. The poverty datum line in some form of regression equation varies according to household characteristics such as size and age profiles (Central Statistics office of Botswana 2008a; Central Statistics office of Botswana 2008b; Chen 2007). Evaluation of non-housing expenses with respect to time would thus require a dynamic estimation of how the household profiles (such as age profiles, family sizes and incomes) would vary with respect to time. Thus the application of birth rates, mortality rates, emigration and immigration rates has to be done for each household from year to year, probably with the help of Leslie Lekovitch matrices. This would involve application of stochastic processes to estimate future household states since there will always be an element of uncertainty in the estimations.

The housing expenses are computed mainly using the factors identified by Brueckner (2011). Generally for an owner occupier in period "i" the housing unit is affordable if the following conditions are fulfilled:

$$y(i) - \left\{ mh(i) + \left[ [1 - tx(i)]. (mg(i) + h(i)) + d(i) + mt(i) + ins(i) - g(i) \right]. v(i) \right\} \geq 0 ; D \geq r.V \quad (2)$$

And for the Renter occupier, the housing unit is affordable if the following condition is fulfilled:

$$y(i) - \left\{ mh(i) + [mg(i) + h(i) + d(i) + mt(i) + ins(i) - g(i)]. v(i) - \left[ e.tx(i). \frac{v(i)}{1 - tx(i)} \right] \right\} \geq 0 \quad (3)$$

where:

- $tx(i)$  is the income tax rate for owner occupier or renter occupier as applicable in period "i" (Chambers *et al.*, 2007; Brueckner, 2011)
- $mg(i)$  are the mortgage related expenses in period "i" discounted to year 0 or base year,
- $h(i)$  is the property tax in period "i" discounted to year 0 or base year,
- $d(i)$  is the depreciation of the housing unit in period "i" discounted to year 0 or base year,
- $g(i)$  are the capital gains in period "i" discounted to year 0 or base year,
- $v(i)$  is the property value in period "i" discounted to year 0 or base year,
- $mt(i)$  are the maintenance expenses as a percentage of the property value in period "i" discounted to year 0 or base year,
- $ins(i)$  are the insurance expenses as a percentage of the property value in period "i" discounted to year 0 or base year,
- $e$  is the excess depreciation discounted to year 0 or base year,
- $D$  is the deposit on a house (of value  $V$ ) from the household savings,
- $r$  is the minimum deposit ratio,
- $y(i)$  is the household income in analysis period unit "i" and  $mh(i)$  is the minimum standard for non-housing expenses is denoted as in period "i"

According to Maritz (1993), the Housing unit value ( $V$ ) with respect to time can also be estimated using the following equation:

$$V = cc - d + l \quad (4)$$

Where:

- $V$  is the current market value of property.
- $cc$  are the construction costs of the improvements (at the time when the property was newly built) based on the current cost of a new comparable structure
- $d$  is the total depreciation on the improvements since the time when the housing unit had just been built property acquisition by current owner and  $l$  is the highest and best current market value of land as though vacant.

For the purposes of this research, the most outstanding factor that has a bearing to the effect of innovative building systems on value of low income housing, and hence affordability is that which deals with the construction costs of the improvements ( $cc$ ). We shall therefore direct our attention to this factor, together with any other factors that are influenced by it.

## **2 RESEARCH METHODOLOGY**

The research methodology that was used mainly involved the collecting of information both on the four (4) of the existing innovative building systems in South Africa that have been approved by the National Home Builder's Registration Council (NHBRC) and on the existing low income subsidy programs in South Africa as specified in the National Housing Code of 2009. These technologies included the Abod, Moladi, Robust, and the National & Overseas Modular Construction Technologies.

Where possible, information about the current technology costs at various levels of construction was obtained both with and without labour costs.

Where possible, each of these technologies was then analysed at different construction stages to assess its affordability status against the various low income subsidy programs by computing the difference between the costs of implementing the technology to build a low income housing unit (up to the desired construction stage) to the respective low income subsidy grant level amount provided (Assuming non-credit linked subsidies). These differences were used as a basis to rank the technologies.

The technologies or their variants that were not affordable under non-credit linked subsidies were further analysed assuming the subsidies were credit linked. The income constraint criterion (Equation 1b) was then used as the statistic for ranking them across the various low income subsidy programs. Although sensitivity analyses of the income constraint criterion statistic were also carried out to ascertain in detail how each of these technologies would withstand lower incomes and higher interest rates while still remaining affordable, generally the information in the initial table showing how the income constraint criterion varies for the different technologies across the various low income housing programs was sufficient to provide the needed information for this research.

Having reviewed the literature dealing with various low income subsidy programs in South Africa a tabular representation was then done to show how each of these technologies can best be applied to each of the low income housing programs, both under the credit linked and non-credit linked categories.

## **3 FINDINGS AND DISCUSSION**

### **3.1 LIFECYCLE EVALUATION OF HOUSING AFFORDABILITY**

The evaluation of housing affordability should not just be limited to the initial process of housing acquisition by a household. It is necessary and more practical to analyse the housing affordability status for households with respect to time throughout the entire household lifecycle. This holistic approach is

also strongly linked to the mode of tenure (either renter occupancy or owner occupancy) that will ensure utility maximization for the household while maintaining affordability throughout the household's lifetime.

### 3.2 WEAKNESSES IN THE PERCENTAGE OF INCOME METHOD

From the review of the related literature, the percentage of income method as used either to determine the standard for housing or non-housing expenses has serious limitations. Incomes of households differ. So applying the same ratio to household incomes will definitely yield different standards for the households which have the same size but different income levels. In addition household sizes may differ. This means the minimum standard for non-housing expenses for a household of a higher size should be higher in monetary value compared to a household of a smaller size, even though the incomes of both households are the same. The percentage of income method fails to set more accurate standards for households whose incomes or sizes differ. A dynamic estimation of household profile changes with respect to time has to be done first before housing and non-housing standards can be properly set.

### 3.3 ANALYSIS OF AFFORDABILITY OF BUILDING TECHNOLOGIES

Critical to ensuring affordability, are the construction costs of the housing units. The foundation and structural costs are heavily influenced by the building technologies applied. There are many approved building technologies in the South African Construction industry. Adopting them instead of the brick and mortar technology, therefore would not compromise the foundation and structural integrity of the housing units.

Table 1 shows the different Low Income (Subsidy) Programs and the respective grant levels for the top structure (Source: South African National Department of Human Settlements, 2018). The price of land has been omitted since the grant amount for it is the same for all applicable programmes in the year 2018 (about R 6000). Table 2, shows the details of the different innovative construction technologies (Source: Moladi, 2018; Robust Structures, 2018; National & Overseas Modular Construction, 2012; Abod, 2018). The default global parameters used were a down payment of 0%, loan term of 240 months, mortgage interest rate of 10%, maximum ratio of housing expenses to income of 40%, and an income of R 3,500 per month. The developer's profit was first set to 0% and then to 20%. It generally affected performance of Disabled Wheelchair and Military Vets subsidy beneficiaries over Moladi\_B Technology (Affordability was achieved so long as Developer's profit was less than or equal to 15%).

Table 1 Subsidy quantum grant Levels

| Subsidy Program                                | Maximum amount (2018/2019)               |
|------------------------------------------------|------------------------------------------|
|                                                | <b>Top Structure_Quantum_Grant_Level</b> |
| <b>IHS:</b> Individual Housing Subsidy         | R 116,867.00                             |
| <b>IRDP:</b> A Grade Services                  | R 116,867.00                             |
| <b>IRDP:</b> B Grade Services                  | R 116,867.00                             |
| <b>CS:</b> Consolidation Subsidy               | R 116,867.00                             |
| <b>IS:</b> Institutional Housing Subsidy       | R 116,867.00                             |
| <b>EPHP:</b> Enhanced People's Housing Program | R 116,867.00                             |
| <b>RHS:</b> Rural Housing Subsidies            | R 116,867.00                             |
| <b>FRHS:</b> Farm Residents Housing Subsidies  | R 116,867.00                             |
| <b>DWH:</b> Disabled Wheelchair House          | R 172,929.00                             |
| <b>MVH:</b> Military vets House                | R 199,014.00                             |
| <b>TSH:</b> Temporary shelter                  | R 57,790.00                              |
| <b>RH:</b> Replacement of houses               | R 115,568.00                             |

Table 2 Building technology types and their relative costs

| CONSTRUCTION TECHNOLOGY_SHORT NAME | INCLUDES: ROOFING, FINISHES | INCLUDES: LABOUR | INCLUDES: DEVELOPERS PROFIT | INCLUDES: FOUNDATION + STRUCTURE | PRICE PER SQUARE METER (2018) | DURATION (Days) |
|------------------------------------|-----------------------------|------------------|-----------------------------|----------------------------------|-------------------------------|-----------------|
| ABODE                              | YES                         | YES              | YES                         | YES                              | 2118.18                       | 1               |
| MOLADI_A                           | NO                          | YES              | NO                          | YES                              | 1147.70                       | 4               |
| MOLADI_B                           | YES                         | YES              | NO                          | YES                              | 3317.50                       | 7               |
| MOLADI_C                           | NO                          | NO               | NO                          | YES                              | 1057.96                       | 4               |
| ROBUST_A                           | NO                          | YES              | NO                          | YES                              | 1316.13                       | 9               |
| ROBUST_B                           | YES                         | YES              | NO                          | YES                              | 2936.03                       | 14              |
| ROBUST_C                           | NO                          | NO               | NO                          | YES                              | 1163.51                       | 9               |
| NATIONAL_OVERSEAS_MCT_A (NOMCT_A)  | YES                         | NO               | YES                         | YES                              | 5296.00                       | 7               |
| NATIONAL_OVERSEAS_MCT_B (NOMCT_B)  | YES                         | YES              | YES                         | YES                              | 6018.18                       | 7               |

### 3.4 AFFORDABILITY RANKING FOR NON-CREDIT LINKED SUBSIDIES

A ranking (See Table 3) was done for these technologies, with respect to their effectiveness in providing affordable units at the different levels of technologies provided. The ranking was done at a developer's profit of 20%. A ranking of Zero means non-affordability (**Subsidy Grant Level minus Construction technology level cost to build is less than zero**). The higher the ranking figure, the better the technology in terms of providing savings on the subsidy granted.

Table 3 Ranking of the building technologies over non-credit linked subsidies

|                                  | MOLADI_A | MOLADI_B | MOLADI_C | ROBUST_A | ROBUST_B | ROBUST_C | ABODE | NATIONAL_OVERSEAS_MCT_A | NATIONAL_OVERSEAS_MCT_B |
|----------------------------------|----------|----------|----------|----------|----------|----------|-------|-------------------------|-------------------------|
| IHS, IRDP, CS, IS, EPHP,RHS,FRHS | 4        | 0        | 5        | 2        | 0        | 3        | 1     | 0                       | 0                       |
| Disabled Wheelchair House        | 5        | 0        | 6        | 3        | 1        | 4        | 2     | 0                       | 0                       |
| Military vets House              | 5        | 0        | 6        | 3        | 1        | 4        | 2     | 0                       | 0                       |
| Temporary shelter                | 4        | 0        | 5        | 2        | 0        | 3        | 1     | 0                       | 0                       |
| Replacement of houses            | 4        | 0        | 5        | 2        | 0        | 3        | 1     | 0                       | 0                       |

Table 4 Order in effectiveness of affordability of the technologies over the non-credit linked subsidies.

| Position | Technology (For Non-Credit Linked Subsidies)    |
|----------|-------------------------------------------------|
| 1        | Moladi_C                                        |
| 2        | Moladi_A                                        |
| 3        | Robust_C                                        |
| 4        | Robust_A                                        |
| 5        | Abod                                            |
| 6        | Robust_B (Disabled Wheel chair & Military Vets) |

The best technologies do not provide completed units at their levels. They need to be combined with the EPHP program to gradually complete those units.

If completed units are required only from the subsidy grant amount, then this can only be achieved by the Abod technology (across all subsidy programs) and the Robust\_B technology (Only for Disabled Wheel chair & Military Vets grant levels).

The unaffordable technologies were further assessed in terms of their affordability over Credit-linked subsidies (Assuming the subsidies provided are credit linked)

### 3.4.1 Affordability of Construction technologies towards credit linked subsidies

Using some of the global parameters, and a variant of the income constraint criterion (Equation 1b), an analysis was made on each of these technologies (or their sub-sets) that are unaffordable when they are assumed to be non-credit linked. The following are the technologies that were analysed:

- Moladi\_B (All subsidies but may exclude Disabled Wheel Chair and Military Vets Quantum grants if the developer's profits allow)
- Robust\_B (All subsidies except Disabled wheel Chair and Military Vets Quantum Grants)
- National Overseas MCT\_A
- National Overseas MCT\_B

### 3.4.2 Affordability Ranking for Credit linked Subsidies

Using the income constraint criterion (Equation 1b), the performance of the above technologies was computed over the set global parameters.

Consequently, a ranking was done for their performance, and Table 5 illustrates this ranking. The higher the ranking figure, the better the technology. The Zero values correspond to technologies that are either already affordable with respect to non-credit linked subsidies or that are unaffordable with respect to credit linked subsidies.

Table 5 Affordability ranking of technologies for credit linked subsidies

|                                  | MOLADI_A | MOLADI_B | MOLADI_C | ROBUST_A | ROBUST_B | ROBUST_C | ABODE | NATIONAL OVERSEAS MCT_A | NATIONAL OVERSEAS MCT_B |
|----------------------------------|----------|----------|----------|----------|----------|----------|-------|-------------------------|-------------------------|
| IHS, IRDP, CS, IS, EPHP,RHS,FRHS | 0        | 3        | 0        | 0        | 4        | 0        | 0     | 2                       | 1                       |
| Disabled Wheelchair House        | 0        | 3        | 0        | 0        | 0        | 0        | 0     | 2                       | 1                       |
| Military vets House              | 0        | 3        | 0        | 0        | 0        | 0        | 0     | 2                       | 1                       |
| Temporary shelter                | 0        | 4        | 0        | 0        | 5        | 0        | 0     | 3                       | 2                       |
| Replacement of houses            | 0        | 3        | 0        | 0        | 4        | 0        | 0     | 2                       | 1                       |

Table 6 summarizes the suitability of each of these technologies in terms of remaining affordable with respect to credit linked subsidies, despite decreasing incomes and higher mortgage interest rates (Thus it is a test of their ability to withstand lower incomes and higher interest rates).

Table 6 Performance of building technologies with respect to credit-linked subsidies.

| Position | Technology (For Credit-Linked Subsidies) |
|----------|------------------------------------------|
| 1        | Robust_B                                 |
| 2        | Moladi_B                                 |
| 3        | National Overseas MCT_A                  |
| 4        | National Overseas MCT_B                  |

Thus Robust\_B had the best ability to withstand lower incomes and higher interest rates, while National Overseas MCT\_B had the worst ability to withstand lower incomes and higher interest rates.

### 3.5 SPECIAL CONSIDERATION FOR EMERGENCY (TEMPORARY SHELTER : TSH) SUBSIDIES

It should be noted that although some variants of MOLADI, ROBUST and National & Overseas Construction technologies are affordable either under credit linked or non-credit linked subsidies for emergency (Temporary Shelter), it may be uneconomical to implement them for temporary shelter

purposes because they lead to very permanent structures. The ABOD construction technology is best suited for emergency (Temporary shelter: TSH) subsidies. Since it (ABOD Technology) takes the lowest amount of time for construction, the units can be easily set up or dismantled with minimal labour.

### 3.6 SUMMARY OF THE EFFECTIVENESS OF THE CONSTRUCTION TECHNOLOGIES OVER THE SUBSIDY SCHEMES

Having done the analysis of the house construction technologies over the low income housing programs in South Africa in 2018, a tabular summary was thus drawn to illustrate the suitability and/ or effectiveness of each of these technologies. Table 7 illustrates this.

Table 7 Summary of effectiveness of the innovative construction technologies

| Technology        | Is it Credit Linked? | Subsidy Programs Applicable        | Technology        | Is it Credit Linked? | Subsidy Programs Applicable                                                           |
|-------------------|----------------------|------------------------------------|-------------------|----------------------|---------------------------------------------------------------------------------------|
| 1 MOLADI_C & EPHP | NO                   | All except Temporary Shelter (TSH) | 7 MOLADI_B        | NO                   | Disabled & Military Veterans (Developer profit <20%)                                  |
| 2 MOLADI_A & EPHP | NO                   | All except Temporary Shelter (TSH) | 8 ROBUST_B        | YES                  | All Except Disabled , Military Veterans, and Temporary Shelter                        |
| 3 ROBUST_C & EPHP | NO                   | All except Temporary Shelter (TSH) | 9 MOLADI_B        | YES                  | All Except Disabled & Military Veterans and Temporary Shelter (Developer profit >19%) |
| 4 ROBUST_A & EPHP | NO                   | All except Temporary Shelter (TSH) | 10 NOMCT_A & EPHP | YES                  | All Except Temporary Shelter (TSH)                                                    |
| 5 ABOD            | NO                   | All Especially Temporary Shelter   | 11 NOMCT_B        | YES                  | All Except Temporary Shelter (TSH)                                                    |
| 6 ROBUST_B        | NO                   | Disabled & Military Veterans       |                   |                      |                                                                                       |

## 4 CONCLUSION AND FURTHER RESEARCH

This research has highlighted the importance of household profile data towards determination of both housing and non-housing expenses, and hence household lifecycle based housing affordability. While the percentage of income method is frequently used as a standard to determine affordability during the house acquisition process, it has a number of inherent flaws that need to be addressed by utilizing the time-based dynamic individual household data.

Most of the current innovative building technologies in South Africa are still affordable in the year 2018, especially if combined with progressive build methods borrowed from the Enhanced People's Housing Process (EPHP).

Following up on this, further research can be done, which involves:

- Modelling and implementation of the method that measures housing affordability by using lifecycle based household profile data.
- Using the developed model to forecast of the performance (In terms of affordability) and suitability of all the approved innovative building technologies in South Africa (later years) if the subsidy quantum grants remained constant, or are to be varied.

## ACKNOWLEDGEMENTS

The research is part of a larger research project being done at PhD level at the Nelson Mandela University. The authors wish to thank the South African National Department of Human Settlements, Shevaughn Botes from Moladi Building Systems, Willem Van Moerkerken from Robust Building Systems, the Owners of Abod homes Building technology in South Africa, and the National & Overseas Modular Construction Company for the help they offered.

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## **Geographic Information System as a technological intervention for leveraging sustainable development**

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### **ABSTRACT**

Urbanisation is continuously transforming the world's demographics and the global economy. Human settlements are facing unprecedented social, environmental and economic challenges now more than ever before. A statistical review by ReliefWeb revealed that nearly 41 million were affected by droughts in 2016 in Africa. Despite threats posed by demographic changes, urbanisation also presents an opportunity to apply innovations and technologies that can alleviate regions plagued with such issues. Geographic Information System (GIS) is one such technology which is gaining popularity in the field of urban and regional planning and Land Information and Management Systems. However, several factors such as limited sources of revenue, lack of technical expertise and other socio-political complexities create barriers to its successful implementation. This paper aims to understand these challenges and showcase GIS as a pioneering technology in leveraging sustainable development in human settlements using the case study of Ghana. As a part of this research broad recommendations have been provided which can support the planning and implementation of GIS as a critical step towards sustainable development.

**Keywords:** Technology, geographic information system, sustainable development, urban and regional planning, developing countries

### **1 INTRODUCTION**

Cities have been drivers for human development through centuries, presenting humanity with platforms for interaction, growth and development. As from the 18<sup>th</sup> Century industrial era, they have evolved to become complex engines, driving the global economy and leading to the rapid consumption of earth's resources ( UN-Habitat, 2016). As per the United Nations report on World Urbanisation Prospects 2018, 4.2 billion people reside in urban areas, accounting for 55% of the world's population. By 2050, this figure is projected to rise to 68%. It is projected that 90% of this growth will take place in large cities and medium-sized towns of Asia and Africa (United Nations , 2017). With the continual physical growth of human settlements and the increase in human populations, more strain has been put on land and the physical environment. Also, urbanisation has not been inclusive and has resulted in many cross-sectional challenges, as cities have not been able to match the surging needs, thus increasing the demand for natural resources and urban infrastructure. Cambodia experienced massive rural to urban migration during the 1975-1979 conflict, which contributed 14 percent of total migrants in urban areas, leading to pressure on land, infrastructure and services in Phnom Penh. Also, the movement of millions of households within the Middle East and mass-migration into Europe since 2015 has increased pressure on housing supplies in the reception regions (United Nations Human Settlements Programme (UN-Habitat), 2016). Globally, human settlements are exposed to high risk of natural disasters and unplanned growth. There is an urgent need to target cities and regions simultaneously to curb challenges posed by urbanisation.

Although urbanisation poses challenges to balanced and inclusive growth of cities and regions, it also provides an opportunity to apply basic, inexpensive and readily available technology for the provision of a variety of solutions in the urban context. Various innovations in Information Communication Technology (ICT) are being tested and adopted by policy makers and professionals to solve complex challenges that urban areas pose to build sustainable and liveable cities. ICT for development, herein, refers to women and men of the urban populace accessing and using ICT as a tool for accelerating social-economic outcomes in the domain of transport, health, education and trade for the purpose of improving their livelihoods and quality of life (Oluoch, 2015).

As summarized by (Sombroek, 1994), the use of ICT in urban contexts mostly involves the utilization of geospatial tools such as geo-databases for governance, planning and service provision and for land information and land management systems which requires vast sets of geo-referenced information. GIS has evolved to become one such fundamental system that captures, stores, checks, integrates, manipulates, analyses and manages display of data which is spatially referenced to earth (Dekolo, 2005). However, the implementation of GIS depends on several factors. The subsequent section provides a brief overview of the term '*sustainable development*' and its link with technology. This paper further attempts to understand the evolution and contribution of GIS in the field of urban and regional planning and land information and management system using the case studies of Singapore and Ghana. Challenges faced in establishing this technology particularly in developing countries have also been discussed. Lastly, broad recommendations have been provided to support implementation of GIS for initiating sustainable development.

### 1.1 AIM AND OBJECTIVES OF THE STUDY

The research aims to demonstrate the significance of GIS in leveraging sustainable development in developing countries and explore the challenges faced in its implementation. The underlying objectives of the study are to:

- Trace the concept of sustainable development and its link to technology.
- Highlight the importance of the use of GIS in the field of urban and regional planning.
- Explore the issues faced by developing countries in establishing an 'appropriate GIS system. In this paper the term 'appropriate' has been used to refer to technology that is cheap, effective, reliable and easy to use. (Klosterman, 1995).
- Identify 'factors' that impact the implementation of GIS technology based on the literature reviewed.
- Provide broad recommendations on the aspects that may be considered for establishing an appropriate GIS to leverage sustainable development.

The research relies on a desktop review of projects. While there has been uptake of technology in planning in developing countries limited studies have been reviewed and presented as there is lack of literature in general (Heeks, 2002). It is intended that this paper will contribute to this body of literature.

## 2 LITERATURE REVIEW

### 2.1 THE CONCEPT OF 'SUSTAINABLE DEVELOPMENT' – AN OVERVIEW OF CONTEXT AND INTERPRETATION

The concept of '*sustainable development*' was conceived in 1987 at the World Commission on Environment and Development. In 1972, Stockholm, United Nations Conference on Human Environment was organised to discuss the prevailing issues of ecological crisis. It was stated that

*'A point has been reached in history when we must shape our actions throughout the world with more prudent care for their environmental consequences...[therefore] to defend and improve the human environment for present and future generations has become an imperative goal for mankind'* (United Nations, 1972) as cited in (Pisani, 2006).

A widely accepted definition of sustainable development as described in the report on World Commission on Environment and Development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs (World Commission on Environment and Development, 1987).

While various organizations embraced the term sustainable development, the concept was understood to be in its infancy stage due to the limited understanding of the context in which the term originated; thus, increasing possibilities to inadequacies and contradictions in policy making (Lélé, 1991).

Dale (2001) describes sustainable development as a process involving the reconciliation of three imperatives: (1) the ecological imperative to live within global biophysical carrying capacity and to maintain biodiversity; (2) the social imperative to ensure the development of democratic systems of governance that can effectively propagate and sustain the values by which people wish to live, and (3) the economic imperative to ensure that basic needs are met worldwide.

To stimulate the process of sustainable development and address the global challenges United Nations developed 17 Sustainable Development Goals (SDG's) and 169 targets as a part of the 2030 Agenda for Sustainable Development. The SDG's are built on the Millennium Development Goals (MDG's) and intend to achieve targets that could not be achieved then. Sustainable development has become a concept of immense importance and that with advancements in technology and breakthroughs in field research, the concept will keep evolving. With the current fast-paced urbanisation that cities and regions are experiencing, achieving the targets laid down in the SDG's pose a significant challenge, particularly for the developing countries. Governments and key decision makers need to intervene at a larger scale and devise strategic integrated approaches to resolve urban issues and realise the SDG targets.

## **2.2 TECHNOLOGY AND SUSTAINABLE DEVELOPMENT IN HUMAN SETTLEMENTS**

There is an increasing recognition and awareness of the impact that technology can have on enhancing the quality of life. As cited in (Pitkin, 2001), William Mitchell, Dean of Architecture and Planning at MIT, interprets the impact of new technologies in urban areas and argues that by employing information age design principles, planners and architects deal with the problems of the industrial-era city and create more liveable cities. ICT can strengthen production and increase market coordination which are the main processes that can contribute to future opportunity and creation of income (Oluoch, 2015).

While the view that technology can enhance quality of life is gaining popularity, it has been observed that rapid growth of ICT usage in high-income countries has raised concerns of 'digital divide' between rich and poor nations (Pigato, 2001). Planners and decision makers need to understand that technology on its own does not lead to social progress (Pitkin, 2001). Several factors need to be considered to tap the 'transformative' capabilities of technology. In this context, the potential of digital property information system as a valuable decision support tool is being recognised (Ralphs, 2003). Land Information Systems (LIS) based on computerised GIS has emerged as a powerful tool for the management and analysis of large amount of basic data and information, statistical, spatial and temporal, needed to generate in a flexible, versatile and integrated manner, information products in the form of maps as well as tabular and textual reports for land use decisions (Sombroek, 1994), taxation for revenue generation and urban and regional planning.

## **2.3 GEOGRAPHIC INFORMATION SYSTEMS – EVOLUTION, DEFINITION, AND FUNCTIONALITY IN URBAN DEVELOPMENT**

Geographical information systems have gained their popularity at a very early time in urban planning, transportation modeling, risk management and geo-demographics (Tao, 2013). It was developed in the late 1960's with very limited number of users. However, with the subsequent fall in the prices of hardware, accompanying improvement in the performance of hardware and software and advances in the data structures and algorithms of vector-based GIS, the technology became affordable, user friendly and less time consuming (Yeh, 1999). Geospatial Information Technology (GIT) practitioners and researchers around the world were able to adopt a range of Geospatial Information Technologies & Systems (GIT&S) to integrate multiple realities and diverse forms of information with the objective of empowering underprivileged groups, promote social learning, support two-way communication and thereby broaden public participation across socio-economic contexts, locations and sectors (Rambaldi, 2006).

GIS is defined as a technological tool for analysing geography and making intelligent decisions (ESRI, 2009). The technology links databases from various software to a geo-referenced location which allows the user to relate and further analyze the information. GIS has much more power than static maps, because of the segregation of geospatial data from graphic representation, the integration with navigational needs of ordinary citizens, the in-depth application of spatial analytics, easiness of

acquiring geospatial data and dynamic combination of various data layers including vector, raster, and images (Tao, 2013).

Singapore was in the first group of countries that advocated the adoption of ICT into city management and defined itself as an Intelligent Island at the start of the 1980's (Tao, 2013). At present, the country ranks fourth as per Countries Geospatial Readiness Index (CGRI) 2018. CGRI is a tool to assist the development of a holistic outlook for framing a national geospatial strategy in tandem with advanced digital technologies (Geospatial Media and Communications, 2018). This has also contributed to the fact that Singapore's energy consumption in land transportation sector is relatively low compared to other developed countries in OECD and EU (Tao, 2013; Boey *et al.*, 2014).

As per 2018 report released by the Department of Statistics, Singapore, the island has an approximate land area of 720 km<sup>2</sup> and a population 5.6 million, resulting in density of 7,796 persons per sq.km. Taking into consideration limited land availability and the need for integrated land-use and transportation planning, the national land-use planning agency, Urban Redevelopment Authority (URA) of Singapore using GIS established the Integrated Planning and land Use System 'iPlan' (ESRI, 2011). iPlan has been operational since 2006, was used to support the development of master plan and concept plan as comprehensive frameworks to guide the economic and future development of the nation with a time frame of 10-15 years and a transport plan guiding development 40-50 years into the future. It involved the layering of over 100 geospatial data layers sourced from 14 public agencies and different analyses performed on them (ESRI, 2011) (Singapore Geospatial Collaborative Environment, 2012).

The Singapore Land Authority has been running the Singapore Geospatial Collaborative Environment (SG-SPACE) as Singapore's national Spatial Data Infrastructure for data sharing between 30 government departments with a vision "*towards a spatially enabled nation*" (Tao, 2013); (Singapore Geospatial Collaborative Environment, 2012). The system was launched in February 2011 which allowed public agencies to share data and use it for planning, analysis, operations, decision making and public service delivery (Singapore Geospatial Collaborative Environment, 2012). Geospatial data from the government is also shared with the public through the internet portal, OneMap which was launched in 2010.

While Singapore has used GIS to direct its vision of a Smart Nation, several factors such as institutional arrangement, financial sustainability, data availability, hardware and software components, capabilities and manpower and method for data standardisation and quality were considered which contributed to its success (Singapore Geospatial Collaborative Environment, 2012). In the case of developing countries, these factors can prove to be challenges to implementation of GIS thus slowing down the progress towards sustainable development. The following section attempts to understand these challenges using the case studies of India and Nigeria.

## 2.4 CHALLENGES TO IMPLEMENTATION OF GIS FOR SUSTAINABLE DEVELOPMENT

The Indian Ministry of Environment of Forests for forestry management attempted to initiate the use of GIS, however, a proper GIS system could not be established for the reasons cited below by (Heeks, 2002) and concluded by (Barrett, 2001):

- The GIS design assumed reliance on formal types of information borne via technical channels "*as compared to the informal channels of information*" that were used in practice (Barrett, 2001:18).
- The GIS design assumed "*a form of working culture wherein decisions are made on criteria of rationality and principles of cartographic science.*" (Barrett, 2001:14). This mismatched an actuality of politicized decision making.
- The GIS design representations of the forest conflicted with the actuality of forest officers' representations, which did not see "*land as something that is out there and that can be objectively measured and standardized in GIS models*" (Barrett, 2001:13).
- The GIS design required values of trust in the technology, in "*new forms of rationality*" (Barrett, 2001:19), and in persons known and absent. This mismatched the real values of trust in persons known and present.

- The result was a significant design–actuality gap along several of the dimensions, and the outcome was failure; there were no real operational systems established by the end of the project period (Barrett, 2001:10).

Another case where implementation of GIS failed was when Lagos State Government attempted to establish a Land Related Information System (LRIS) to support the functions of Ministry of Lands and Housing of the State using a loan from the World Bank. A Land Information System Support Unit was set up (LISSU), and a pilot project was conducted which involved small-scale mapping and ortho-photographs covering the entire city. The primary application was revenue generation, i.e., effective collection of land base charges, however, the project failed as a result of 'top to bottom approach' in implementation which led to limited participation of the local government who were the end-users. Also, due to lack of follow up strategy, the plan could not be implemented (Dekolo, 2001; 2005; 2011). Another attempt was made to set up a GIS laboratory in the Regional and master Planning Department of Lagos State Urban and Regional Planning Board (LSURPB). However, the project was not successful as there were no GIS trained personnel to use or manage the project.

From the two cases above it may be established that several factors influence in the setup of an appropriate GIS. These factors have been discussed below.

#### **2.4.1 Technology as a part of a social process**

Technological innovation is always a part of social, economic and political context (Pitkin, 2001). In this aspect, Public Participatory GIS (PPGIS) is a growing approach that seeks to resolve some of the long standing tensions between critical traditions in human geography and the ever expanding field of GIS (Radil, 2015). There are several interpretations of "*Participatory GIS*" one of them being the merging of community development with geospatial technologies for the empowerment of the less privileged (Rambaldi, 2006). As identified by Weiner (2002) one of the most significant difficulties in implementing community-based GIS is integrating complex and socially differentiated information. He explains that while NGOs are enthusiastic about using advanced information technology, the challenges they face are magnified due to the significant differences in power, language, culture, and wealth.

#### **2.4.2 Limited sources of revenue and weak financial base**

Experience in the industrialized world reveals that construction of the database is the most significant expenditure in implementing a GIS with costs that are commonly five to ten times those of the hardware and software (Klosterman, 1995). Acquiring the hardware and software components may not be enough, as the implementation involves an additional cost of cleaning existing data, converting it to digital form, and filling in data gaps and deficiencies. Worall (1994) reviewed the cost-benefit analyses for three UK authorities and concluded that productivity gains and cost avoidance are possible with GIS, but not immediately (Budic, 1998). Also, seeking loan, aid or grant from national and international financial institutions such as the World Bank, IMF, ADB, and other financing agencies might not turn out useful as terms and conditions are more inflationary (Tiwary, 2016).

#### **2.4.3 Political complexities and Influences**

Klosterman (1995) stresses that GIS implementation and adoption process is not a straightforward technical process of model development, introduction, and that its use often becomes a focus for political dispute, negotiation, and bargaining as system developers, agency personnel, senior management, and public officials wrestle with the fundamental political questions of identifying the most appropriate system design, the data it should contain, the types of analyses to be performed, and the policies to be used for disseminating the analysis results.

#### **2.4.4 A dearth of technical skills**

GIS requires highly skilled human resources for running, operating and managing GIS. The main reason for lack of technical skills in developing countries as cited in (Musakwa, 2017 & Machakaire, 2015) is the deficiency of GIS training in planning schools. It author noted that in various municipalities the GIS department is still in its infancy and that planners still struggle to put cadastral data, land use and zoning data in GIS.

#### **2.4.5 Data availability and accessibility**

While a considerable amount of social and economic data is collected at a national level, very little has been collected on a local or regional level (Klosterman, 1995). In the practice of urban planning in the developing nations most decisions are being made on the basis of inadequate information and in a disjointed and incremental manner (Dekolo, 2005). The issue of limited data availability is further exacerbated due to inconsistencies in the data quality (Klosterman, 1995)

### **2.5 CASE STUDY OF GHANA – GIS FOR PARALEGAL TITLING AND LAND REGISTRATION**

Ghana attained middle-income status in 2010 following the discovery of offshore oil reserves and has experienced a robust economy characterized by a per capita income of 1,730 dollars in 2013 as compared to 430 dollars in 1980 which significantly improved livelihood for its citizens (World Bank, 2018). The national level of poverty between 1992 and 2013 reduced by nearly half (from 56.5% to 24.2%), achieving the MDG1 target; however, despite this, it is recorded that poverty reduction is not keeping pace with the population growth as the number of people living in poverty since 2006 has only declined by 10% (UNICEF, 2016).

Poverty is characterized by lack of finances and/or skills as well as by lack of assets such as property (land and housing) which one can leverage to access an income. In situations where the poor have access to land, their right to ownership of land is usually informal or unrecognized legally, accentuating their poverty and vulnerability. Without property rights, one lacks the authority to make investments on or based on the land (Meinzen-Dick, 2009). It is important to note that land holds a continuum of human rights (Whittal, 2014). It is a resource that provides an avenue for means of livelihood such as crop production and also enhances human dignity through shelter provision, thus providing one with a sense of identity and security.

In 1986, the Land Title Registration Act was enacted in Ghana in which the State backed new titles and eliminated the need for deed records, however, the process was slow (Focus on Land In Africa, 2011). The Land Administration System comprising poor maps and poor records made conversion from Deeds to Title almost impossible and the uncooperative attitude of multiple agencies involved in Land Administration, poor public education, lack of professional and technical skills and the sporadic way of implementation created more problems (Sittie, 2006). Also, land administration was divided among six land sector agencies, namely, the Office of the Administrator of Stool Lands (OASL), the Land Valuation Board (LVB), the Town and Country Planning Department (TCPD), the LC, the Land Title Registry (LTR) and the Survey Department, thus resulting in fragmentation of responsibility and lack of coordination (Ehwi & Asante, 2016). It was observed between 1986 and 2006, only 42,000 applications for land administration had been submitted to the Land Title Registry, and less than 30% of those were registered (Focus on Land In Africa, 2011). Rectifying this ambiguity, therefore, through legislative processes to give the poor property rights, is considered a crucial step towards alleviating poverty (Meinzen-Dick, 2009).

Taking this approach, the Government of Ghana with support from the Clinton Global Initiative (CGI) launched a pilot project from 2007 to 2009 in Ashaiman district, Accra. The project aimed at using GIS to create a new land records system and provide paralegal land titles thus formalizing land ownership. Paralegal title indicates that the titling process has been initiated for acceptance by the private sector, thus making land parcel owners eligible to apply for micro-financing loans. The pilot project was conducted in approval and interest of the Ghana Ministry of Lands.

#### **2.5.1 Factors to analyse in the case study**

To understand the contribution of GIS and the factors involved in its establishment, four key components have been identified to analyse the case study of Ghana. The components are as described by (Klosterman, 1995). The author states that "technology" consists not merely of tools and machines but four interdependent components:

- equipment, the tools, instruments, and machines used to perform a particular set of tasks;
- technique, the specialized skills, procedures, methods, and policies employed in using a particular piece of equipment;
- organization, the formal and informal relationships between the individuals and groups that utilize a particular piece of equipment and related techniques; and
- knowledge, the supplemental information about the physical and social world required to employ a particular set of equipment, technique, and organization effectively.

Through the application of the components described above, it is intended to understand the role of GIS in leveraging sustainable development in Ghana.

#### **2.5.1.1 Equipment**

Open Title is a low-cost ESRI OEM product used for cadastral data management and document management. Data can be stored and captured in the form of scanned documents, photographs, and videos. All the documents that were received from the site surveys which proved the ownership of the land parcel were recorded in this software. Trimble GeoExplorer ProXH devices and other supporting survey equipment were used for fieldwork.

#### **2.5.1.2 Technique**

The project involved the use of of-the-shelf GIS software as the core technology for the creation of parcel maps through land surveying and mapping activities. Mobile GPS equipment was also used for point location of the property and to record ownership and property information in a cost and time efficient manner. The scope of the project was limited to private schools looking to expand facilities to accommodate the growing demand for education services in the region as microfinancing institutions in Ghana had developed a special scheme for those interested to seek loans to build schools. Also, it was noted that the boundary of the schools was clearly defined. Hence, land parcels where schools were proposed to be built were targeted first.

The school owners actively participated in the process, as it was the first time that their property was being formalized. Interviews and fieldwork were conducted using a handheld GPS system, and the proof of documents was collected. The questionnaires were filled by the property owners. The neighbours and the relevant authorities for the properties to be surveyed were notified of the process and interviewed. Minor disputes were resolved on site through the field adjudication process. The data was uploaded on the *MultiCadastrre* system which linked the land parcel with the respective ownership documents. Once, the procedure was completed, paralegal titles were awarded. Using the paralegal titles, the owners could then lend finances from microfinance institutions of significant amounts unlike before, where the institutions lent small amounts of money, \$50-\$500.

#### **2.5.1.3 Organisation**

A consortium of private companies implemented the project. The Ghana Ministry of Lands supported the project team.

- International Land Systems (ILS) provided project management and technical consulting services. ILS provided the MultiCadastrre software.
- SAMBUS Company Ltd supplied the hardware and software support
- Losamills Consult Inc is a Ghanaian geoinformatics company specialized in land surveying and deploying of trained survey teams
- Sinapi Aba Trust is the largest microfinance lender in Ghana. The loan officers of the trust surveyed the properties under the pilot project and recorded the property information.
- Trimble Navigation of Sunnyvale, California, provided handheld mobile GPS devices and supporting equipment and technology that was used to map the parcels in the field.
- Corporate Initiatives Development Group (CIDG) founded the project and provided project direction.

#### **2.5.1.4 Knowledge**

During the implementation of the pilot project, the landowners were informed of the process and benefit of land registration. Local private organisations were involved in the execution of the pilot project. The loan officers of the microfinance trust were trained to use the mobile GPS equipment in the field to determine point location of the property and to record primary ownership and property information. The success of the pilot project led to the formation of Medeem – a new company created by Corporate Initiatives Development Group in partnership with a local enterprise in Ghana to expand on the progress achieved. The company is implementing projects of similar scale in other regions as well as providing asset management education and training on protecting land assets.

### **3 FINDINGS**

It can be gathered from the analysis of the pilot project that the implementation of GIS in this case satisfied the key factors as highlighted by (Klosterman, 1995) which led to the success of the project. The project succeeded in awarding paralegal titles to more than 51 schools in the district which profoundly impacted the social and economic aspects of human lives thus making a step towards sustainable development. As per the articles published in ESRI's ArcNews magazine, one of the first recipients of the paralegal title was interviewed and one of the key benefits stated was the fact that the land parcel was formally recognised and titled under the recipients name, thus making it an asset.

### **4 CONCLUSIONS**

The fast-paced nature of urbanisation has resulted in immense pressure on land for infrastructure, housing and other natural resources, particularly in developing countries such as Asia and Africa where most of the population growth is projected to take place. Implementing technology-based solutions to support urban and regional planning and develop an appropriate land information system has been considered as a medium to leverage sustainable development in these regions. In this context, GIS has proved to be one such technology that if successfully implemented can significantly contribute to the sustainable development of the nation, as was observed in the case of Singapore. However, extensive planning and consideration needs to be given to the various factors such as hardware-software requirements, manpower, financing, organisational structure, data availability and the political environment involved in its establishment. An integrated approach considering the aspects of implementation for an appropriate GIS can contribute to sustainable development in developing countries.

#### **4.1 GENERAL RECOMMENDATIONS AND WAY FORWARD**

##### **4.1.1 An incremental approach to Implementation Strategy**

It is suggested to adopt an incremental approach to implement GIS wherein the system is gradually shifted from manual methods of information management to a more technological advanced information system. It provides users with enough time and flexibility for adapting to the changes as opposed to the 'big bang approach' in which the entire data management system is transformed. This approach can be disruptive and inconvenient as well as demanding in terms of financial resources, technical expertise and time.

##### **4.1.2 Efficient project management**

Project management is crucial from the pre-planning to the post-implementation support of any local government GIS project (Dekolo, 2005). A project management team must involve all key stakeholders such as the local authorities, the private sector, providers of technology and equipment and other experienced professionals who can guide the project to achieve its goal.

##### **4.1.3 Overall guiding information strategy and supporting policies**

While it is ideal to carry out a phased implementation strategy, it should be supported by broader data management strategy and planning policies that ensure the quality management of data, accessibility, availability, reliability of information and its application. A data management plan may include but not be limited to (1) management policies for the coordinated development and maintenance of the GIS software, database, and applications; (2) procedures for data collection, processing, analysis, retrieval, and dissemination; (3) employment and working conditions for the GIS technical staff; and (4) guidelines for data access and data protection (Klosterman, 1995).

##### **4.1.4 Coordination at all levels of governance and support from national and regional**

Lack of coordination between government agencies, particularly in developing countries impedes sustainable development. With the introduction of GIS, data of all agencies can be integrated into a single dataset which may be accessible to all with varying degrees of privacy. Issues of inconsistencies and redundant data can be resolved. Establishment of a national or regional GIS center may be useful in ensuring coordinated development efforts across various government departments and authorities and in promoting standardization of data as well as support in terms of technical expertise.

#### 4.1.5 Participation of all stakeholders and ultimate beneficiaries

The form of participation of the beneficiaries is more crucial than the technical configuration of the software, as they are aware of the ground reality and can provide accurate information required to proceed with the project.

#### 4.1.6 Training and skill development

Limited number of professionals to operate GIS is a significant barrier to the adoption of this technology. There is a need to attract a larger set of audience, by providing necessary training and awareness about the software which necessitates the involvement of local universities and other professional institutions. Specialised training may also be carried out for a smaller group of professionals to bring in advanced skills to support effective use of advanced information technologies

#### 4.1.7 Partner with the private sector and critical institutions

The involvement of the private sector played a crucial role in initiating development in the poverty-stricken district of Ghana. A similar model tailored to context applied can be explored. It can help developing countries to become independent and tap potential opportunities to develop their system of planning and models of implementation.

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Thank you to all delegates, presenters, academic panel, reviewers and scientific committee for your contribution to the Out-Of-Box Human Settlements 2018 Conference.



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ISBN 978-0-7988-5639-3

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