Energy Water Green Building Waste

Sustainability Handbook

EDITION 03
DECEMBER 2021

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The Circular Economy is recognized as a new source of economic growth for South Africa.

The Council for Scientific and Industrial Research (CSIR) launched its 'Science, Technology and Innovation for a Circular Economy' (STI4CE) Project, providing early findings on what a more circular economy could mean for South Africa in terms of much-needed social, economic and environmental opportunities.

Webinar launch recording **https://youtu.be/S_XB99T6gfw**

THE CSIR HAS ALSO RELEASED A SERIES OF PUBLICATIONS AVAILABLE FOR PUBLIC DOWNLOAD

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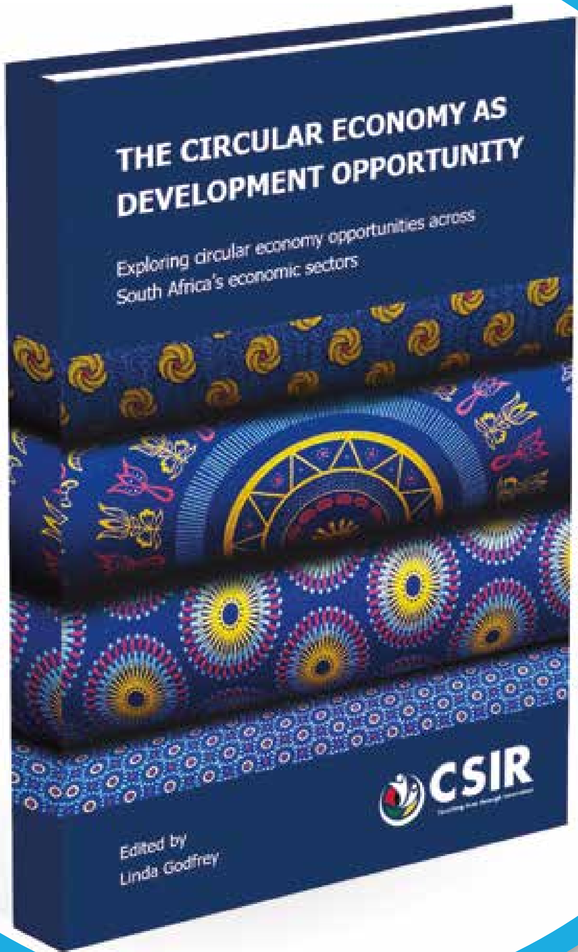

CSIR

Touching lives through innovation

The Sustainability Handbook
Volume 03 - December 2021

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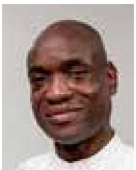
IMRAAN AKHALWAYA, CSIR SMART MOBILITY CLUSTER

Imraan Akhalwaya is a pavement engineer that holds an undergraduate degree in civil engineering (BSc.Eng) from the University of Witwatersrand and a post-graduate degree in transportation engineering (B.EngHons) from the University of Pretoria. He is currently working as a researcher at the CSIR in the field of transport infrastructure engineering. His predominant role at the CSIR has been focused around conducting Accelerated Pavement Testing (APT) with the aid of the Heavy Vehicle Simulator (HVS). Some of his current research interests include applications of nanotechnology in pavement engineering, 4IR sensors and instrumentation, smart road technologies as well as the use of alternative and waste materials for road construction.



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NCPC
NATIONAL CLEANER PRODUCTION CENTRE
SOUTH AFRICA

Supporting industry to **return to business unusual**

There is no better time to implement changes that can make your operations more efficient and sustainable.
As industry gears up, the National Cleaner Production Centre South Africa (NCPC-SA) is there to help and advise.

Through the implementation of resource efficient and cleaner production (RECP), companies can increase efficiencies and lower utility costs. Assessing your operations or production processes can lead to much-needed improvements:

- RECP **stimulates innovation** i.e. new solutions that have substantive benefits
- Resource savings translate directly into a **reduction in production costs**
- Sustainability initiatives **open up new markets**
- **Quality and safety can be improved** through systems such as an ISO 50001 energy management system
- RECP implementation creates an opportunity to **streamline** processes

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If you are ready to embrace a new normal, contact us to take the first step. Services are subsidised and advice costs nothing.

We are currently not all in the office so please email us on ncpc@csir.co.za. For more information, visit **www.ncpc.co.za**
*The NCPC-SA is a programme that promotes the uptake and implementation of resource efficient and cleaner production (RECP), funded by **the dtic** and hoisted by the CSIR.*

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REPUBLIC OF SOUTH AFRICA

CSIR

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Peer review

Alive2green has introduced and is committed to peer reviewing a minimum number of published chapters in all Sustainability Series handbooks. The concept of peer review is based on the objective of the publisher to provide professional, academic content. This process helps to maintain standards, improve performance, and provide credibility.

Alive2Green peer review process

The review process is blind, and multiple reviews are generally sought. Authors are provided with a redacted copy of a review form (that is with the identity of the reviewer removed). Reviewers are provided anonymised submissions and complete a review report which is returned to the editor. Reviews are assigned to individuals not affiliated with the authors' organisation.

Review has both a quality assurance role and a developmental role, therefore constructive feedback and justification for outcomes is encouraged. For a chapter or article to be published in the handbook it should be clearly written, of interest to readers and be methodologically and technically sound. By submitting authors attest that they have referenced source material and have not violated copyright. For a chapter or article to be considered as a peer-reviewed item, it should also make a new contribution to knowledge. Authors and reviewers may be identified in the handbook front matter with a photo and short biography. Reviewers are required to excuse themselves from reviewing or participating in editorial decisions in any instance where conflicts of interest (including financial interests and relationships) arise or are likely to arise in the foreseeable future. Review reports are classified by the editor and stored in compliance with POPIA to protect the integrity of the review and publishing processes.

Peer
Reviewed

The coronavirus pandemic took the world by surprise in 2020. The virus created a dire need for new processes and interventions that needed to be adapted, adopted and proven.

Although Covid-19 has been dominating all local and global news headlines with its centrefold positioning on vaccines, restrictions, and containment, issues of sustainability were not completely kicked off mainstream media's centre stage. The recent Glasgow climate pact shone a brighter spotlight on relevant sustainability narratives concluding in the unforeseen phasing down of coal reliance.

Robust, optimistic participation and progress were celebrated at the summit for a few days only to be quenched by a last-minute phrasing adjustment that witnessed a quick sudden migration from "phasing out" to "phasing down" of coal. This echoed widespread dissatisfaction by most COP 26 delegates who felt that transparency and procedural consistency has been compromised by great haste.

The summit followed the ground-breaking announcement by some EU member states, United Kingdom and the United States of America, for a new ambitious, long-term Just Energy Transition Partnership, complete with funding commitments to support South Africa's decarbonisation efforts. Meanwhile, on South Africa's eastern seaboard, Shell is preparing to continue prospecting for off-shore oil and gas, amidst mounting heightened attention, as well as both watchdog and public criticism and a failed interdict.

Earlier in the year, Durban's main beaches were closed for several months during the peak holiday season. This was reportedly due to contamination by raw sewerage and chemical spills that rendered water unsafe for humans and were deleterious to marine life. The suitability of the engineering design of the Cornubia warehousing, the source of the spillage, was brought into question, as was the planning and maintenance of the sewerage system and its operational stresses.

Public protests escalated into civil unrest, vandalism, and the destruction of key municipal infrastructure. These seemingly unrelated incidences boldly highlight the intricacy of environmental sustainability. Sustainability relies on history, infrastructure, planning, forecasting, smooth operation and maintenance, as well as politics and economics of resources.

These unforeseen spills demonstrate our lack of foresight and risk mitigation displayed through poor planning. They resonate with an ever-increasing sense of urgency and a need to get involved, even if the best trajectory is unknown. The third Sustainability Handbook holds some interesting thoughts on how households, communities, practitioners, and governments can deepen awareness, critically assess and adopt new technologies with a fresh approach. Steyn and Oberholzer point out that sustainable development and the global move towards a more circular use of resources, premised on waste reduction and recycling have prompted a paradigm shift. Their phytoremediation study discusses nutrient recovery from organic waste streams that directly point to critical opportunities for a development agenda with direct economic, health, and environmental benefits through the recovery of nutrients from waste-water streams.

Another look at seawater and treated wastewater inspired CSIR researchers to explore the potential in innovation for road construction. In another chapter, researchers explore the potential for plastic waste in road construction. This directly speaks to the current dilapidated state of secondary roads and the need for better-performing ones. Building on themes of waste, and recognizing that sustainability and the environment affect everyone and are everyone's responsibility, researchers at Nelson Mandela University have scientifically concluded that the residents of Joe Slovo township are generally not aware of the innovative and technological practices of reducing, reusing, recovering, and recycling energy from waste.

Undercutting of concrete fords, crossings, road erosion, and culverts, especially in remote and rural settings, is a direct result of climate change. To mitigate the effects of damage, a multi-national project was initiated to provide regional guidance on sustainable climate-resilient rural access in Africa, via research and knowledge sharing. One of the objectives of the project was to identify, characterise, and demonstrate the engineering and non-engineering sustainable adaptation procedures that may be implemented to strengthen the long-term resilience of rural access. Researchers studied several interventions on a gravel road in Mozambique to ascertain climate adaptation measures that give insight into effectively addressing climate-change related problems affecting roads

Limpitlaw explores the topic of how households can reduce their carbon emissions and considers the associated investment costs. His conclusions not only point to some "low-hanging fruit" but also to the current marginal feasibility of some measures with recommendations to standardise these measures to achieve the necessary impact. Adeniran et al observe that while studies have acknowledged numerous environmental challenges in South Africa, there is a lack of attention to their implications for sustainable development. They argue that achieving healthy human lives and ecosystems demands adequate infrastructure, holistic planning, waste management, and greening, together with legislative, economic and educational tools backed up with political will.

Van Wyk maintains that while green building assessment methodologies generally acknowledge the role of land through ecological conservation, there is greater weighting on land cover than land use. However, climate change and land use affect each other, prompting him to challenge our current conceptual frameworks.

The Sustainability Handbook as a publication identifies the pursuit of disseminating quality and original research whilst spearheading new developments demonstrated by advancing local scholarship that ultimately promotes sustainable development and infrastructure. The publication relies on its authors and blind peer-review process to vet the quality of submissions and to present a wide range of research interests, perspectives, and insights. The Handbook takes pride in providing a local platform for the participation of emerging early-career researchers both as contributors and reviewers, with the support and encouragement of well-established scholars and academics.

The CSIR has identified an opportunity to passionately contribute to developing skills and confidence in this growing space. A virtual peer reviewers' summit has been earmarked for May 2022. The summit is tailored for aspiring and new reviewers to engage with more experienced academics and professionals.

GREEN BUILDING

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"Reinventing Planning, Changing Lives"

The South African Council for Planners (SACPLAN) is the statutory Council established in terms of the Planning Profession Act, 2002 (Act 36 of 2002) for the Planning Profession.

SACPLAN assures the quality of planning qualifications (such as degrees and diploma's) offered by educational institutions. This relates to professional registration because any person who intends to register as a planner in any of the categories in terms of the Act must have completed a qualification that has been accredited by SACPLAN. In addition, registered planners are expected to engage in continued professional development (CPD).The core business of SACPLAN is to regulate, monitor, and manage the Spatial Planning Profession and – industry in South Africa by protecting the public's interest, whilst serving the Spatial Planning Profession. The true mark of a planning practitioner is recognized through the use of the following designations:

- Professional Planner (Pr.Pln)
- Technical Planner (Tch.Pln)

These practitioner titles carry considerable prestige and is an indication that competent planning professionals are capable to accept professional responsibility for the planning work performed. The designation does therefore validate the planning professional's knowledge, experience and commitment to working to the highest standards. It confirms that the registered professional is working under a Code of Ethics and Professional Conduct.

Vision Statement

The vision of SACPLAN is to foster the spirit of innovation in facilitating inclusive, sustainable, and transformative development in the planning profession of the country.

Mission Statement

The SACPLAN's mission is to profile the planning profession in South Africa to world class standards through:

- Regulating the Planning Profession so as to promote and protect the interests of the public in relation to Planning;
- Increasing the numbers of registered planners and increasing representativity in the planning profession;
- Inculcating discipline and ethical principles;
- Ensuring and promoting a high standard of education and training in the Planning sector;
- Protecting and promoting the interests of registered planning professionals;
- Promoting good planning practice informed by ethos, values and spirit of social justice, poverty eradication, spatial equity, environmental sustainability;
- Promoting social and Environmental justice by continuously transforming the spatial form in order to realise equitable distribution of resources; and
- Promoting innovative planning techniques in order to advance both rural and urban development.

General

In addition to a formal educational background, planners possess a unique combination of skills that enhance their professional success:

- Knowledge of urban spatial structure or physical design and the way in which cities work;
- Ability to analyse demographic information to discern trends in population, employment, and health;
- Knowledge of plan-making and project evaluation;
- Mastery of techniques for involving a wide range of people in making decisions;
- Understanding the local, regional and national government programmes and processes;
- Understanding the social and environmental impact of planning decisions on communities;
- Ability to work with the public and articulate planning issues to a wide variety of audiences;
- Ability to function as a mediator or facilitator when community interest conflict;
- Understanding of the legal foundation for land use regulation;
- Preparation of Land Use Master plan/blueprint;
- Ability to envision alternatives to the physical and social environments in which we live; and
- Mastery of geographic information systems and office software.

AB InBev sustainability in Africa

At AB InBev, we are building a company to last for the next 100+ years, and we know that brewing great beers depends on a resilient natural environment and thriving communities. We are committed to creating a better world for all our stakeholders, including our colleagues, consumers, communities and ecosystems where we live and work.

AB InBev's global sustainability goals align with the UN SDGs and are targeted to areas where we can drive the greatest impact in the communities where we operate. They comprise four pillars, each of which has ambitious associated commitments and initiatives of which we're proud. These four pillars are: Smart Agriculture, Water Stewardship, Climate Action and Circular Packaging.

AB InBev has 12 subsidiaries working in 11 countries in Africa.

Smart agriculture

As a global brewer, we depend on high-quality agricultural crops to brew our beers. That's why we support the livelihoods of farming communities worldwide, working with direct farmers to grow natural ingredients that allow us to brew the best beers.

We believe research, knowledge, technology and financing are the key to transforming agriculture at scale. We leverage these to advance agricultural development and measure our impact through yields, resource-efficiency, soil health and smallholder incomes. Our goals are applied across regions in Africa to consider the wide variance in conditions and realities experienced by farmers across the continent.

As of 2021, approximately 15 000 African farmers are directly linked to our Supply Chain and thus included in our Smart Agriculture goals. Our ambitious 2025 goal is to have 100% of our direct farmers skilled, connected and financially empowered.

Water stewardship

Water is the number one ingredient in beer. That's why we're improving water access and security in the communities where we live and work. Our goal is that by 2025, 100% of our communities in high-stress areas will have measurably improved water availability and quality.

Within our operations, we drive water use efficiency, effluent reuse and responsible discharge. Beyond the brewery gate, we invest in shared watershed

security through Partnerships in the public-private-non-government sectors. In local communities, we promote water access and disaster relief efforts and across our value chain, we promote water security through our brands, key brewing materials and by engaging our major suppliers.

Through innovative partnerships and initiatives, AB InBev has been able to make substantial progress on ensuring that water resources are protected, and that farmers and communities are better able to access sustainable sources of water without depletion.

Climate action

We believe climate change remains the most pressing global challenge facing society.

Our business is one that is closely tied to the natural environment: agricultural crops and water are our key ingredients, we require raw materials for our packaging, and we need energy and fuel to brew and transport our beers. All of these have the potential to be impacted by climate change, and we are already experiencing some climate-related impacts in our value chain.

Our goal is that by 2025, 100% of our purchased electricity will be from renewable sources and we will reduce our carbon emissions by 25% across our value chain.

In South Africa, Castle Lite is switching to brew with renewable electricity. All seven of our breweries within South Africa contribute to this through solar power, with Alrode brewery in Johannesburg also making use of bio-gas facilities.

Building on the progress we have made towards our 2025 sustainability goals, on 6 December 2021, we announced our Global ambition to achieve net zero across our value chain by 2040.

Circular packaging

Our responsibility extends beyond the last sip. Our goal is that by 2025, 100% of our product will be in primary packaging that is returnable or made from majority recycled content.

Our motivation goes beyond just the environmental impacts – circular packaging enables us to contribute to building economic security and resilience through the creation and support of networks of local businesses that improve livelihoods.

In Nigeria, and Ghana, solutions are being trialed to recycle and increase recycled content in polyethylene terephthalate (PET) preforms, and in Tanzania, our subsidiary Tanzania Breweries Limited has taken bold steps to entirely eliminate the use of PET from production lines. Post-consumer waste recycling programmes are active in South Africa, Zambia and Nigeria.

Sustainable communities, planet, and business

AB InBev is rooted in local communities and economies around the world. We believe we are an important engine for economic growth. As we look forward, we believe we can also be a driving force for a more sustainable and inclusive future. Our ambitious goals will help build environmental resilience, reduce the harmful consumption of alcohol and promote inclusive growth and sustainable livelihoods across our value chain. We believe these efforts will also drive value for our company, because when our communities thrive, our business thrives.

Misrepresentation of professional qualifications and a category of registration

Whether failure to disclose professional qualification and category of registration to a client amounts to misrepresentation or not

SACAP has, over the years, seen a surge in the number of complaints from the public about misrepresentations of professional qualifications and / or categories of registration. This conduct manifests itself in cases where some registered persons promote themselves as Professional Architects whereas they are registered in lower categories of registrations or where such registered persons fail to disclose to a client their professional qualification and category of registration.

The misrepresentation is defined as a false or incorrect statement that is made to a contracting party which consequently induces the contracting party to conclude a contract. A conduct constitutes misrepresentation if:

a) It is material in that the other party would not have entered into a contract had it not been due to the misrepresentation
b) There is a failure to disclose a material fact to the other contracting party when there is a legal duty to do so.

This was confirmed in the matter of McCann v Goodall Group Operations (Pty) Ltd 1995 (2) SA 718 (C). Furthermore, in UMSO Construction Pty Ltd vs Tau Pele and others, the court indicated silence and failure to disclose a material fact may in certain circumstances amount to misrepresentation. Registered persons have a legal duty to disclose their professional qualification and category of registration to their clients from the onset. Thus, it is incumbent upon all registered persons to disclose their professional qualification and category of registration prior to undertaking to perform architectural work for the public.

Misrepresentation in the architectural profession arises where:

a) A registered person makes a false statement about the professional qualification and the category of registration.
b) There is a non-disclosure of professional qualifications and category of registration to a client.

Often members of the public argue that they would not have appointed a registered person if they had known the professional qualification and the category of registration. This means that a client relies on the information provided by a registered person to make an informed decision before contracting for the provision of architectural services. A client involuntarily relies on a registered person to make a full disclosure pertaining to professional qualification and the category of registration. In most cases, this information is within the exclusive knowledge of a registered person. Members of the public may not differentiate between the various categories of registration, professional qualifications and the level of competence attached to the registration category. In order to redress the public's knowledge deficit relative to a professional's knowledge and expertise, a registered person has a duty to disclose professional qualification and the category of registration.

Naturally, the objective of misrepresentation, non-disclosure or overstating professional qualifications or registration category is to secure work, job offers and other professional recognition. The temptation to misrepresent or overstate the qualifications is on the rise due to minimal work in the profession. This is aggravated by a current economic climate coupled with Covid-19 pandemic impact on the built environment.

Rule 1.5 of the Code of Conduct is meant to prevent the improper conduct. It provides that a "registered person shall not misrepresent, or knowingly permit misrepresentation of their own or any other persons' academic or professional qualification or competency, nor exaggerate their degree of responsibility for any architectural work".

The misconduct cuts across various rules in the Code of Conduct. Registered persons are called to act with honesty and integrity at all times when performing architectural work. Where a registered person makes false statements or overstates his or her professional qualification and / or category of registration, it goes beyond a mere exaggeration, but an intentional deception and gross dishonesty. This conduct will certainly have a negative impact on the professionalism and the reputation of the profession.

The misconduct poses a serious risk to the built environment and the public due to the fact that clients may end up appointing registered persons who may not be competent to perform the work. This may result in inadequate design details or design deficiencies, inadequate specifications, and poor workmanship. Rectifying design deficiencies and poor workmanship to ensure that a structure meets the minimum technical requirements, and structural integrity may be very costly.

The only way to address these challenges is to ensure that registered persons disclose upfront their professional qualifications or registration category and confirm that they are competent to perform the work for the client in line with the Identification of Work.

Advocate Toto Fiduli,
Registrar, SACAP

SAICE Welcomes 119th President, Prof. Marianne Vanderschuren

The South African Institution of Civil Engineering (SAICE) welcomed their 119th President, Prof. Marianne Vanderschuren, into office at a special inauguration event. The auspicious occasion, held on Friday 26 November 2021, was attended both virtually and in-person at The Westin Cape Town, in the presence of SAICE members, stakeholders and members of the press.

In her presidential address, Prof. Vanderschuren discussed four themes – civil society, appraisal, responsibility, and education. On civil society, she addressed the civil infrastructure needs for the future for South Africa. "According to the United Nations, the South African population is due to grow by another 25% in the next 50 years. Growth is expected to be larger in cities, due to migration. This increasing population translates into a further need for civil infrastructure and services." Meeting these needs will require competent and professional civil engineering professionals.

On appraisal, Marianne discussed challenges which may hamper the meeting of future needs. "To make sure South Africa meets the multiple societal objectives, a more holistic optimisation appraisal approach is required. Our industry, perhaps even in collaboration with other industries, needs to move towards holistic appraisal practices, to make sure that investments prioritise projects with the highest overall impact." To achieve this, she said that criteria should include strategic fit, societal impact, and deliverability.

Further, she said: "The responsibility to implement civil infrastructure and services is, to a large extent, carried by municipalities. However, there has been a decline in technical capacity in municipalities, including some cities, that affects their ability to spend capital budgets. An aging infrastructure and prolonged underinvestment in maintenance has led to major challenges, as articulated in SAICE's 2017 Infrastructure Report Card (IRC)."

In terms of education, Prof. Vanderschuren believes that in a country with a growing population and decreasing technical skills in municipalities, education and capacity building are core. "The education challenge is to guarantee that the basic engineering competencies are taught. Amid the pandemic, online emergency teaching provided many solutions for universities. SAICE has similarly stepped up through the launch of the SAICE Academy ,which aims to foster transformation in the civil engineering sector through skills and professional development."

In conclusion, she said: "When you combine the first letter of each of my themes, you will see that the word 'CARE' appears. Those who correspond with me know that 'Dare to Care' has been my motto since the start of the pandemic. I believe we must now work together to reboot and rebuild our beautiful nation."

Meanwhile, outgoing President for 2021, Vishal Krishandutt, welcomed the new President, Prof. Vanderschuren: "She is a capable, skilled, well-respected, individual, and I wish her the best in driving the SAICE agenda for the betterment of our profession and for our country into the future."

Krishandutt reflected on the past year at SAICE, as well as the state of the civil engineering industry and the economy. He believes that "despite the current state of the South African economy and its impact on infrastructure service delivery, with a renewed focus on training and investment, 2022 holds potential for improved sector growth."

Krishandutt's presidential theme for 2021 focused on gender diversity and inclusivity. He said that SAICE is committed to contributing towards a diverse and inclusive civil engineering and built environment sector, where every individual is a valued contributor, with a sense of belonging and with equal opportunity to succeed. In fact, to promote an inclusive environment, which encourages equality and fairness, the number of women on its Council, as well as its executive board has increased for 2022.

He concluded: "We've done it because we believe our strength lies in our diversity, and because everyone of us brings to the table a different set of skills,

Prof. Marianne Vanderschuren

intelligence, charisma and determination regardless of race, age or gender; and because transformation must start from within. To drive change, you have to first embrace it and we will continue to drive this transformation at SAICE."

Prof. Vanderschuren is the third female president in SAICE's history, following in the footsteps of the renowned Dr Allyson Lawless and Prof. Elsabe Kearsley. In recent years, SAICE has strived to promote diversity and inclusion in the civil engineering industry, and members can look forward to this ongoing transformation under the leadership of Prof. Vanderschuren.

The evening also celebrated Innocentia Mahlangu, winner of the President's Award for the most outstanding SAICE member, and Mr JHV Viljoen as the 2021 Honorary Fellow.

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Preservative treated wood –a sustainable choice

A construction material provided and renewable by Nature, with predictable performance, that captures carbon from the atmosphere and locks it away for decades, with low energy demand and a feel-good appeal appreciated by almost everyone – that's treated wood.

Part of the bioeconomy, wood is a flexible and adaptable material wood that can be sourced responsibly and used efficiently in alignment with the circular economy. At the end of its life wood can be reused in an ongoing process of uses, recycling or recovery of energy. Wood is consequently one of the few truly renewable construction materials.

Wood offers a simple way to reduce the CO_2 emissions through:

- the carbon sink effect of the forests;
- the carbon storage effect of wood products; and
- substitution for carbon-intensive materials.

Not only is wood production and processing energy efficient, giving wood products a low carbon footprint, but wood can often be used to substitute for other energy-intense materials like steel, aluminium, concrete or plastics.

Every cubic metre of wood used as a substitute reduces CO_2 emissions by an average of 1.1 tonnes (t). Combined with the 0.9 t of CO_2 stored in wood, each cubic metre of wood saves a total of 2.0 t CO_2. Based on this, an increase in buildings whose main structural components are made of wood, will produce significant CO_2 savings.

Wood protection

The natural durability of wood is limited to the heartwood, but this depends on the species, growth conditions and provenance. Most untreated wood is vulnerable to biodeterioration by fungal decay and wood destroying insects. These biological agencies also degrade the sustainability credentials of untreated wood leading to early failure in service, premature release of CO_2 and economic loss more characteristic of a linear economy than a circular economy.

Commercially important wood species are typically derived from locally grown well-managed forests delivering high growth rate material. Modern processing practices are designed to maximise wood production yield, meaning it is impractical and uneconomic to exclude sapwood.

This requires protection against insect attack and, in prolonged wet conditions, fungal attack. Non-durable heartwood may also require protection depending on the species, conditions of use and service life required. Most South African grown commercially important species of pine and eucalyptus are non-durable and require preservative pre-treatment.

Sustainable use of biocides

Products containing biocides, such as wood preservatives, are intended to destroy or control harmful or unwanted organisms (such as fungi and insects) that have detrimental effects on the environment, animals, humans, their activities and the products they use or produce. Biocidal products are used in a wide variety of ways by industrial and professional users and the public.

Sustainable use of biocidal products is intended to reduce the risks and impacts of biocidal product use on human health, animal health and the environment.

Wood preservatives were among the first biocidal products to be subject to regulation and standardisation in respect of these characteristics and consequently are now accepted as both effective and safe, if and when used correctly and appropriately.

Treated wood as a sustainable material

Treated wood is the material of choice in every situation where its characteristics make it suitable. With such protection, designers have the choice of the foremost renewable and sustainable material.

SAWPA South African Wood Preservers Association

When structures come to the end of their life, treated wood may be segregated for cascading and recycling to extend the useful life of the material. Even when disposal eventually becomes the only option, energy generation by burning certain types of preservative treated timber returns carbon to the atmosphere where it is turned back into wood by trees using the energy of sunlight.

As the amount of CO_2 emitted from combustion is no more than the amount previously stored, burning wood is carbon neutral: a truly circular economy.

Download the complete brochure "Treated Wood – A Sustainable Choice" from www.wei-ieo.eu or www.ewpm.org

For more information visit www.sawpa.co.za or contact the South African Wood Preservers Association: admin@sawpa.co.za or +27 11 974 1061

Construction efficiency the Peikko way

The Peikko Group is the global forerunner in slim floor structures and connection technology for precast and in-situ applications. In only three years, Peikko South Africa has made a significant impact on the building industry. Increasingly, local built environment professionals are bringing innovation and efficiency to their projects with Peikko's range of cutting-edge systems and products.

High-impact project solutions

The effectiveness of Peikko SA's solutions can be gauged from their impact on the construction projects that the company has been involved in. Take the 2016 extension of the Fourways Mall. An integral part of this R9 billion, 178,000 m^2 project was an enormous parkade designed to allow for the construction of a two-storey hotel on top.

"All the precast columns were designed, manufactured and erected using Peikko's mechanical, bolted connections for precast concrete. They can be erected with a small crew on site, without the need for temporary propping, for a much shorter, more cost-effective floor-to-floor construction cycle time," says Peikko SA managing director Daniel Petrov.

Peikko's connection system was the selected method of design and construction for the King Edward School Aquatic Centre in Johannesburg, which called for a strong, stable large-span roof without using too much floor space.

"Peikko's COPRA® Anchoring Couplers were the perfect product, transferring tensile, compression, and shear forces through the connection during erection and in the final stage. Moreover, they require no welding, eliminating the need for work at dangerous heights," explains Petrov.

This robust yet elegant innovation saw the Centre being nominated for a Concrete Society of Southern Africa (CSSA) Fulton Award 2022.

Daniel Petrov, Peikko SA managing director

In another South African first, Peikko's DELTABEAM®, Bolted Connections and Bolted Frames have been chosen for the design and building of Building Class I, II and III projects in Johannesburg.

"The DELTABEAM® slimfloor solution reduces floor-to-floor height with slim structures by combining DELTABEAM® Composite Beams and hollow-core slabs. The structural concrete infill ties beams and slabs together to create composite action on-site," says Petrov.

Tailor-made Solutions

Peikko's construction products are equally suited to heavy industry, mining, and energy, especially wind farms. Each case is different, depending on the customer's unique project requirements.

"It takes a lot of involvement with our customers and with the project teams to find the right product and the right solution for a given project in a specific sector of the industry," says Petrov.

"For the wind farm application, we offer foundation solutions that take into consideration the ground conditions of the specific location. With our Designer Optimiser tool, we can assist the project team to determine the best foundation solution for a given wind turbine design."

Committed to sustainability

Peikko's commitment to sustainability is thoroughly pragmatic. Petrov explains: "The high road to sustainability is through offering high quality products in an environmentally sound way, which means that Peikko is committed to constantly improving its operation and sustainability in all R&D and manufacturing at Peikko Group.

"In addition, it's important to transparently communicate how Peikko operates when it comes to environmental, social and governance matters. It is not only important for our customers and employees, but it's also important to other stakeholders and communities where we are locally represented, and where our product exists."

Sustainable skills development

Peikko is also determined to contribute to sustainable skills development within the Construction sector.

"We are looking towards developing a Peikko Africa Learning Academy initiative and linking it with suitable platforms, such as those related to reputable industry bodies. Our technical and engineering responsibility around Peikko systems and products also links us to various educational institutions and universities in South Africa. We give graduate students the opportunity to do job shadowing and potentially work further with us," says Petrov.

Ultimately, the future of the Construction Industry depends on young professionals. Petrov concludes: "The only way is through committed young people who want to make a difference by learning the right skills, the right way. With us, you learn the right way from the word go. We call it the Peikko way."

The King Edward School Aquatic Centre in Johannesburg

Photo by Yelena Odintsova from Pexels

The Climate Change/Land Use/Land Cover Nexus, and Green Building Land Use and Ecology Assessment Criteria

Llewellyn van Wyk

1.0 Introduction

Climate change and land-use change are two significant global ecological challenges (the twin challenges) predicted for the future. Until recently, causes and consequences of anthropogenic climate change and land-use activities have largely been examined independently. As the IPCC's report Climate Change and Land notes "most discussions of climate action focus on energy, industry and transport" (2019). It states further that "land is critically important as well —both as a source of greenhouse gas emissions and as a climate change solution."

However, it is important to distinguish between land use and land cover: land use involves the transformation of the natural landscape into alternative uses typically associated with economic activities (Paul and Rashid 2017) whereas land cover is best described as how that land use change is expressed (Dale 1997).

On the one hand, land is critical to human livelihoods and well-being while, on the other hand, actions related to land use play a significant part in the climate system. Land use changes are often nonlinear and may trigger feedbacks to the ecosystem, stressing living conditions and increasing vulnerability of people (Paul and Rashid 2017). Human activities influence climate change by altering the distribution of ecosystems and their associated fluxes of energy. In this way, land-use change is related to climate change as both a causal factor and a major way in which the effects of climate change are expressed.

In response to this, culturally embedded systems of management need to be established across regional urban landscapes – from parks to verges to housing estates – as the new status quo in response to climate change and biodiversity loss (Cook in Hicks 2021). McDonald (2020) argues that environmental planners and designers should plan for nature in the same manner that roads and schools are planned for. This includes planning how cities can prevent habitat damage from urban growth, which is one of the main drivers of global diversity loss (McDonald 2020). There needs therefore to be a dramatic shift in the standard typologies of urban and rural landscapes and management systems if we aim to be successful in integrating biodiversity into the fabric contemporary life.

Infrastructure planning and design is a driver for both changes in multiple ways, not least through the physical displacement of ecosystems. Buildings form a significant component of infrastructure, being both an infrastructure asset as well as requiring other infrastructure assets to support its functioning.

Globally, buildings are responsible for 19 per cent of greenhouse gas emissions and cities up to 70 per cent (Hurlimann, Browne, Warren-Myers, and Francis 2018). As they note, changes are required in the way cities currently function, including land use, energy, industry, buildings, and transport. Infrastructure and ecosystems are generally approached as separate entities, however, Boulton (2021) argues that urban green space is essential infrastructure as it provides city inhabitants with multiple ecosystem services and benefits.

While green building assessment methodologies generally acknowledge the role of land through ecological conservation, this paper argues that their interest has more to do with land cover than land use. The emergence of green building assessment tools in the early 1990's was a property sector response to reducing the environmental impact of buildings. Although these assessment methodologies are largely dominated by energy reduction considerations, one of the categories is land use and ecology. This is of critical importance: private gardens can make up between 16-40 per cent of the total land cover, and between 35-86 per cent of the total greenspace (Christensen-Dalsgaard 2021).

This study examines whether green building land use and ecology performance attributes, using Green Star SA Office v1.1 as a proxy, adequately mitigate these twin challenges within the conceptual framework of the land use/land cover nexus. The study argues that significant changes are required to green building assessment methodologies to align the goals and strategies of green buildings with those of climate change and land use management.

1.1 Climate Change and Land Use

To halt the decline of nature and meet the Paris Agreement objectives, strategies must be designed and implemented to improve the management of land use for agriculture, infrastructure, biodiversity conservation, climate change mitigation and adaptation, water provision, and other needs (Jung, M., Arnell, A., de Lamo, X., García-Rangel, S., Lewis, M., Mark, J., Merow, C., Miles, L., Ondo, I., Pironon, S., Ravilious, C., Rivers, M., Schepashenko, D., Tallowin, O., van Soesbergen, A., Govaerts, R., Boyle, B. L., Enquist, B. J., Feng, X., Visconti, P. 2021). The authors note that this will require clarity on how these aims can be operationalized spatially and how multiple targets can be pursued concurrently. To support the implementation of strategies and actions, spatial guidance is needed to find which land areas have the potential to generate the greatest synergies between conserving biodiversity and nature's contributions to people. Critically the authors argue that biodiversity should not be looked at in isolation but that other factors such as conserving carbon stocks should also be considered.

Until recently, causes and consequences of anthropogenic climate change and land-use activities have largely been examined independently. As the IPCC's report Climate Change and Land (2019) notes "most discussions of climate action focus on energy, industry and transport." It states further that "land is critically important as well —both as a source of greenhouse gas emissions and as a climate change solution."

Hibbard, Hoffman, Huntzinger and West (2017) note that changes in land use and land cover due to human activities produce physical changes in land surface albedo, latent and sensible heat, and atmospheric aerosol and greenhouse gas concentrations. They estimate, with high confidence, that the combined effects of these changes may account for 40 per cent of the human-caused global radiative forcing from 1850 to the present day. They note, with high confidence, that land use and land cover changes have turned terrestrial biosphere (soil and plants) into a net sink for carbon, and that this sink has steadily increased since 1980. Due to this, and the uncertainty of the trajectory of land cover, they argue that the possibility exists that land could become a net carbon source in the future. In addition to the land use and land cover changes accompanying urban development, climate change and induced changes in the frequency and magnitude of extreme events such as floods, droughts, and heat waves, have resulted in large changes in plant community structure with subsequent effects on the biogeochemistry of terrestrial ecosystems. The uncertainties associated with climate change and its effect on land cover make it difficult, they argue, to project the magnitude and sign of future climate feedbacks from land cover changes. Climate change has altered the growing season in many regions with important variability at smaller scales. Plant productivity has however, not improved because of the longer growing season due to plant-specific temperature thresholds, plant-pollinator dependence, and seasonal limitations in water and nutrient availability. They find that future consequences of changes to the growing season for plant productivity are uncertain. In addition, recent studies confirm and quantify that surface temperatures are higher in urban areas than in surrounding rural areas for several reasons, including the concentrated release of heat from buildings, vehicles, and industry.

Enhanced ecosystem carbon storage is a key component of many climate mitigation pathways as terrestrial ecosystems are currently large carbon sinks (Coffield, Hemes, Koven, Goulden and Randerson 2021). They note that natural ecosystem's ability to store carbon will diminish as these ecosystems are themselves being impacted by climate change. This degradation plays out unevenly across different ecosystems as well with some areas appearing more vulnerable to carbon loss than others. Their study found that in a changing climate scenario certain tree species will perform better than others regarding carbon storage. Similarly, they identified spatial patterns of vulnerability most notably regarding elevation. They therefore argue that the design of land management strategies and policies needs to anticipate the impacts of climate change in terms of both species and spatial vulnerability and emphasising that climate mitigation strategies should not assume carbon storage stationarity. They argue that spatial patterns of climate-stable and climate-unstable locations should inform land use management. They stress that the one-size-fits-all strategy to maximise carbon stocks appears poorly suited to the projected shifting mosaic of carbon with climate change and suggest a more climate-aware approach is adopted.

Dale (1997) suggests that land-use change is related to climate change as both a causal factor and a major way in which the effects of climate change are expressed. As a causal factor, land use influences the flux of mass and energy, and as land-cover patterns change, these fluxes are altered. Dale notes that "a review of the literature dealing with the relationship between land-use change and climate change clearly shows that (1) in recent centuries land-use change has had a much greater effect on ecological variables than has climate change; (2) the vast majority of land-use changes have little to do with climate change or even climate; and (3) humans will change land use, and especially land management, to adjust to climate change and these adaptations will have some ecological effects."

2.0 The Land Use/Land Cover Nexus

When engaging with a site from a land use and ecology perspective the site, its soils and landforms and the species on it needs to be understood as part of developing a contemporary response but also understanding and reading the landscape and developing a sense of its past management and history of disturbance (Hicks 2021).


Photo by Francesco Ungaro from Pexels

2.1 Land Use

AS Dale notes, "land-use activity contributes to climate change, and changes in land cover patterns are one way in which the effects of climate change are expressed" (1997). Land use refers to the management regime humans impose on a site. Land-use effects on climate change include both implications of land-use change on atmospheric flux of CO2 and its subsequent impact on climate and the alteration of climate-change impacts through land management. Effects of climate change on land use refers to both how land use might be altered by climate change and what land management strategies would mitigate the negative effects of climate change.

Ravetz, Fertner and Nielsen (2013) argue that one of the critical zones of land use activity is the peri-urban, or urban fringe, as it may be the dominant urban form and spatial planning challenge of the twenty-first century.

2.2 Land Cover

Land cover on the other hand is a descriptor of the status of the vegetation at a site (Dale 1997).

Christensen-Dalsgaard (2021) notes that the extent to which vegetation modifies the micro-climate varies with plant composition and structural features. This modification varies between different types of low-height green infrastructure. Surface temperatures are higher in sites with less plant volume. Arthropods —such as beetles, spiders, and centipedes as well as butterflies, bees, and other insects important for pollination—are more abundant and diverse in areas with more plant varieties. She notes that the value of gardens as biodiversity refuges relates to a concept called functional diversity. This is a measure of how many different functional groups are present in a habitat. With vegetation, a high functional diversity implies that there is a variety of different types of plants present. Gardens with high functional diversity excel in most ecosystem services. The multi-layered canopy and root systems are more effective in promoting water infiltration into the soil. Deeper roots allow transpiration during hotter days. And a greater functional diversity of plants tends to result in a greater variety of animals living in the garden. Because of this, properly managed gardens can replace the habitat lost due to urban development, making urban greenspaces increasingly important as refuges for native biodiversity. Critically Dale notes that the biodiversity of gardens managed for habitat improvement can match that of natural areas (1997).

McDonald (202) notes that the goal of planning efforts in Melbourne, Australia, is to strategically increase the abundance of trees, shrubs, and grasslands in the metropolitan area to help cool the city, but more critically from a land-use perspective, is the reconnecting of "remnant patches of natural habitat, providing a safe haven for some of Australia's distinctive animals". More critically, Jung et al (2021) argue that biodiversity should not be looked at in isolation but that other factors such as conserving carbon stocks should also be considered.

2.3 The Role of Nature-based Solutions

Nature-based solutions (NbS) include actions that involve working with nature to address societal goals, climate change and biodiversity loss, while simultaneously supporting economic recovery and tackling environmental problems (Seddon, Daniels, Chausson, Harris, Hou-Jones, Huq, Kapos, Mace, Rizvi, Reld, Roe, Turner, and Wicander 2020; Austin, Cohen, Coomes, Fairbrass, Hanley, Lewis, Luque-Lora, Malhi, Savaresi, Seddon, Smith and Wheeler 2021; Seddon, Chausson, Berry, Girardin, Smith, and Turner;2020). NbS generally involves the protection, restoration, and connection of native habitats, sustainable management of working lands, and critically from a green building perspective creating new habitats in urban areas and across the broader landscape. There is substantive evidence supporting the cost effectiveness of NbS to support climate change adaptation and mitigation while reducing sources and increasing sinks of GHGs (COP26 Universities 2021).

Christensen-Dalsgaard (2021) makes the point that green infrastructure is now central to urban planning in most cities. She includes planting trees and bushes, naturalizing parks, restoring wetlands, and promoting other greening forms such as green roofs under the description of green infrastructure.

The notion of NbS has more recently been conceptually linked to the idea of the commons (McPhearson, Raymond, Gulsrud, Albert, Coles, Fagerholm, Nagatsu, Olafsson, Soininen, and Vierikko 2021). They argue that the recent surge in cities investing in NbS showcase the pathways needed to rethink the natural resources and open space commons beyond the creation of green space. For the authors, rethinking the commons includes the generation and qualitative improvement of new and existing public open spaces. They note that whereas urban development is often focused on private development, emerging thinking in urban development illustrates rethinking of urban spaces and an orientation toward greener, just, and healthy neighbourhoods, also termed urban recalibration.

3.0 Green Building Assessment Tools and Land Use Criteria

Green building assessment tools generally acknowledge land use and ecological conservation. As noted earlier, climate change and land use affect each other since land use is both a source of greenhouse gas emissions and as a climate change solution.

In terms of this, the key intent would be to both avoid GHG emissions (source) and absorb GHG (sinks).

Table 1: Land Use Credits and Intent

ASSESSMENT TOOL CREDIT CATEGORY	INTENT SUMMARY
BREEAM NC: Land Use and Ecology	
Site Selection	To recognise the reuse of previously developed and contaminated land where appropriate remediation has taken place
Ecological Risks and Opportunities	To identify and understand the ecological risks and opportunities associated with the site to inform the determination of the strategic outcome for the site
Managing Impacts on Ecology	To recognise steps taken to avoid impacts on existing site ecology as far as possible
Ecological Change and Enhancement	To recognise steps taken to enhance site ecology
Long Term Ecological Management and Maintenance	To encourage the long-term maintenance and management of ecology on site to ensure both new and existing ecological features continue to thrive
LEED: Sustainable Sites	
Construction activity pollution prevention	To reduce pollution from construction activities by controlling soil erosion, waterway sedimentation, and airborne dust
Environmental Site Assessment	To protect the health of vulnerable populations by ensuring that the site is assessed for environmental contamination, and remediated
Site Assessment	To assess site conditions, environmental justice concerns, and cultural and social factors
Protect or Restore Habitat	To conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity
Open Space	To create open space that encourages interaction with the environment, social interaction, passive recreation, and physical activities
Rainwater Management	To reduce runoff volume and improve water quality by replicating the natural hydrology and water balance of the site, based on historical conditions and undeveloped ecosystems in the region to avoid downstream flooding
Heat Island Reduction	To minimise inequitable effects on microclimates and human, especially frontline communities, and wildlife habitats by reducing heat islands
Light Pollution Reduction	To increase night sky access, improve night-time visibility, and reduce the consequences of development for wildlife and people.
Site Master Plan	To ensure that the sustainable site benefits achieved by the project continue, regardless

	of future changes in programs or demographics
Tenant Design and Construction Guidelines	To educate tenants in implementing sustainable design and construction features in their tenant improvement build-outs
Joint Use of Facilities	Credit applies to schools only
Green Star SA Office v1.1	
Conditional Requirement	To exclude projects which are located on prime agricultural land, located on vegetation of high ecological value or within 100 metre buffers of vegetation of high ecological value, located on land with a confirmed presence or high probability of threatened red listed species, or is located within buffer zones of watercourses
Topsoil	To encourage and recognise construction practices that preserve the ecological integrity of topsoil
Reuse of Land	To encourage and recognise the reuse of land that has previously been developed and where the site is within an existing municipality approved urban edge
Reclaimed Contaminated Land	To encourage and recognise developments that reclaim contaminated land that otherwise would not have been developed
Change in Ecological Value	To encourage and recognise developments that maintain or enhance the ecological value of their sites

3.1 BREEAM, LEED and Green Star SA Land Use Credits

Table 1 provides an analysis of the credits of three leading green building assessment tools, namely BREEAM, LEED v4.1, and Green Star SA. These three tools are selected because BREEAM and LEED were the pioneers in the field, and Green Star SA due to its local relevance.

3.2 Analysis

The following observations are made:

There are many similarities between the three tools in this credit category. Many of the credits listed under this category in LEED are found in other credit categories in the other tools.

The credits generally favour the "do-least-harm" approach as articulated by conservation management.

Enhancing ecological value of the site is common to all these tools. However, biodiversity should not be looked at in isolation but that other factors such as conserving carbon stocks should also be considered.

The aim of the category credits is orientated toward the protection of sites with high ecological content. The discouragement of developing on ecologically valuable sites is a sine qua non.

At the same time, the category credits aim to encourage development of sites with limited ecological value.

Where development occurs on such greenfield sites the requirement is for no reduction in ecological value. While this sounds laudable, the bar is quite low as the site is already of limited ecological value. What the credit does not do is recognise that climate change and land use will impact on those species so protected, and that any development will contribute to these impacts.

The credit does not encourage the enhancement of the site's carbon sink potential, integration of the site into broader ecological conservation frameworks, or the encouragement of adding to the greening of the public domain, i.e., the commons. This is a serious omission in terms of land use management.

There are no requirements for the rehabilitation (as compared to decontamination) of brownfield sites, and an increase in ecological value beyond protecting topsoil. This is a serious omission in terms of land use management.

The credit criteria apply only to the site under development. No credits are granted for restoring connectivity by enhancing biodiversity and ecosystems beyond the site boundaries.

The rewarding of restoring and increasing biodiversity has the potential to lessen climate change impacts like the urban heat island effect while also boosting mental health.

3.3 Case Studies

To evaluate the efficacy of the approach of this credit category, projects achieving 60 points or more (5-star Or South African Excellence and 6-star or World Leadership) as listed on the GBCSA website were reviewed (GBCSA 2021). The projects include office buildings and multi-unit residential. Seven case studies complied with the search criteria.

- **Central Building, Black River Park** achieved a total of 66 points (South African Excellence), and the maximum points available for land use and ecology category. No information is provided for why this office project achieved the maximum points. However, since it is a refurbished site, the reason is self-evident when viewed against the credits listed above.
- **@Parkside, 130 Independence Avenue, Windhoek, Namibia**. This office project achieved 64 points overall (South African Excellence), and approximately 30 per cent of the total land use and ecology credits. Again, no explanation is given for the outcome, but from the description of the site (in the heart of the Windhoek CBD), it can be deuced that no open space is provided.
- **1 Discovery Place, corner of Rivonia and Katherine Street, Sandton**. This office project achieved an overall score of 75 points (World Leadership), and a land use and ecology score of about 30 per cent of the category total. As in the other examples, no explanation is given for the outcome. The sustainable building features are described as, inter alia, predominantly indigenous and xeriscaping landscape, and green roof. Again, one may deduce from the location that this is a refurbished site and that the use of indigenous and xeriscape landscaping together with the green roof resulted in a gain in ecological value.
- **144 Oxford, 144 Oxford Road, Melrose, Johannesburg**. This office project achieved 62 points overall (South African Excellence), and zero land use and ecology credits. Again, no explanation is given for the outcome, but from the description of the site (in the heart of the Rosebank), it can be deduced that no open space is provided.
- **203 Oxford, 203 Oxford Road, Dunkeld, Randburg.** This office project achieved 61 points overall (South African Excellence), and about 10 per cent of the available land use and ecology credits. Again, no explanation is given for the outcome, but from the description of the site, it can be deduced that no open space is provided.

- **4 Bucksburn, Cape Town**. This multi-unit residential project achieved 61 points overall, and about 55 per cent of the land use and ecology credits available. Again, no explanation is given for the outcome, but from the description of the site, it can be deduced that the project benefitted from its proximity to the existing surrounding garden.
- **78 Corlett Drive, Melrose North, Johannesburg.** This office project achieved 79 points overall (World Leadership), and about 20 per cent of the available land use and ecology credits. Again, no explanation is given for the outcome, but from the description of the site (brownfield site), it can be deduced that some ecological enhancement is provided.

From the above the following observations can be made:

i. There is a poor correlation between the overall ratings – even when rated as 'South African Excellence' and 'World Leadership' – and land use and ecology performance. In most of the case studies included, the credit performance would, in academic terms, be deemed an 'F'.
ii. It is especially noteworthy that the project descriptions rarely address land use and ecology interventions, suggesting overall that the category is poorly valued.
iii. The case studies demonstrate little urban rewilding, i.e., the reintroduction of nature back into the city.
iv. The case studies do not provide evidence of enhancing biodiversity.
v. The case studies do not provide evidence of reducing the heat island effect.

4.0 Discussion

Several factors emerge which land use and ecology performance criteria in green building assessment methodologies should be responsive toward.

4.1 Impact of climate change on species

Credits must anticipate the impacts of climate change in terms of both species and spatial vulnerability, recognising that climate mitigation strategies should not assume carbon storage stationarity. Spatial patterns of climate-stable and climate-unstable locations should inform land use management. The one-size-fits-all strategy to maximise carbon stocks is poorly suited to the projected shifting mosaic of climate change and suggesting a more climate-aware approach is adopted.

4.2 Human activities produce changes in land use and land cover

Credits must acknowledge that changes in land use and land cover due to human activities produce physical changes in land surface albedo, latent and sensible heat, and atmospheric aerosol and greenhouse gas concentrations, and that evaluation requirements include mitigation strategies.

4.3 Land use and land cover changes have created carbon sinks

Credits must acknowledge that land use and land cover changes have turned terrestrial biosphere (soil and plants) into a net sink for carbon, and due to this, and the uncertainty of the trajectory of land cover, mitigatory strategies be implemented in anticipation of the possibility that land could become a net carbon source in the future.

4.4 Land use and land cover implications of extreme events

Credits must adapt to and mitigate land use and land cover changes accompanying urban development, climate change and induced changes in the frequency and magnitude of extreme events such as floods, droughts, and heat waves resulting in large changes in plant community structure and the biogeochemistry of terrestrial ecosystems.

4.5 Climate change and plant productivity

Credits must recognise that notwithstanding higher daily temperatures plant productivity has not improved because of the longer growing season. Performance attributes must mitigate future consequences of changes to the growing season for plant productivity.

4.6 Impact of the heat island effect on plant productivity

Credits must mitigate the heat island effect in daytime and night-time temperatures and the impact this will have on plant species, growing seasons, and productivity.

4.7 Reciprocal relationship between climate change and land use

Credits must recognise that land use has a reciprocal relationship with climate change and be responsive to land-use effects on climate change and the effects of climate change on land use.

4.8 Land Use and Spatial Planning

Credits must be based on a spatial planning approach that supports integrated conservation strategies. By jointly considering biodiversity, carbon, and water, synergies can be gained from conservation efforts compared to placing emphasis on any individual asset alone.

4.9 The role of land cover

Credits must acknowledge the extent to which vegetation modifies the micro-climate varies with plant composition and structural features. The value of gardens as biodiversity refuges relates to a concept called functional diversity. Gardens with high functional diversity excel in most ecosystem services: properly managed gardens can replace the habitat lost due to urban development, making urban greenspaces increasingly important as refuges for native biodiversity. Adopting the right approach can result in the biodiversity of gardens matching that of natural areas. Biodiversity should not be looked at in isolation but that other factors such as conserving carbon stocks should also be considered

4.10 The role of nature-based solutions in the climate change/land use nexus

Credits use must include nature-based solutions (NbS), and landscapes designed to store carbon at scale. Opportunities in green building assessment criteria include robust assessments of the suitability of land-based approaches from the local to regional scale and how changes in land use affect resources required in other sectors. Reconceptualizing the commons goes beyond the generation and qualitative improvement of new and existing public open spaces to include the private domain in a quantitative and qualitative manner.

5.0 Findings and Recommendations

Having regard for the information derived from the literature as set out above, the study finds that:

Green building assessment criteria should promote strategies that support land use change decision making at several landscape scales.

Climate change will impact species vulnerability, including those species currently deemed as regionally and locally indigenous. Therefore, species migration in response to climate change must be factored in. Spatial patterns of climate-stable and climate-unstable locations should inform land use and ecology credits.

Environmental designers must recognise that the act of building is in and of itself a land use change as are the infrastructure services supporting it. The design of land use and ecology credits must recognise that land use has a reciprocal relationship with climate change.

Land use and ecology credits should not assume carbon storage stationarity. In this regard biodiversity should not be looked at in isolation but that other factors such as conserving carbon stocks.

Photo by TheFacesISeek (Saptarshi) from Pexels

Land use and ecology credits should mitigate land use and land cover changes accompanying urban development, climate change and induced changes in the frequency and magnitude of extreme events such as floods, droughts, and heat waves, and the subsequent effects on the biogeochemistry of terrestrial ecosystems.

Plant productivity must be factored into the land use and ecology credits because of the longer growing season.

Although the heat island effect of hard landscaping is acknowledged elsewhere in the rating tool, land use and ecology credits need to mitigate the heat island effect of the building itself in daytime and night-time temperatures and the impact this will have on plant species, growing seasons, and productivity.

Connectivity to existing open space systems must be acknowledged in the land use and ecology credits. The design of land use and land cover management must be based on an approach for spatial planning that supports integrated conservation strategies. By jointly considering biodiversity, carbon, and water within the private and public domains, synergies can be gained from conservation efforts compared to placing emphasis on any individual asset alone.

The value of gardens as biodiversity refuges must be acknowledged in the land use and ecology credits. The biodiversity of gardens managed for habitat improvement can match that of natural areas.

No recognition is given to a project's contribution to a greener public domain. There needs to be a dramatic shift in the standard typologies of urban and rural landscapes and management systems if we aim to be successful in integrating biodiversity into the fabric contemporary life. Reconceptualizing the commons goes beyond the generation and qualitative improvement of new and existing public open spaces to include the private domain in a quantitative and qualitative manner.

No recognition is given to the role of nature-based solutions as an approach that can solve the twin challenges of climate change and ecological degradation simultaneously. Opportunities in green building assessment criteria include robust assessments of the suitability of land-based approaches from the local to regional scale and how changes in land use affect resources required in other sectors.

6.0 Conclusion

In conclusion, land use and ecology credits need a significant revision regarding its current level of granularity. The increase in our understanding of climate change and the land use/land cover nexus provides numerous small details making it possible to understand very clearly what is happening. Granularity will include the:

- Temporal scale regarding time and the variability of habitat quality over time
- Spatial scale regarding space and position, area, and the size of things within it.
- Carbon stationarity
- Species vulnerability
- Species productivity

The latest IPCC report provides a stark reminder of the stakes of the climate crisis. Without ambitious action, the world will likely reach or exceed 1.5 degrees C of warming within the next two decades. Because of their unique characteristics, urban areas will experience some of the most intense effects of extreme heat, precipitation, drought, and coastal flooding.

Preventing the most catastrophic damage depends on the actions taken this decade, and just as cities bear the brunt of some climate impacts, they also offer some of the most effective solutions. Infrastructure investment and climate action are urgently needed.

With the right approach (as suggested in this study), both goals can be achieved simultaneously. The current one-size-fits-all approach evidenced in the land use and ecology credits need immediate recalibration.

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Frans Dekker, SAIAT Managing Director

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Bedroom walls facing south or west should have well-insulated cavity walls using a construction material with high thermal mass to prevent a "hot-box" effect. Windows should be double glazed.

Here comes the sun!

We've all experienced it: some homes are always cold, some are too hot, and some are just right. How can you ensure that the home you build or buy is going to be cost-effective when it comes to electricity use?

Sustainable buildings save money, reduce your carbon footprint and provide a healthy living environment, transforming buildings from consumers of energy to producers.

South Africa is lucky to have abundant free energy throughout the year from the sun. The design and construction materials you choose to build your house can harness solar energy, without any capital-intensive technology or ongoing maintenance costs!

Passive solar design is the starting point of sustainable building. Passive solar heating requires careful application of the following passive design principles:

1. high density, high thermal mass construction materials that store heat
2. northerly orientation of daytime living areas
3. passive shading of glass in summer and selection of appropriate glazing
4. insulation and sealing.

This maximises winter heat gain, minimises winter heat loss and concentrates heating where it is most needed. Good passive design helps to keep homes cooler in summer, reducing the need for air-conditioning.

Thermal mass and the energy efficient home

Thermal mass is the ability of a material to absorb and store heat energy and is particularly practical in regions that experience big differences between day and night outdoor temperatures.

A lot of heat energy is required to change the temperature of high-density materials like clay bricks. They are therefore said to have high thermal mass.

Lightweight materials such as glass, timber and aluminium have low thermal mass. Research shows that in hot climate zones, 77% of the heat enters a building through ordinary clear glass windows. Conversely in zones with frosty nights, 55 % of heat is lost through the windows.

Therefore incorporating thermal mass and passive solar design into built structures can dramatically reduce the property owner's reliance on expensive electricity generated in South Africa by coal-burning power stations.

How does thermal mass affect internal temperatures?

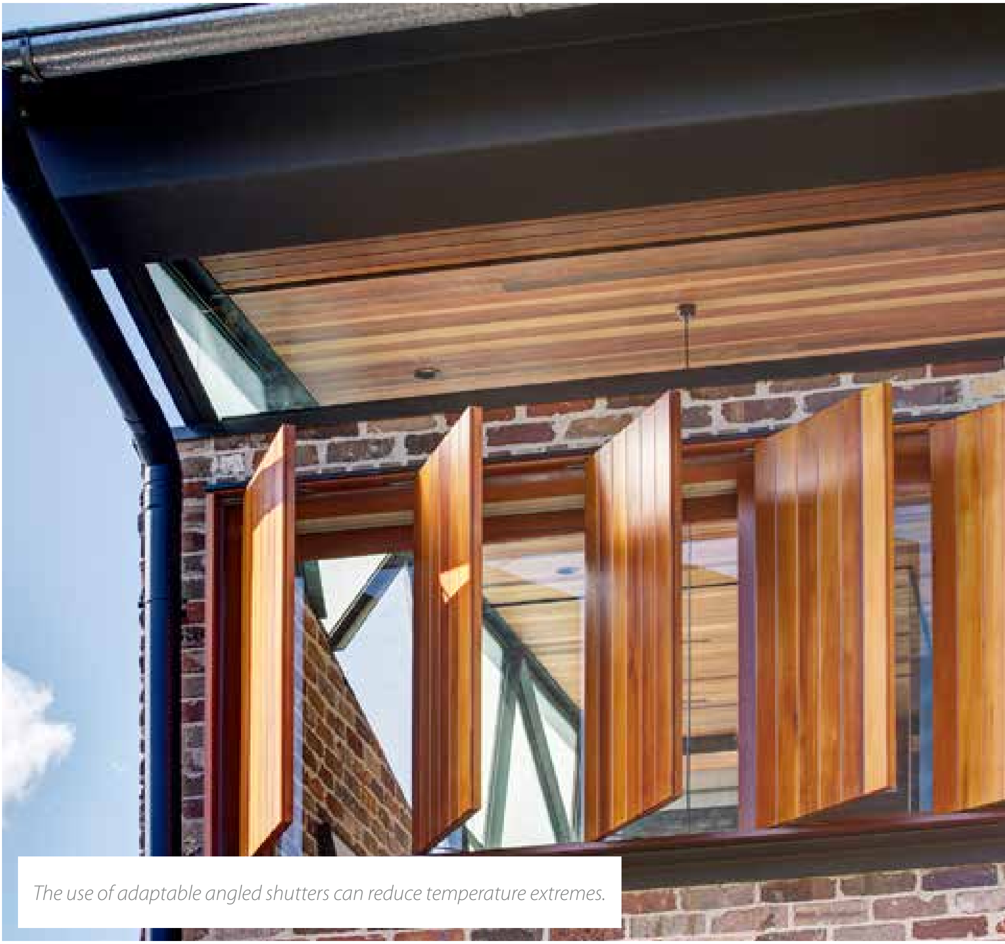
Sustainable construction materials with a high thermal mass will slowly capture some of the sun's energy during the day – but it takes many hours for that heat to pass through the dense material. Due to the high thermal mass of clay brick, the heat transfer delay for an insulated cavity wall is up to 8 hours which coincides with nightfall. Therefore the house remains cool during the day, and then stays warmer at night.

Appropriate use of thermal mass throughout your home will improve your comfort while cutting heating and cooling bills. Poor use of thermal mass can exacerbate the worst extremes of the climate, turning a home into a hotbox during the day, or quickly losing all the heat you produce on a winter night.

Where should you locate thermal mass?

- Main living spaces in the southern hemisphere should face north to take advantage of light and solar gain. Where you can control the sun striking walls on the North side, high thermal mass such as clay brick makes sense.

Bedroom walls facing south or west should have well-insulated cavity walls using a construction material with high thermal mass to prevent a "hot-box" effect. Windows should be double glazed.



The use of adaptable angled shutters can reduce temperature extremes.

- The kitchen is often on the east side to make the best use of the early morning sun – big windows are perfect as you don't want to be too "well-insulated" against the morning sun!
- Secondary bedrooms and bathrooms are often tucked away to the south or west as they are occupied less frequently. Therefore these should have well-insulated cavity walls, and glass must be double-glazed to protect from an afternoon "hot-box" effect, or a 2am freeze.
- Deciduous trees can be planted on the west to shade the house in summer and but allow in winter sun.
- A wine cellar should be on the south side (and preferably surrounded by earthern walls below ground) to take advantage of the cooler temperatures.
- Dark, matt or textured surfaces absorb heat and should be used in cold rooms. Smooth, light surfaces reflect heat and should be used in rooms that are too hot.
- Outdoor brick pavers will retain their warmth well into the night, and experience less frost.

For further information:
The Clay Brick Association of South Africa
Website: www.claybrick.org

The implication of urban environmental challenges for sustainable development in South Africa

Adeniran AA, Mngomezulu SK, Botha B, Mbanga S

1.0 Introduction

Approximately 55 per cent of the world's population live in urban areas as of 2018 and this is projected to have grown to 58 per cent by 2050 (Profiroiu, Bodislav, Burlacu and Rădulescu, 2020). About 66 per cent of the entire world's population lived in the countryside in the early 1950s (Leeson, 2018). Of the figures in the projection, UNFPA (2007) documented that the increase will occur in low and middle-income countries. As a result, the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 and 2012 Rio+20 (UNCED) Conference called on all countries to tackle the difficulty of providing suitable housing, sanitation, and water to residents in low-income areas like slums and informal settlements (Hens and Nath, 2003; United Nations (UN), 2012). While developed countries have generally stabilized their population growth and economies, most African, Asian, and Latin American countries have been unable to improve their inhabitants' poor living conditions (O'Sullivan, 2020).

Africa is widely seen as a rural and underdeveloped continent with a high incidence of crime, slum growth, underdevelopment, and overpopulation with a rate of urbanization two times that of Latin America and Asia (Tannerfeldt and Ljung, 2012). Hall and Pfeiffer (2013) observed that while rapid urbanization is a key public health challenge for the twenty-first century, Africas' urbanization does not match up with economic growth and improved citizen welfare. This observation is resonated by the report of UNDP (2020) where only South Africa has the human development index (HDI) of 0.7 and other African countries are within the range of the lowest HDI.

Table 1: Urban Population living in Slums (in millions)

Region	2000	2014	2016	2018
World	803.126	897.651	1003.083	1033.546
Sub Saharan Africa	131.716	202.042	228.936	237.840
Northern Africa and Western Asia	43.335	63.814	71.720	82.123
Central and Southern Asia	205.661	206.704	223.643	221.092
Eastern and South Eastern Asia	317.123	349.409	364.684	368.898
Latin America and the Caribbean	115.148	104.662	112.602	106.946
Oceania (Excluding Australia & New Zealand	0.234	0.602	0.648	0.643
Australia and New Zealand	0.03	0.03	0.01	0.01
Europe and Northern America	0.764	0.833	0.842	1.022

Source: UN-Habitat Global Indicators Database, 2020

As shown in Table 1, the UN-Habitat (2020) indicates that there has been over 90 per cent growth rate of urban slum dwellers in the past 2 decades rising from 131 million in 2000 to over 237 million in 2018 and thus there is increasing urban poverty and low life expectancy in the region.

In response to the increasing environmental deterioration caused by fast-growing urban populations without commensurate economic growth, seven African cities (Rabat in Northern Africa, Bamako and Lagos in West Africa, Durban in South Africa, Lusaka in Southern Africa, Douala in Central Africa and Nairobi in East Africa) were chosen to launch the New Partnerships for African Development (NEPAD) Cities Programme (Mboup, 2019).

Several types of environmental problems have been identified by different works of literature such as Darkoh (2009), Ameen and Mourshed (2017) and Meyer (2018) to be challenging developing countries. The key problems highlighted by Darkoh (2009) as challenging Southern Africa include global warming and climate variability, loss of biodiversity, deforestation, desertification, land degradation from mining, waste and littering, population growth, urbanization, pollution, poverty and health hazards. Zhang (2016) argues that rapid urbanisation is triggering huge problems and challenges, such as urban sprawl, urban poverty, higher urban unemployment rates, higher urban costs, housing affordability issues, lack of urban investment, weak urban financial and governance capacities, rising inequality and urban crimes, and environmental degradation among others, Wan and Wang (2014) agree with him but argues further that urbanisation could also bring about solutions to the identified challenges.

In view of the above, this paper examines the implication of environmental problems on sustainable development in South Africa by addressing the causes of urban environmental problems and their effects on humans and the surrounding ecological system. This is in order to make recommendations that could provide a road map for addressing the problem, as the concept of sustainability will remain a myth in South Africa and other developing countries unless the present trajectory of urban population and increasing environmental decay is complemented by commensurate economic development and eco-friendly development practices.

2.0 Literature review

The environment has been viewed as a concept from numerous perspectives and defined in various ways, with each view tending to generate and embrace definition(s) in line with its interest (Singh, 2003). However, the National Environmental Management Act (NEMA) (1998) defines "environment" as the surroundings within which humans exist and it is made up of the land, the water and the atmosphere of the earth; micro-organisms, plant and animal life; any part or combination of the first two items on this list, and the interrelationships among and between them; and the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being. In addition, the Environment Conservation Act (1989) defines the environment as "the aggregate of surrounding objects, conditions and influences that influence the life and habits of man or any other organism or collection of organisms". These two definitions give an overarching definition of the environment.

The potential of the environment to meet the minimum demands for the sustenance of the living and non-living elements of the ecological, economic, and socio-cultural systems in a way that does not constrain the intention of meeting the present and future needs of the multiple elements and aspects of the environment is referred to as sustainability (Salas–Zapata and Ortiz–Muñoz, 2019). Sustainability has three sub-systems namely economic, social-cultural and environmental subsystem. The Bruntland Report defined sustainable development as "the development that meets of the present without compromising the ability of future generations to meet their own needs need development" (WCED, 1987:43). This suggests that the aim of sustainable development is meeting present human needs in such a way that will not jeopardize the potential of the future to meet their needs. However, the prevailing global environmental degradation continues to pose a serious threat to the sustenance of the ecosystem (Dube, Nhamo and Mearns, 2020) hence making environmental sustainability a priority in housing, infrastructure provision, planning, land use and urban development among others (Ichimura, 2003).

Costa and Monte-Mór (2015) observed that urban areas are the result of urbanization, which has far-reaching economic, socio-spatial, and health implications, whereas Peter and Yang (2019) stated that sustainable development as applied to urban areas is the ability of metropolitan centres to continue to function at levels of ideal liveability by communities without limiting the options available to the present and future generations. However, the process of industrialization has left an ever-widening ecological and sociological "footprint" of cities and is not limited to developing countries (El Sakka, 2016). However, the rate and size of expansion have outpaced the ability of less developed countries in Africa, Asia, and Latin America to maintain acceptable standards of public health, environmental safety, and long-term economic growth in urban areas (Yoade, 2015).

Several studies such as Cloete (1995); Cloete (1997); Baloyi (2007); Dyantyi (2007); Jeffery (2010); Eddy (2010); Bonner and Nieftagodien (2012); Steenekamp (2012); Harrison (2013); Nathan (2013); The Housing Development Agency (HDA) (2013); Horn (2019); Marutlulle (2019); Salahuddin et al., 2019; Parikh et al. (2020); Malpass (2021); Mahachi (2021) and UN-HABITAT, 2005b) have identified many of the environmental problems as highlighted in Table 2 as having serious adverse socio-economic and ecological implications in South Africa. The majority of these issues can be traced back to a variety of factors, including the apartheid antecedent of most South African cities (Malpass, 2021), the high rate of urbanization (Salahuddin et al., 2019), the poor psychological perspective of urban dwellers toward the environment as well as poor environmental management practices (Wilhelm-Solomon, 2017) The spatial organization of South African cities evolved before, during, and after the apartheid system, making the installation of new infrastructural amenities challenging and expensive, particularly in townships (Landman, 2018). It is also suggested by demographic experts that the high rate of urbanization has the tendency of spurring up environmental degradation (Firman, 2009) and with South Africa's urbanization rate of 66.86 per cent (Statista, 2020). There is an imbalance between the people and the environment (Ofoegbu, Chirwa, Francis and Babalola, 2017), which has harmed the carrying capacity of the country's metropolitan regions, resulting in increasingly bad living conditions and a low liveability score in South African cities (Kasim, Wahab and Olayide, 2020).

Environmental issues are often caused by developmental processes and have local, regional, and global implications which are frequently damaging to humans, livelihoods, animal and plant life now or in the future (Nash et al., 2019). This has far-reaching consequences for long-term development, particularly in the face of deteriorating economic conditions and as result, in the coming decades, urban environmental concerns will continue to dominate the sustainable development agenda in developing countries in particular and the world in general (Gu, Renwick and Xue, 2018).

3.0 South African initiatives on sustainable development

In order to address the millennium development goals and meet regional objectives, targets, and commitments in respect of sustainable development, South Africa has made significant efforts at both the planning and implementation levels in terms of policies and strategies to establish priorities for action and expenditure (Haywood et al. 2019). Many of these efforts, such as the inclusion of sustainable development concepts into laws like the National Water Act and the National Environmental Management Act, came before the MDGs (Van der Bank, 2014). Following that, South Africa established a policy that reacts at the national level and is backed provincially through Provincial Growth and Development Strategies, inspired by both the MDGs and pledges made at the World Summit on Sustainable Development (Engela and Ajam, 2010). The government has also reacted to the MDG targets of correcting environmental resource loss, increasing the number of citizens with access to safe drinking water, improving the quality of life of people living in informal settlements, and health targets such as disease eradication, infant mortality reduction, and maternal health improvement (Chopra et al , 2009).

Some of the initiatives include National Biodiversity Strategy and Action Plan (NBSAP) (Reyers and McGeoch, 2007), Renewable Energy Policy (Krupa and Burch, 2011), National Water Resources Strategy (Schreiner, 2013), National Disaster Management Framework (Van Niekerk and Wentink, 2017), Cleaner Production Strategy (Maama, Doorasamy and

Rajaram, 2021) and National Waste Management Strategy (Mokoena, 2019) among others. In addition, some vital strategies and plans in place to address the South African developmental challenges within the economy include inter alia the Black Economic Empowerment Strategy and various BEE Charters (Makgoba, 2019), National Strategy on Sustainable Production and Consumption; National Framework for Local Economic Development (LED) (Oyekunle, 2017), Urban Renewal Programme (Venter, Marais and Morgan, 2019), 'Breaking New Ground: National Policy for Sustainable Human Settlements (Esch et al., 2017) and various national policy frameworks for Social Development.

4.0 Research approach

The data used in this paper were retrieved from archival sources with respect to environmental challenges arising from the influences of human activities in major urban centres of South Africa. The archival source used include Google®Scholar® and government websites and policy documents. Specifics keywords around environmental challenges specifically in South Africa was searched. In addition, some of the observations of the authors in their other research interactions in urban settings have also been used.

5.0 Sources and impacts of Environmental challenges in South Africa

South Africa is primarily an urban country, with over 67 per cent of the people residing in cities (Statista, 2021). Table 2 shows the most common environmental concerns highlighted in this chapter that relate to human activities and create a significant challenge to the country's sustainable development in urban areas.

Table 2: Sources and impacts of Environmental challenges in South Africa

Environmental Challenges	Sources	Impacts
Informal Settlements and Slums	i. the apartheid government (Cloete; 1995; Malpass, 2021; Shackleton and Gwedla, 2021) ii. population growth (migration, urbanisation and demographics) (Jeffery, 2010; Bonner and Nieftagodien, 2012) iii. government economic policies [Reconstruction and development programme (RDP), Growth, employment and redistribution (GEAR) and Accelerated and shared growth initiative (ASGI-SA) (Eddy, 2010; Marutlulle, 2019; iv. administrative issues (municipal maladministration, lack of control and corruption) (Harrison, 2013; Nathan, 2013) v. economic variables (poverty, unemployment, unaffordability and poor access to housing finance) (Cloete, 1997; Steenekamp, 2012; The Housing Development Agency (HDA), 2013) vi. housing shortage (Baloyi, 2007;	-rapid depreciation and deterioration of infrastructure and physical environment -breeding ground for social vices. -Constitution of disrespect for human dignity with associated adverse health implications on residents, and thus negate the goal of environmental sustainability.

	Mahachi, 2021.) vii. unavailability of land and unaffordability (Dyantyi, 2007, Parikh *et al* 2020)	
Urban Sprawl	Lack of updated master plans uncoordinated spatial urban growth; decay of inner cities; land speculation and rapidly growing urban population (Horn, 2019)	- biodiversity loss, air pollution, and traffic congestion as a result of the depletion of green spaces and open spaces. - increased usage of private vehicles resulting in carbon emission. -upsurge of incompatible land use due to uncontrolled growth and lack of planning.
Pollution of the air, land and water	Inefficient waste management systems, emissions from automobiles and industrial plant bush and refuse burning; solid and liquid minerals extraction activities and agrochemicals. Weak institutional and regulatory framework for enforcing appropriate legislation (Dlamini, Simatele and Serge-Kubanza, 2019; Mngomezulu, Mbanga, Adeniran and Soyez, 2020; Salahuddin *et al.* 2019	-Pollution in general endangers the health of humans, as well as terrestrial and marine life. -Land pollution caused by indiscriminate solid waste disposal offers breeding grounds for infectious disease vectors. -air pollution causes acid rain, which destroys buildings and infrastructure. By diminishing the ozone layer, air pollution leads to global warming.
Flooding	Blocked or absence of efficient stormwater discharge system; Physical development on natural flood plains and non-adherence to physical development regulations result to flooding in low plane areas (Olorunfemi, 2011, Malulu, 2016)	Destruction of human lives, properties and means of livelihood as well as public infrastructure, leading economic losses. Destroys plants and animal lives, and thus leading to destabilization of the ecosystem which

		comes with adverse consequences.
Erosion	Destruction of vegetation indiscriminately for fuel and construction materials. Construction and installation of infrastructure, agriculture, and mining (Rankoana, 2016)	Threat to human lives, means of livelihoods and infrastructure as well as loss of land areas and reduction in biodiversity.

6.0 Key Environmental Issues and Challenges in Achieving Sustainable Development

South Africa's urban environmental challenges are hydra-headed and are primarily associated with its cities' apartheid antecedents, urbanization and issues associated with developmental challenges, urban production and consumption patterns, psychological orientation of urban residents as well as institutional inadequacies (Table 2).

The essence of sustainable management of environmental resources and their harmonious relationship with nature has though been given attention for decades but as documented by Fourie and Poggenpoel (2017), the lack of political will within the public sector to address environmental problems remains one of the most intricate problems in South Africa. Furthermore, in the face of increasing urban population, there is an insufficient supply of housing and infrastructure for the growing population; as a result, existing infrastructure and housing are overstretched, while general living conditions are characterized by the filthy landscape, polluted air, waste-filled streets, overflowing drains and sub-standard houses tend to dominate the urban landscape in South Africa (Howe, 2021). The concentration of more people in urban areas of the country has brought more pressure on the land space for the production of food, infrastructure, housing and industrialization (Baffi, Turok and Vacchiani-Marcuzzo, 2018). This has an impact on the carrying capacity of the environment since each migrant increases the demand for infrastructure and natural systems, resulting in ecological imbalance and negative environmental repercussions such as risks and tragedy (O'Sullivan, 2020). In this situation, Mokoele and Sebola (2018) argue that attempts to address the situation are difficult and capital intensive because the rapidly growing population does not allow for the introduction of new and innovative approaches to addressing the problems. This study does not argue for or against population expansion; rather, it is concerned with commensurate socioeconomic growth.

The daily activity of South African urban inhabitants generates levels of air, land, and water pollution, threatening human lives and wreaking havoc on the ecosystem (Gnade, Blaauw and Greyling, 2017). According to statistics, most urban people in the country are low-income and this group is the most susceptible to widespread environmental issues such as illnesses connected with a lack of access to natural resources and essential urban amenities, as well as pollution (Pasquini et al., 2020). According to Williams-Bruinders and de Wit (2020), they suffer the consequences of inadequate urban planning and management systems and hence live in disaster-prone areas of cities, which in turn has an impact on their quality of life, health, thereby reducing their economic development capacity and productivity.

In the loss of biodiversity, of South Africa's 3.97Mha of natural forest, extending over 4.3 per cent of its land area, 240kha of land has burned by August 2021 not talking about other loss factors of tree felling, wind etc. (Global Forest Watch, 2021). These losses pose a significant threat to environmental sustainability because the various flora and fauna and animal species required to establish and sustain the various food webs and chains and natural cycles are systematically depleted, resulting in ecological imbalance and endangering man's survival in the environment.

In the social context, Shackleton and Gwedla (2021) stated that environmental concerns pose severe challenges to the social well-being of the majority of South African urban dwellers and asides from the general health consequences, there are possibilities of it impacting their psychology. For instance, residents of urban slums are known to show deviant attitudes, apathy to government programmes and anti-social values (Mahajan, 2014). Most importantly, social indicators in South Africa are something of a paradox as the country is rich in natural resources but the people are living in abject poverty meaning that the wealth has not translated to enhance the quality of life. South Africa's 2019 Human Development Index (HDI) of 0.709 is an indication of its poverty level as it is below the average of 0.753 for countries in the high human development group (Datta and Singh, 2019, UNDP, 2021).

Furthermore, environmental issues are inimical to social justice and wellbeing in terms of access to social infrastructure and work possibilities. It is believed that urban poverty in South Africa has significant linkages to its apartheid history, and as a result, the majority of the people are hesitant to participate in economic development activities; instead, in the face of diminishing work prospects, they have opted to rely on subsidies and handouts (Dewar, 2019).

According to Rakodi (2016), the inability of South African cities to cope with increasing environmental challenges has manifested itself in poor economic growth and development, as rapid city growth due to urbanization has resulted in the emergence of low-income informal settlements both in the inner-city and on the peripheral. Although South Africa's informal sector is small compared to other developing countries, and it provides livelihoods, employment and income for millions of workers and business owners, some of them hardly pay tax, have no financial records, do not form part of government statistical records, and have limited or no access to formal credit facilities (Fourie, 2018). In addition, with the outbreak of the COVID-19 pandemic which has resulted in job losses arising from business shut down, South Africa's major development challenges which have to do with the acceleration of economic growth, reduction of the level of poverty and improvement of environmental quality continue to grow unabated, and thus achieving sustainability in the country slowing down (Leal Filho et al. 2020, Ikwegbueet al. 2021).

In South Africa, the urban and rural populations will become increasingly interconnected in terms of economic, social, and environmental well-being and Starkey (2015) projected that more than half of the country's population is anticipated to reside in cities by 2030 but as of 2020, Statista (2021) reported that over 67.35 per cent currently live in urban centres. As a result, unless appropriate actions are taken, environmental degradation will keep rising posing a continuous danger to sustainable development since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South Africa's economy and society depend on its ecosystem for food production, electricity generation, and raw materials for industrial operations

7.0 Recommendations

In the face of rising urbanization and increasing environmental challenges in South Africa, the New Partnership for Africa's Development (NEPAD) initiatives and the South African National Development Plan 2030, commonly known as Vision 2030, have progressively adopted a new notion of sustainable development. These techniques address the interaction between all human settlements, from small urban centres to metropolises, as well as between towns and cities and the rural areas that surround them. As difficult as these techniques appear to be, they are powerful, dynamic, and desired drivers for progress. To have the intended impact in South Africa, these efforts must implement methods that have a substantial influence on challenges and issues connected to urbanization, attitudinal orientation, and gaps in legal and institutional frameworks in environmental management. Based on these findings, this article makes the following recommendations for resolving these concerns.

The rural-urban migration continues to be a key contributor to South Africa's ever-increasing urban population expansion and according to Walker and Mathebula (2020), this is premised on a perceived vast disparity between urban and rural regions in terms of employment opportunities and availability of basic infrastructure. We recommend in line with Mabasa (2010) a comprehensive rural infrastructure provision towards bridging this gap and further advise on the critical need for the government to enter into public-private partnerships (PPP) to provide rural infrastructure. This will promote the growth of agro-based industries thereby providing incentives for young people to pursue agri-preneurship and make rural living more desirable. This according to (Sudharani, 2012) will in the long run will gradually limit the number of immigrants to metropolitan regions, slowing the rate of urban population development.

Similarly, this study recommends that in line with Gulati and Scholtz (2020), the concept of PPP in the provision and improvement of urban infrastructure should be adopted towards increasing the urban environmental carrying capacity. This could enhance

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the liveability of urban areas in South Africa as it will be a departure from the current government initiatives wherein focus will be on the revitalisation and remodelling of informal settlements in urban areas. This could be through the introduction of basic infrastructure services and incorporation of mix-use development to enhance property values, and thus checking further deterioration of such areas. Furthermore, appropriate legislations backed up with political will should be put in place to check indiscriminate discharge of wastes while the relevant regulatory institutions and agencies should be empowered to monitor the level of compliance and mete out appropriate sanctions to offenders (Akintayo and Akinbola, 2012).

Plants have been shown to be helpful to humans not only as a source of food but also as a natural supply of oxygen while they further give shelter from the sun, beautify the landscape, and protect the soil from erosion (Reed and Stibolt, 2018), this study hence recommends the greening of the environment.

Furthermore, Opoku (2019) recommended that towards harnessing the benefits of greening, the volume of green areas and open spaces in urban areas must be increased through promoting the preservation of green areas and open spaces. This study hence recommends that to achieve greening benefits, residents can be encouraged to plant trees, ornamental plants and engage in horticulture gardens around their homes as against the use of hard landscaping elements while there should be a strong prohibition of bush burning and illicit mining operations.

Given the degree of construction works in South Africa as indicated by Oyewobi, Windapo, Rotimi and Jimoh (2020), this study suggests efficient evaluation of each construction activity to guarantee that it does not have a detrimental influence on the environment. In addition, this study agrees with Schoeman and Gunter (2018) that the construction industry must embrace the concept of "green/eco-construction" while creating new techniques and materials that are neither damaging to the environment or pose health concerns.

The management of solid waste in metropolitan areas appears to have piqued the interest of South African government officials at all levels but despite the establishment of waste management organizations, the problem of solid waste management persists in the country's metropolitan regions (Mngomezulu, Mbanga, Adeniran and Soyez, 2020). This study recommends in line with Ishawu, Guangyu, Adzimah and Aminu (2020) in the case of Ghana, public-private partnerships (PPPs) or outright privatization of municipal waste management activities wherein they would be involved in educating the people about zero waste as well as the establishment of waste recycling or treatment plants towards sustainable development.

As it is with other African countries, South Africa has never lacked great policies, legislation, or institutional frameworks, but that successful implementation through political will has always been a challenge (Hope Sr, 2017). The perceived failure of present laws and institutions to have a significant impact on environmental conservation and preservation may be attributed to insufficient legal frameworks, insufficient funding, and a lack of competent employees (Lindsey et al., 2021). As a result, restructuring organizations and stimulating them with an appropriate political will has become the most feasible method of ensuring horizontal and vertical collaboration among agencies Carter and Roberts, 2000). Similarly, any legal uncertainty, lack of qualified personnel, and insufficient funding must be addressed while the private sector must be encouraged to contribute significantly to the capacity improvement of such organizations. This would improve the institutions' ability to enforce environmental laws and physical development restrictions, lowering the rate of unlawful projects, violations of planning laws, street trade, and indiscriminate dumping of waste in unauthorized areas.

Furthermore, citizens psychological re-orientation toward good environmental management techniques is critical in establishing environmental consciousness hence environmental education is critical in this regard (Lim, Arita and Joung, 2019). Hence, incorporating environmental studies into the curriculum of the educational system at all levels is likely to stimulate the desired level of environmental consciousness, thereby reducing unhealthy environmental practices in South African cities.

Finally, built environment professionals should be encouraged to assume the duty of becoming the environment's "police" by directing their professional skills toward sustainable development through proper design, construction and management solutions.

8.0 Conclusion

Geographical, climatic, and cultural variables all have a role in urban environmental challenges of various proportions. cultural aspects appear to be more prominent in the RSA setting since most of the identified urban environmental concerns are so closely related to people's way of life, either as responses to urbanization or as their spatial legacy. The consequences of the challenges have far-reaching implications for the country's aspirations to achieve sustainable development and because no part of the country's urban landscape is exempt from them, there is an urgent need to identify practical solutions using the planning, economic, legal, institutional, and educational instruments proposed here. It is anticipated that if these tools are properly implemented, they will result in the recognition of the right environmental management practices, preventing further degradation of our physical urban setting; thus, the potential of sustainability in South Africa in the near future is guaranteed.

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TRANSPORT

Inside a healthier construction economy

Do swimming pools have a future in a world of social distancing? Will robotics build roads and fix potholes? Will my smartphone get smarter at running the house? Will airport toilets flush automatically? Will new offices offer workspaces that resemble glass cubicles?

What will be the defining milestones of a healthier construction-led economy?

Much has been deliberated on the past few months regarding what a post-pandemic environment will look like across the globe. Debates on redesigning residential and commercial properties that reflect a sensitivity towards hygiene and health are heating up in boardrooms as much as they are hot topics at home.

Human beings are now conscious that the world can both predictable and unpredictable. Which begs the question: What defines a safer world today? And how does the built environment make a positive and lasting contribution towards manifesting this safer world?

A health-conscious paradigm shift

There is no doubt that industries are more committed to re-assuring stakeholders that health is now a valuable driver of quality. Architects, engineers, construction project managers have always paid attention on the integration of health and safety regulations throughout a typical project journey. Hence, the biggest transformation that is shaping the built environment is not in project execution per se, but in re-imagining an environment where citizens FEEL safer. Whether it's a visit to the local hospital, a trip to the mall, a quick dash to the airport or a playdate for kids with neighbours, being safe is now part of the design experience, making innovation the most compelling discussion for architects and investors to consider when shaping the world today. Innovation has always involved disruption, and the industry is about to undergo perhaps the most defining chapter of disruption, one that will likely impact it for many

Dr Tshidi Gule


Photo by Olga Lioncat from Pexels

years to come. Here are four key areas that the built environment will experience the most convincing positive shifts. The interesting thing to note is that the individual and collective consciousness towards health will play the quiet common denominator in each one of these areas.

Technology Migration & Integration

The prospect of an indefinite hybrid off-site and working from home model is a real possibility for the built environment. Many operational elements of project management have undergone digitization and the next five years will see many more of this trend. The computer, once seen as a simple administration device, is now evolving into a communication hub that contractors and designers will need to use as the main method to plan, collaborate and execute project objective and operational tasks. Teleworking and telecommuting is here to stay in many departments and productivity will need to be measured by outputs as well as wellbeing parameters. Many companies are investing in online data and project tracking systems to oversee large scale projects and operations will evolve to include more digital models. One of the areas that will need to experience a digital overhaul will be the transport and manufacturing industries. According to the Robotics Industry Review report back in 2019, Tractica projected a $226 million revenue market by 2025 for the construction robotics space, and this projection is estimated to have increased by at least double due to the influence of the pandemic. Robotics will definitely become quite an eye-catching disruption for the built environment and hopefully a smart option for many small and large firms handling large scale operations.

Communication

How business is conducted has changed drastically in these past eighteen months. The conversations in many boardrooms in the past year have had to include the inevitable transition of face-to-face communication to virtual management of teams, projects and stakeholders. Tricky scenarios such as generating new client relationships, keeping current ones healthy and letting go of cost-intensive relationships are undoubtedly being pondered by decision makers of the built environment as with all other sectors. Re-evaluating communication policies,

Photo by Mathias P.R. Reding from Pexels managing client needs virtually, smoothing over communication hurdles during project management are some of the priorities facing construction project managers. The construction economy will not recover without sound communication models, and understanding the balance of personal touch and health-compliant networking is going to be a discussion that continues to be thrashed out in many committee meetings. The world cannot stay virtual forever, and construction companies will need support in designing business development, marketing and communication strategies that are low-risk in health and safety, but high-yield in revenue generation.

Design

When the pandemic began, very few construction professionals could visualize what buildings in the "new economy" needed to look like. Eighteen months later, that picture is starting to look a little clearer. In addition to the greater emphasis on safety, architects have become sensitive to the need of incorporating freedom of movement (space) with the power of blending outdoor and indoor space. Outdoors offers the perception of bring less infectious a space, creating the impression that one is safer in spaces that offer as much open ventilation as possible. This new model of spacious design is significant in driving home the consciousness of social distancing, and special attention will be paid to how this mindset affects communal areas such as restaurants, cafeterias, gyms, airports, shopping malls, religious facilities and more. Being creative with space whilst encouraging connection is a dance that architects will find both rewarding and challenging, and one that is sure to introduce breakthrough design gems.

Sustainability

A safer world starts with perception. While the focus of property in particular has loan towards sustainable eco-friendly living, an added dimension to design will now factor contactless design. Life indoors has taken over life outdoors, prompting disruptions in product and space design.

The buzz word is without a doubt contactless living. In 2020 alone, Amazon reported a staggering search increase of contactless products that exceeded 2000% pre-pandemic. From soap dispensers, to storage units, home medical devices, the demand for a contactless lifestyle is definitely an economy-defining one. Companies who meet this demand with well considered designs are going to see sales spikes and become leaders in the pandemic-proof movement. The built environment offers many advantages in this movement, and real investment into contactless experiences must be considered in real estate, healthcare, retail and hospitality design. The slightest change, i.e. changing a manual door to an automated one, will create more comfort in the user than before, and it's ultimately these smaller changes (e.g. automated dispensers) scientists encourage experts of the built environment to prioritize. The domino effect will go a long in reshaping citizens' feeling of safety and peace of mind.

The economy supporting of contactless products may have started off small, but it is rapidly emerging as a much larger contributor towards sustainable design. There's no doubt it, automation is here to stay and devices that are durable, eco-friendly and prove harmless to the environment will be the big global winners of the day.

Whether your perception of healthier world includes an automated office with spacious design and a new appreciation of outdoor breaks, the pioneering leaders of this new economy will undoubtedly include architects. The ever present anxiety induced by the pandemic is unlikely to abate in the next five or ten years and how the built environment can make use of its voice is by offering solutions that are as appealing as they are sustainable. More importantly, construction companies and contractors will need to re-structure off-site and on-site activity more attentively, paying attention to how working from home affects the timelines and deliverables of projects. Designing effective wellness programs and touchpoints for construction workers will impact the company's ability to attract and retain its best talent, on the ground and in the boardroom. Because however you believe the new world should be, the one fact that Covid-19 has left us to contend with is that our world will never be the same again. How we navigate this change will require collaboration, innovation and an extraordinary amount of patience for the inevitable journey of trial, error and success ahead. Let the new economy begin.

Dr Tshidi Gule

SA's Pothole Problem Won't Just Disappear: SAICE Advises On The Road Ahead For Infrastructure Maintenance

As the rainy season arrives in many parts of South Africa, motorists are once again on the lookout for road conditions that threaten to damage tyres and undercarriages. It is estimated that there are over 100 000 potholes in Johannesburg, and countless more across South Africa's 157 900 kilometres of roads. A recent interview with the South African Institution of Civil Engineering (SAICE) explained why potholes are so common, and what can be done about this problem.

"Our road infrastructure is a vital part of our economy, and requires constant maintenance and upgrade. There has been an increase in potholes in recent years, caused largely by an increase in traffic and especially heavy vehicles. At the same time, we have seen a general decline in infrastructure spending," explains Tauqeer Ahmed, SAICE Knowledge Trailblazer Champion and Deputy Port Engineer at Transnet National Ports Authority.

Organisations such as the Johannesburg Road Agency (JRA) and Transport for Cape Town (TCT) are mandated to repair potholes. They are well funded and have dedicated teams trained and equipped to fix potholes. "However, the backlog of potholes has seen the private sector become eager to intervene. For example, Dial Direct and Discovery Insure have

partnered with the City of Joburg on an app called Pothole Patrol, which they hope will speed up road maintenance. While this is a great initiative, we need proper road maintenance programmes in place to tackle current potholes as well as a preventative maintenance programmes to tackle this issue holistically," explains Ahmed.

Tauqeer Ahmed, SAICE Knowledge Trailblazer Champion and Deputy Port Engineer at Transnet National Ports Authority

Technical advice on the road ahead

SAICE recommends that the Department of Transport draws up detailed solutions and action-based maintenance programmes. "These must be given appropriate oversight to ensure that the required maintenance budgets are obtained and spent on time to ensure the upkeep of our roads. At SAICE, we are looking at where and how we can assist. We can offer advice to the various government institutions, providing them with guidance on maintenance planning, technical specifications and matters to consider when selecting a contractor to execute any required works," says Ahmed.

SAICE members who are employed by government are also offered valuable technical advice and assistance via the institution's technical divisions and committees. The SAICE Transportation division offers various talks and seminars on road infrastructure design, development and maintenance, given by experienced professionals.

"We are also updating and compiling the latest Infrastructure Report Card. This will provide an expert perspective on the infrastructure development across South Africa and the current status of the condition of infrastructure in the country. This will be an excellent starting point for the formation of maintenance programmes."

In the meantime

South Africa's pothole problem is not going to disappear overnight. In the meantime, SAICE advises motorists to remain vigilant. "Last year, claims to the Department of Transport from motorists for pothole damages amounted to R5.2 million. Avoid the damage – treat puddles like potholes, be wary of driving in the dark, and take heed of warning signs such as slowing traffic and maintenance signs," concludes Ahmed.

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Design and Construction of Sustainable Climate Resilient Rural Access Road Infrastructures

Julius Joseph Komba, Raquel Langa, Phil Paige-Green, Benoit Verhaeghe and Refiloe Mokoena

1.0 Introduction

One of the focuses of the Research for Community Access Partnership (ReCAP) climate vulnerability project was to identify, characterise and demonstrate the appropriate engineering and non-engineering adaptation procedures that may be implemented to strengthen the resilience of rural roads. As part of the project, a 50 km gravel (unpaved) road between Mohambe and Maqueze in the Gaza province of Mozambique was identified for the construction of demonstration sections. The selected road links to a small village that has not more than 2,000 inhabitants that have been isolated during the rainy season. The road is located along the edge of various natural lakes making it more vulnerable to the increased flooding frequently experienced in Mozambique. The road was estimated to carry about 25 vehicles per day on average, with very few heavy vehicles – approximately Traffic Loading Class (TLC) 0.03 (Paige-Green et al., 2019). However, after the completion of the construction works, a significant increase of vehicles was observed.

The road also forms part of a climate adaptation programme funded by the World Bank. Significant damage was done to this road during the 2013 flooding and six concrete fords (under emergency repairs) were installed to improve passability in 2014 and various short sections were spot re-gravelled with a blend of sand and Calcrete material. However, these interventions did not yield positive outcomes, necessitating a comprehensive road assessment to identify problems and design and construct alternative sustainable adaptation measures.

This chapter covers the road assessment, the design of sustainable climate adaptation solutions and the construction of four demonstration sections aimed at demonstrating different sustainable adaptation measures to address climate change-related problems that are causing undercutting of concrete fords/crossings, damage to the road approaching concrete fords, damage to culverts and erosion, and damages to a gravel road. The long-term performance of the demonstration sections is planned to be monitored over time. The outcomes of the monitoring programme are expected to inform on the appropriate adaptation procedures for wider implementation in Mozambique, and possibly elsewhere.

The chapter is organized and structured as follows; this introduction section is followed by an overview of climate change-related challenges affecting Mozambique. The study methodology (approach) is then described, followed by a discussion of findings and quality control test results. This is followed by a brief discussion of the preliminary performance of completed construction works. Conclusions and way forward a presented at the end of the chapter.

2.0 Climate Change Related Challenges Affecting Mozambique

The African continent is one of the most vulnerable regions that the impacts of climate change is much felt. Like other African countries, Mozambique is facing a challenge of repair and maintaining roads damaged from the effect of climate change (i.e., floods, storms, and cyclones).

Climate change associated road damages have direct socio-economic impacts, particularly to the rural community. To help address this significant threat to Africa's development, the Research for Community Access Partnership (ReCAP), a research programme funded by UKAid, commissioned a project that started in April 2016, to produce regional guidance on the development of climate-resilient rural access in Africa through research and knowledge sharing within and between participating countries (Verhaeghe et al, 2019).

The latest Intergovernmental Panel on Climate Change (IPCC) report AR6 presents ten key areas for the African region relating to observed and projected climatic changes, where in general, an increase in mean and extreme temperature is expected (IPCC, 2021). The rate of increase in surface temperatures has also been a concern, with higher rates observed in Africa than the global average, and this is expected to increase for the foreseeable future. As per IPCC's classification, Mozambique falls under the East Southern Africa (ESAF) area, which is reported to have a decrease in observed mean precipitation. However, a projected increase in heavy rainfall is expected, thus increasing the country's risk and exposure to flooding, causing socio-economic losses and severe infrastructure damage.

Mozambique is also one of the African countries most frequently affected by natural disasters, thus contributing to its high vulnerability and exposure to climate hazards, particularly flooding, droughts, and cyclones (Ferguson, 2005). The country has already experienced three major cyclones in the past two years, namely Cyclone Idai and Cyclone Kenneth, both in 2019, as well as Cyclone Eloise in 2021, all occurring during the country's rainy season between November and April. Between 1975 and 2015, a total of 15 tropical storms were recorded by the International Disaster Database, contributing to 577 deaths caused by storm events alone (Le Roux et al., 2019). Similar figures for flooding revealed 31 recorded flood events (20 due to riverine flooding), resulting in a total of 1738 deaths and nearly 9 million people being affected (Le Roux et al., 2019).

Due to Mozambique's location and geography, large areas are exposed to frequent tropical cyclones and river/coastal storm surge flooding (Zermoglio et al., 2018). Combined with institutional capacity constraints and an already suffering economy, the country is particularly vulnerable to natural disasters. Mondlane (2004) showed that, on average, more than 2 per cent of the country's GDP is affected whenever a natural disaster occurs, undermining its economic development and further

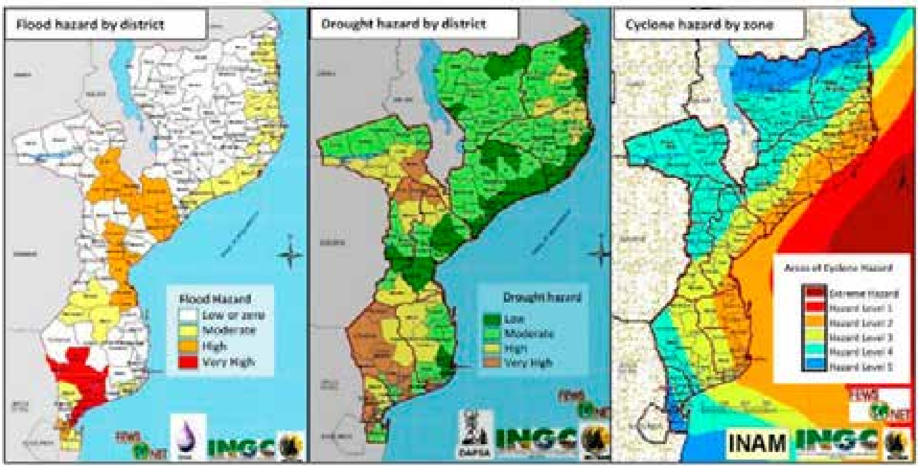

Figure 1 Weather related hazards for Mozambique (Le Roux et al., 2019)

increasing its dependency on external economic relief and survival. In addition, the country has also not been able to preserve and protect its economic infrastructure and national assets.

According to Mozambique's National Road Authority (ANE, 2017), a third of Mozambique's road network is in a poor, very poor or impassable condition contributing to high infrastructure vulnerability of these sections of the road network, particularly to climate hazards. For the study presented in this chapter, the project location falls within the very high-risk category for flood hazard (Le Roux et al., 2019), as depicted in Figure 1.

3.0 Methodology

3.1 Road Selection

As part of the ReCAP climate vulnerability project, the selection of a road for the construction of demonstration sections was required. These roads needed to be on an improvement/upgrading/rehabilitation programme with funding already allocated for their work. Following discussions with Mozambican National Road Agency, Administração Nacional de Estradas (ANE), the Mohambe-Maqueze road in the Gaza province was selected. This research investigation is a case study. The selected road is particularly troublesome as it weaves among and along the edge of various large natural lakes (Figure 2). The altitude varies between 11 and 30 m above sea level along the entire 50 km road.

Figure 2 Project location and road main drainage features (Google Earth)

Following the selection of the road for the case study, the methodology (approach) for the implementation of the project consisted of three main tasks, namely:

- Road assessment and identification of problems;
- Design of adaptation measures, and
- Construction of demonstration sections.

The subsequent sections describe the activities that were carried out as part of each of the three main tasks.

3.2 Road Assessment and Identification of Problems

The Project Team visited the Mohambe-Maqueze road during Phase 1 of the ReCAP Climate Adaptation project in September 2016, and information regarding some of the problem areas was made available (Verhaeghe et al, 2017). The road was revisited in August 2017, as well as during a climate adaptation workshop held in Chibuto in September 2017, and additional measurements and observations were carried out (Paige-Green et al, 2019). The road assessment was undertaken in accordance with procedures contained in the Climate Adaptation Handbook and associated Guidelines and a Manual, that were developed as part of Phase 2 of the ReCAP Climate Adaptation project (Verhaeghe et al, 2019).

As part of training and capacity building activities of the project, the assessments were undertaken jointly with engineers from Mozambican road authority (ANE), as well as engineers from a Consultant and a Contractor working on the demonstration project. On-site training activities included:

- Condition and vulnerability assessments;
- Selection of appropriate adaptation options, and
- Implementation of the adaptation measures.

A detailed assessment of the Mohambe-Maqueze identified four frequently occurring problems, namely:

- Erosion and undercutting of concrete fords/crossings;
- Damage to the road approaching the concrete fords;
- Damage to culverts and erosion protection, and
- Damage to the road surface.

The identified problems are briefly described below.

3.2.1 Erosion and Undercutting of Concrete Fords

Erosion and undercutting of concrete fords (Figure 3) were observed at two of the new concrete fords. This was mostly restricted to the lake side of the fords and was either the result of over-topping from the downhill side or more likely softening of the support material (black clay in this case) and subsequent wave action as well as alternative wetting/drying of the clay. Furthermore, the underlying soils (expansive clay) were unsuitable, and susceptible to slaking and collapse when the material moves from a dry to saturated state. Slaking of the dried black cotton soil was demonstrated on site.

Figure 3 Erosion and undercutting of concrete fords.

3.2.2 Damage to the Road Approaching the Concrete Fords

Damage to the approach fill of concrete fords was observed at several locations (Figure 4). The damages were likely to continue to aggravate if the design was not changed. The problem appeared to be exacerbated by braking of vehicles approaching the concrete fords.

Figure 4 Damage to the road approaching concrete fords.

3.2.3 Damage to Culverts and Erosion Protection

Numerous culverts had been damaged by flooding. Most of the damage was caused by erosion at the exits with undercutting (Figure 5) and cracking. The incidence of undercutting of erosion protection measures (mostly grouted stone pitching) was evident at many of the structures. wThis was often due to poor compaction of the embankment material allowing access of water behind the structures as well as surface erosion. The main areas affected were the approach fills that were eroded during flooding, protection works that were left unsupported or washed away, and scour of the stream-bed at the outlets.

Figure 5 Damage to culverts and erosion protection.

3.2.4 Damage to the Road Surface

Damages to the unpaved road surface were observed at several locations (Figure 6). The main causes of the damages were attributed to erosion by uncontrolled water, poor compaction of the materials and the use of erodible materials as the wearing course.

Figure 6 Damage to road surface.

3.3. The Design of Adaptation Measures and Construction Methods

To address the problems identified during the road assessments, four sections of road were identified for the implementation of appropriate adaptation measures. The designs for each of the four adaptation measures and construction methods are described in the subsequent sections.

3.3.1 Undercutting of Concrete Fords

The undercutting of the fords was a major problem requiring urgent repair (see Figure 3). To address the undercutting of the fords problem, the adaptation measure that was proposed was to incrementally construct a vertical concrete wall (200 mm thick with 16 mm Ø reinforcement at base at 250 mm intervals) near the edge of the concrete ford slab (on inert material), backfill the voids with an inert fill and a high slump concrete (0.5 m thick) and then extend the concrete slab to the top of the wall. The wall had to be founded on imported inert material at least 1 m deep and have a concrete protection slab at the base. The schematic sketch of the design of the concrete wall is shown in Figure 7. It should be pointed out that the actual concrete dimensions and depth of the wall depended on the founding conditions. In addition, it was necessary to provide some weep-holes in the concrete wall at 2 m intervals to facilitate drainage.

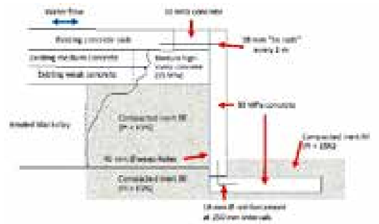

Figure 7 Cross-section of the concrete wall to prevent undercutting of concrete ford

The demonstration section to address the undercutting of the fords was constructed at km 17.6, using an adaptation measure designed. The construction activities involved the following:

- Cleaning of the cavity and placement of inert fill foundation;
- Construction of the wall foundation slab on inert material;
- Incremental increase in wall height with simultaneous backfill behind it up to concrete level;
- Placement of concrete into cavity beneath final slab;
- Insertion of dowels between existing slab and upper portion of concrete wall, and
- Filling of void between existing slab and wall with 30 MPa concrete

3.3.2. Damage to Road Approaching Concrete Fords

The proposed adaptation measure to address the damage on the approach fill to the concrete ford was to construct a 45 m long and 150 mm thick continuous (i.e. unjointed) roller compacted concrete (RCC). However, during construction, the contractor in consultation with the consultant decided to change the design. Instead of constructing the proposed RCC layer, the damage to the road approaching concrete ford was repaired by constructing an improved gravel road, as it was considered cheaper.

The adaptation measure to address the damage to the road fill approaching concrete ford was constructed at km 36, which involved a constructing an improved gravel road. The construction process involved:

- Excavating the existing damaged gravel road;
- Import improved material and compact in layers, and
- Construct 150 mm gravel wearing course, and improvement of the side slopes.

3.3.3. Damage to Culverts and Erosion Protection

Overtopping of the road has resulted in damage to the culverts and erosion protection in several places (see Figure 5). To address these problems, the road had to be properly shaped and levelled off at the top of the culverts with the grade, and 5 per cent camber with a well-compacted wearing course. Any expansive clay to 300 mm depth had to be replaced with inert material.

All damaged protection works had to be removed, and the materials in these areas replaced with inert material and compacted to at least 95 per cent Mod AASHTO density. The stone pitching then had to be repaired with a cement grout filling all joints. The top, bottom and edges of the stone pitching had to be cemented to concrete strips as shown in Figure 8. To avoid undercutting and erosion of the soil adjacent to the stone pitching, lined drains/chutes 150–200 mm deep and 250 mm wide had to be constructed at the edges of the stone pitching and integral to it to guide water from the shaped road surface down the embankments.

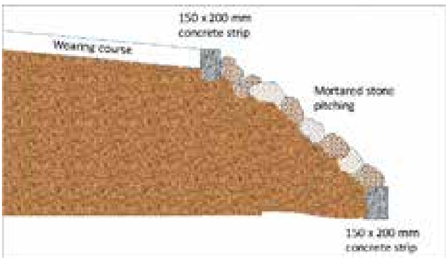

Figure 8 Cross-section of concrete strips to retain stone pitching.

The demonstration section to address the damage of culverts and erosion protections was constructed at km 43. The construction activities involved the following:

- Extension of wing walls of the existing culvert;
- Construction of additional new culvert approximately 45 m south of existing one, and
- Construction of erosion protection and wearing course on culverts approach.

3.3.4. Improved Gravel Road

The road was in a poor state with areas that would be impassable during wet weather (see Figure 6). It was proposed that a 200 m long section of road in Maqueze be upgraded to illustrate that a well-constructed unpaved road can be climate resilient. The cross-section of proposed improved gravel road is shown in Figure 9. It was essential that the wearing course material complied as closely as possible with the standard specification and placed in a 150 mm, compacted layer at not less than 98 per cent mod AASHTO effort. The camber of the wearing course after construction had to be 5 per cent. In addition, the smaller culverts at the start section had to be replaced with larger culvert to improve drainage capacity.

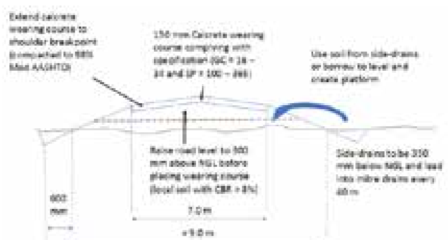

Figure 9 Cross-section of improved gravel road.

4.0 Findings and Quality Control Test Results

This section discusses the findings from the construction of the demonstration sections for each of the design solutions (adaptation measures) that were developed to address the identified problems. The quality control test results of each of the four demonstration sections are also discussed.

4.1 Undercutting of Concrete Fords

Figure 10 depicts the progression of the concrete wall construction activities. It should be noted that, due to practical reasons and the availability of the construction material, the contractor made some modifications to the original design. Instead of using 16 mm reinforcing steel spaced at 250 mm interval, 12 mm steel was used, but at a smaller spacing (i.e., 150 mm). Furthermore, a foundation bed was constructed using low strength concrete, following which the specified foundation was constructed.

Figure 10 Construction of concrete wall.

During the construction of the concrete wall, quality control tests were conducted on the concrete as well as on the gravel material used for backfilling. The material for the concrete consisted of aggregate with 19 mm Nominal Maximum Aggregate Size (NMAS), river sand, and a 42.5N cement class.

Concrete compressive strength tests were conducted on various batches. The tests were conducted 7 and 28 days after concrete casting, according to method D1 of the South African Standard Test Method for Highways 1 (TMH 1). Table 1 provides a summary of the test results. It should be noted that the design for the concrete ford protection wall recommended 30 MPa concrete be used for the construction. However, the average 28 days strength of the concrete used ranges from 25 to 27 MPa, which was considered to be satisfactory, despite being slightly lower than the recommended concrete strength. The 30 MPa specified was to be in line with the original upper concrete layer strength, but as the new concrete is only near the edge, the slightly lower strength obtained would be adequate.

Material for backfilling was sourced from a borrow pit established at km 3. The Liquid Limit (LL), Plastic Limit (PL), Plastic Index (PI) and Linear Shrinkage (LS) of the material as determined according to THM1 methods were 23, 16, 7, and 2.3, respectively. The California Bearing Ratio (CBR) of the material at 98 per cent MDD was 29. Overall, the quality of the backfill material was satisfactory.

	Average compressive strength (MPa)	
Casting date	7 Days after casting	28 Days after casting
06/10/2018	19.17	26.36
16/10/2018	19.27	26.91
17/10/2018	18.10	25.45
18/10/2018	21.60	27.07
22/10/2018	17.97	25.08
23/10/2018	18.09	26.45

Table 1 Summary of concrete compressive strength test results (Paige-Green et al, 2019).

4.2 Damage to Road Approaching Concrete Fords

Figure 11 depicts the condition of the approach to the concrete ford after the construction of the improved gravel road. Calcrete material used for the construction of the improved gravel road was sourced from a borrow pit established at km 39. The liquid Limit, plastic limit, plastic index and linear shrinkage of the material were 46.1, 34.5, 11.6, and 4.3 respectively. The CBR of the material at 98 per cent MDD was 40. After completing the construction, in situ density and moisture content tests were carried out to assess the compaction quality of the improved gravel wearing course. The tests were carried out using a nuclear density gauge. The density and in situ moisture content were determined at three chainages 0 (joint of ford and gravel road), 20 and 40 m away from the ford. For each chainage, the tests were carried out on the right wheel path (RWP), the centre of the lane (CL) and the left wheel path (LWP).

Table 2 presents a summary of the compaction results. The specified compaction density for the gravel wearing course was 98 per cent Mod AASHTO. The test results indicate that the compaction density achieved was generally lower than specification, and highly variable. The percentage compaction at the centre of the lane was generally lower than the wheel paths. This was expected as the tests were conducted approximately four months after the construction of the wearing course; hence, construction and normal traffic may have caused further densification of the gravel wearing course. Furthermore, the compaction densities appeared to decrease with increasing distance away from the concrete ford (i.e., from chainage 0 to 40 m). This could be due to the slow-moving vehicles near the concrete ford.

Figure 11 General view of the approach to concrete ford.

Table 2 Summary of field compaction results (Paige-Green et al, 2019).

Distance from ford (m)	Side	Wet density (kg/m3)	Dry density (kg/m3)	Moisture (per cent)	Compaction (per cent)
	RWP	2066	1980	4.3	97.3
0	CL7	1959	1880	4.2	95.3
	LWP	2039	1965	3.8	97.5
	RWP	1980	1890	4.8	93.8
20	CL	1912	1827	4.7	90.7
	LWP	2040	1943	4.2	96.4
	RWP	1910	1808	5.7	89.7
40	CL	1948	1866	4.4	92.6
	LWP	1971	1875	4.3	93.0

In order to further assess the quality of the gravel wearing course, Dynamic Cone Penetrometer (DCP) tests were carried out at 0, 10 and 20 m away from the concrete ford in the northern direction, and on the left wheel path, the centre of the lane and right wheel path respectively. The DCP results were analysed using ReCAP's Low Volume Road (LVR)-DCP software (De Beer and van Rensburg, 2016). Figure 12 shows layer diagrams of individual DCP tests for the left wheel path and right wheel path. The DCP test results indicate that the structural strength of the gravel road is adequate for TLC 0.03 (i.e., the field DN values are less that TLC 0.03 DN values).

At each of the DCP test point, soil samples were taken for laboratory determination of in situ moisture content using the gravimetric method. The moisture samples were taken from the wearing course (top) and the (subbase) bottom layer. The moisture content results are presented in Table 3. The laboratory determined moisture content values ranged from 5.0 to 10.9 per cent, and are generally lower than those measured using the nuclear gauge device.

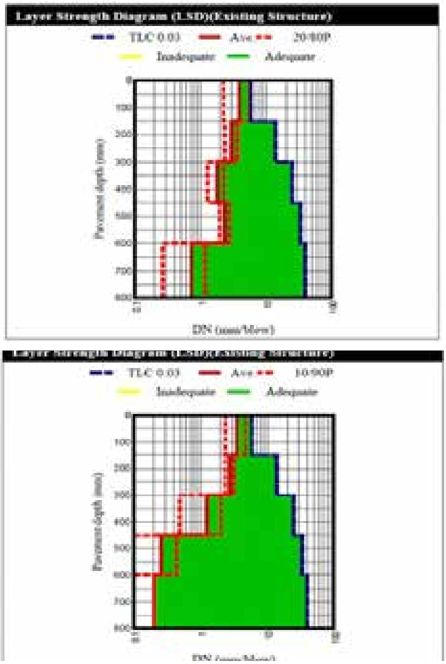

Figure 12 DCP results.

Table 3 Summary of moisture content results (Paige-Green et al, 2019).

Distance from ford (m)	Moisture (per cent)	
	Top layer	Bottom layer
0	5.0	-*
10	6.0	5.4
20	10.9	7.9

only one layer sampled because the layer thickness was greater than 300 mm.

4.3 Damage to Culverts and Erosion Protection

Figure 13 depicts the progression of the culverts and erosion protection construction. It should be pointed out that the design for the culvert protection work recommended that the beam had to be constructed first, followed by the stone pitching to ensure adequate bonding between the stone pitching and the beam. During the implementation, the contractor constructed the stone pitching first, followed by the beam; hence, the performance should be closely monitored during the long-term performance monitoring.

Figure 13 Construction of culverts and erosion protection works.

The wearing course of the road approaching the new and old culverts at km 43 was constructed using Calcrete material sourced from a borrow pit established at km 39. After completing the construction of the gravel wearing course, in situ density and moisture content tests were carried out. The tests were carried out at the interface of the culverts and the gravel road (i.e., 0 m) and 10 m away from the interface for both, the new (toward north direction) and existing culvert (towards south direction). For each position, the tests were carried out on the right wheel path (RWP), the centre of the lane (CL) and the left wheel path (LWP). Table 4 presents a summary of the compaction results, which with some exceptions, complies with the specification of 98 per cent Mod AASHTO.

4.4. Improved Gravel Road

An approximately 200 m long of gravel road section to illustrate that a well-constructed unpaved road can be climate resilient was constructed at km 51. The construction activities involved constructing a 300 mm high fill from the existing ground level, followed by a 150 mm gravel wearing course with 5 per cent camber, using good quality Calcrete material. A new culvert to replace the existing smaller culvert was also constructed. Figure 14 depicts the progression of the construction of the improved gravel road and new culvert. Overall, the gravel wearing course appeared to have been constructed properly.

Table 4 Summary of field compaction results at km 43 (Paige-Green et al, 2019)..

Culvert	Distance from culvert (m)	Side	Wet density (kg/m3)	Dry density (kg/m3)	Moisture (per cent)	Compaction (per cent)
New	0	RWP	1931	1852	4.3	95.7
		CL	1999	1918	4.2	98.9
		LWP	1963	1908	2.9	98.4
	10	RWP	1988	1902	4.6	98.0
		CL	2061	1966	5.7	100.5
		LWP	1980	1881	5.5	97.0
Existing	0	RWP	2053	1916	7.2	98.8
		CL	2056	1915	7.4	98.7
		LWP	2123	1979	7.3	102.0
	10	RWP	2078	1937	7.6	99.8
		CL	2036	1922	5.9	99.1
		LWP	2025	1895	6.9	97.7

Figure 14 Construction of improved gravel road at km 51.

5.0 Preliminary Performance of Completed Construction Work

5.1 Technical Performance

Overall, most of the construction activities had been completed satisfactory. Figure 15 shows the before and after construction pictures. The following observation and recommendations were made:

Side slopes of the concrete ford embankments (km 17.6), as well as side slopes of the embankments of the newly constructed approach to the concrete ford at km 36 need to be vegetated to minimise erosion;

Sand was found to have accumulated at the inlet and outlet of the culverts at km 43 as a result of rainfall, necessitating routine inspection and cleaning. Furthermore, side embankments appeared to have been damaged by rain due to inadequate compaction, and required some improvements, and

Some drying cracks were observed on the newly constructed gravel wearing course at km 51. The progression of the cracks should be closely monitored during the planned long term performance monitoring.

Figure 15 Before and after construction pictures of the demonstration sections.

5.2 Cost of Improvements

These actual costs of the improvements will be helpful at the end of performance monitoring to compare the costs of the implemented adaptation measures with conventional construction practices. As part of the final inspection, the total construction costs of each of the four demonstration sections were obtained from the contractor. The costs are summarized in Table 5.

6.0 Conclusions and Way Forward

The chapter presented the outcomes of road assessment and identification of problems, as well as the design and construction of four demonstration sections along the Mohambe and Maqueze road to address climate change-related problems leading to the undercutting of concrete fords, damage to the road approaching the concrete ford, damage to culverts and improved gravel road. Based on the information and discussions contained in this chapter, the following conclusions are drawn, and recommendations made:

Although still preliminary, observations during a rainy season indicated that the demonstration sections are performing well;

The proposed adaptation measures have also been implemented on other roads with similar conditions in Mozambique;

The long-term performance of the demonstration sections had been planned, the outcomes of which

Table 5 Summary of construction costs (Paige-Green et al, 2019).

Section	Total cost (MZN)	Total cost (USD)*
Undercutting of concrete ford	3 250 000	53 719
Damage to road approaching concrete ford	36 000	595
Damage to culverts and erosion protection	2 660 300	43 973
Improved gravel road	1 988 780	32 872P
Sub-total	**7 935 080**	**131 158**
VAT	**539 585**	**8 919**
Total	**8 474 665**	**140 077**

*1 USD = 60.5 Mozambican metical (MZN).

are expected to inform on the appropriate adaptation procedures for wider implementation in Mozambique, and possibly elsewhere, and

Furthermore, the outcomes of the long-term performance monitoring of the demonstration sections are expected to improve manuals and guidelines for the design of low volume climate-resilient roads, and possibly the incorporation of the adaptation options in the Road Asset Management System (RAMS).

7.0 Acknowledgment

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Photo by Matt Hardy from Pexels

Sustainable Pavement Construction: Use of Non-Potable Water and Smart Techniques for Compaction

Ashiel Rampersad and Gculisile Mvelase

1.0 Introduction

1.1 Background

Climate change is contributing to the observed increases in longer-lasting drought periods and warmer temperatures. The National Climate Change Adaptation Strategy published by the Department of Environmental Affairs in the Government Gazette [1] highlights the projected future changes in climate in South Africa. The impact of longer-lasting drought periods is relevant to the available potable water and use in the construction process in South Africa. The projected future changes in climate in South Africa are [2]:

- Increases in the number of heat-wave days and very hot days.
- 2080–2099 period: Temperature increases greater than 4°C across South Africa. Increases greater than 6°C are possible in the western, central, and northern interiors.
- Under low mitigation: temperatures to increase drastically.
- Under high mitigation: temperature increases in the interior could be constrained between 2.5 and 4°C

The western cape government [2] reported an annual mean near-surface (2m) temperature (°C) change from the median and the 10% and 90% percentiles projected for 2036 – 2065 and 2066 – 2095. Across most of the country, model-simulated rainfall is slightly lower than observed, although the east-west gradient in rainfall is adequately represented. Autumn, which is the transition period between summer and winter, denotes slightly higher rainfall in the observed east and Western Cape region. Winter rainfall is higher in the Cape Town region in the observations, compared to the model simulations.

The temperature and rainfall variations have a direct impact on the restriction of available potable water required. Due to the limited peer-reviewed research and use of non-potable water in road construction, this chapter will investigate preliminary laboratory research into the area as well as smart compaction techniques.

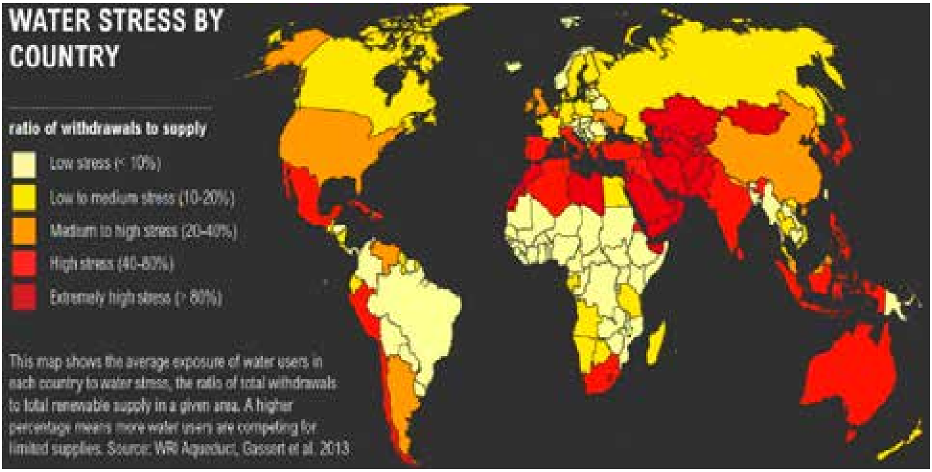
1.2. Relevance

The relevance of addressing and reporting on using non-potable water and smart compaction techniques has long-term effects on the sustainability of the country. It will form a critical component in obtaining alternatives to using potable water for road compaction in water-constrained environments as well as reviewing current practices on water use in road compaction. There are direct impacts on the socio-economic and environmental impacts in addressing the relevant issues such as the diversion of potable water from the construction industry to water-scarce communities.

1.3. Objective

- The objectives of this chapter are as follows:
- To create awareness of the threats of longer-lasting drought periods on the construction industry

Figure 1: Water stress by country [3]



- To understand alternative construction processes, feasibility, and international technologies not reliant on potable water
- To improve the understanding of the use of non-potable water in road construction and its effect on performance
- To investigate smart compaction techniques relevant to the road and pavement industry

2.0 Status of potable water in South Africa

The Department of Water and Sanitation (South Africa) has published a situation report on the status and drought regarding water in the Western Cape [2]. Statistics and highlights are depicted below.

South Africa is an arid country and one of the 30 driest countries in the world.

The country has not recovered from the 2014 drought, with the Western Cape Province experiencing the worst drought in 400 years, at that given time.

Level 6 restrictions were announced but are still not achieving the target of 500 megalitres per day and consumers are overusing by approximately 86 megalitres per day, with a slight decrease of 8 megalitres per day week on week.

Residents were required to use no more than 87.5 litres of municipal drinking water per person per day in total irrespective of whether at home, work, or elsewhere.

Gassert et al [3] investigated the water stress per country by determining the ratio of withdrawals to supply of water. Figure 1 shows that South Africa is at high stress (40 – 80%).

3.0. Pavement compaction and use of potable water in construction

Compaction is the process of mechanically increasing the density of a material. Soil and asphalt are made denser by reducing the voids between the particles, which make them up. In time, loose material would settle and compact itself naturally. By applying various mechanical forces, we shorten the time required to get compaction from years to hours [4].

Compaction is the process of compressing a material from a given volume into a smaller volume. This is done by exerting force and movement over a contact area, causing particles within the material to move closer together. The voids between the particles–air, water, or a combination of force and movement. The four forces that are used in compaction are static pressure, manipulation, impact, and vibration.

To achieve optimum compaction, materials are usually compacted at or about optimum moisture content which for pavement layer materials will usually be between about 7 and 12 % of the mass of the material being compacted. In broad terms, this requires the use of between 150 and 200 thousand litres of water per layer per kilometre. Figure 2 shows a water truck spraying a layer and preparing it to be compacted.

Although much of the water used in construction ultimately evaporates from the road and is returned to the earth's surface as precipitation, this is a long process and local depletion can occur rapidly, particularly in areas becoming drier through progressive climate change [5].

There are many factors to consider when compacting a pavement. Due to the large variability, there may be a need for further investigation into the specifics of each parameter in providing the best option for sustainability. These properties include mix property factors (aggregate grading, size, shape, and binder specifications), construction factors (roller types, passes, timing, production temperatures, foundation support, and suitability for different surfaces) and environmental factors (wind, air, and ground temperatures).

There are no direct specifications for the quality of water used in road construction; however, COLTO [6] specifies the following definition:

"Only clean water, free from undesirable concentrations of deleterious salts and other materials, shall be used. All water sources used shall be subject to the engineer's approval".

This statement does not provide any specifications in terms of the concentrations of deleterious salt, undesirable concentrations, and other materials.

A water consumption study was conducted by the Blackwood Solar Energy Facility [7] for the development of the area in the Free State. Water consumption during the construction process is associated primarily with the compaction of roads to meet minimum quality requirements. The requirement is estimated to be 50 l/m^3 for 35 000 m^3 of granular material. Given the cost of water, the cost of water per cubic metre of construction material was R2.23.

4.0 Literature review

4.1. Use of seawater in pavement construction

Research has been conducted by academics and investigators in the pavement construction field on the use of seawater in road compaction. Although the focus area is limited and project-specific, progress has been made in the advancement of knowledge. Research advancements include:

- Experimental sections were constructed in 1976 at Lüderitz on the arid coast of Namibia to develop methods of successfully using seawater for the

Figure 2: (Left and middle): Use of potable water in compaction (picture taken by G Mvelase at Transnet track formation layers construction), (Right): Video of use of water tanker sprayer on base layer to ensure optimum moisture content near King Shaka International Airport

compaction of all layers of a new road with a G3 base course under a Cape seal surfacing. These experiments have shown that, provided certain precautions are taken in the design and construction, seawater can be used in all layers including a G3 base course without experiencing any significant degree or extent of salt damage, either during construction or in the long term – at least up to 36 years [8].

- Long-term experimental sections of slurry seal made with seawater were used to complete a 19 mm Cape seal near Saldanha Bay, South Africa. Sections included seawater in both layers of slurry, in the top only, and in the bottom only, as well as control sections using freshwater. It is concluded that saltwater at least as saline and of similar composition to the seawater (3.2 % total salts, dominantly sodium chloride with some sulfate) can safely be used to make cationic slurries [9].
- The effect of salt on bituminous pavements has been quantified by Shahin et. al [10]. In the study, 80/100 pen-grade bitumen was used with aggregate and varying amounts of salt. Material properties of the salt, aggregate, and filler were characterized. The salt content was varied and its effect on solubility, softening point, penetration, flash point and ductility was captured.
- Emarah and Saleem [11] investigated a case study on lime-treated soil mixed with seawater to determine engineering properties for road construction. In clays, the introduction of swelling can result in stress. The material properties, chemical characteristics, and samples are defined. The presence of seawater as mixing water in the lime-treated soil has formed a new fabric structure of high rigidity as well as high shear strength. Accordingly, the new fabric structure became capable of resisting the compression process.
- Otoko [12] investigated the effect of saltwater on the physical properties, compaction characteristics, and unconfined compressive strength of clay, clayey sand, and base course. Results of laboratory investigation show that the plasticity index decreased when using saltwater as opposed to tap water.
- The effect of salty water of the Persian Gulf was investigated on the proctor compaction and CBR tests on the SP-SM (poorly graded sand with silt and gravel) soil samples which were taken from five trial sections in Abu Dhabi (UAE). The maximum dry unit weight increased by adding Persian Gulf water compared to the samples tested using tap water in the lab [13].
- The occurrences of salt-damaged pavements have been described covering Botswana as well as international situations. A detailed examination of soluble salt damage to bituminous sealed roads was investigated in several regions of South Africa following the widespread occurrence of blistered surfacings. Early occurrence of salt damage, sodium and magnesium sulfates present in mine waste material used for pavement construction were identified to be responsible for the salt damage problem. The pavement material was a quartzite waste from industrial mine processes [22].

4.2. Use of treated wastewater in pavement construction

Similar to the advancements made on research using seawater as a non-potable source in pavement construction, there has been limited work done on the use of treated wastewater in the same context. Research advancements include:

- Attom et al [14] investigated the effect of treated wastewater on compaction and compression of fine soil. The main objective of this paper was to study the effect of treated wastewater (TWW) on the compaction and compressibility properties of fine soil. Two types of fine soils (clayey soils) were selected for this study. The maximum dry unit weight increased for both soils and the optimum water content decreased as much as 13.6% for highly plastic soil.

Local experience has confirmed that although it is possible to achieve acceptable compactions at low moisture contents, the strength obtained is usually less than that obtained during dry compaction

- Al-Jabri et al [15] investigated the effect of using wastewater on the properties of high-strength concrete. Chemical analysis results showed that although more chemicals were found in wastewater than in tap water, the water composition was within the ASTM standard limits for all substances indicating that the wastewater produced can be used satisfactorily in concrete mixtures. It is noted that excess organic material can delay the setting of concrete and the development of strength.

Usable return flows of runoff (i.e. treated wastewater), which comprise about 14% of the overall yield and approximately double the groundwater yield, are indirectly reused for potable supply i.e. extracted by drinking water treatment works from surface waters after discharge from wastewater treatment works (WWTWs) a distance upstream. With the aridity of the region and the substantial quantities of usable return flows generated daily, there is an argument for the direct reuse of these return flows for some non-drinking applications [16].

4.3 Dry compaction techniques

Normally all types of soil are compacted most efficiently at optimum water content. However, in some areas such as arid or semi-arid areas, it may be impractical or too costly to water the soil. In such cases, gravel and sand can be compacted in a dry state (water content < 1.5 %).

Steyn and Paige-Green [5] reviewed the use of the dry compaction technique. It has been shown that many materials have a second maximum dry density peak over and above the traditional peak at optimum moisture content, at very low moisture levels (usually below 3%).

Limited work on dry compaction has been carried out concluding that the majority of materials can be compacted at moisture levels at or below about 3% [17] although the findings were that the air voids are very high, and the strength development is not as good as when wet compacted.

Local experience has confirmed that although it is possible to achieve acceptable compactions at low moisture contents, the strength obtained is usually less than that obtained during dry compaction as no strength due to soil suction (developed during drying back) develops. This is critical for unsealed roads. The strength of lower layers will influence the engineering properties of the layer and the bearing capacity of the structure.

For the dry-bound Macadam pavement, the voids in a layer of almost single-sized stones (usually 53 mm nominal size) are filled with dry, cohesionless fine aggregate filler. The voids are filled with filler with equipment only, and no water is used [18]. PIARC [19] defines the layer as dry crushed rock or crushed slag prepared by laying the larger sizes of aggregates (50 mm) first and then vibrating into the layer the finer aggregates (less than 5 mm).

4.4. Use of smart compaction techniques

Intelligent compaction (IC) techniques have been researched in recent years and provide several benefits for roadway construction over the conventional compaction processes. IC rollers are vibratory rollers equipped with instrumentation fed to a documentation and feedback control system that processes compaction data in real-time for the roller operator.

In addition to reducing the compaction variability of road-building materials, these include:

South Africa is an arid country and one of the 30 driest countries in the world

- *Optimized labor deployment and construction time* – Contractors can roll the material with the right amount of compactive effort on each pass to help ensure that the proper stiffness is achieved. Both under rolling and over- rolling can lead to poor performance.
- *Reduced material variability* – Intelligent compaction equipment allows contractors to more closely monitor the stiffness of the material so that there is less variability in the result. Over the long run, lower variability will result in better pavement performance and reduced maintenance and repair costs.
- *Reduced compaction and maintenance requirements* – The flexibility to make fewer passes to achieve the correct compaction level minimizes fuel use and equipment wear and tear.
- *Identification of non-compactable areas* – Areas that fail to reach the target compaction level can be identified as potential areas for reworking the defective material or removing and replacing it.
- *Ability to make midcourse corrections* – The ability to correct compaction problems in a subsurface layer (before additional layers are placed) ensures that subsurface problems do not affect the entire road surface.
- *Ability to maintain construction records* – Data from intelligent compaction operation, along with GPS coordinates of compaction activity, can be downloaded into construction quality databases and stored electronically by the contractor for future reference.
- *Ability to generate an intelligent compaction base map* – Contractors can identify weak spots (typically used in pavement rehabilitation projects such as mill and fill).
- *Ability to retrofit existing equipment* – Most existing rollers can be easily converted to an intelligent compaction roller using a retrofit kit.

Intelligent Compaction Measurement Value (ICMV) is a generic term for a calculated value based on accelerometer measurements on vibratory roller drums. ICMVs are in different forms of metrics with various levels of correlation to compacted material's mechanical and physical properties. The following describes the "Levels of ICMV" for the systematic classification of ICMV. The classification is based on four criteria [24]:

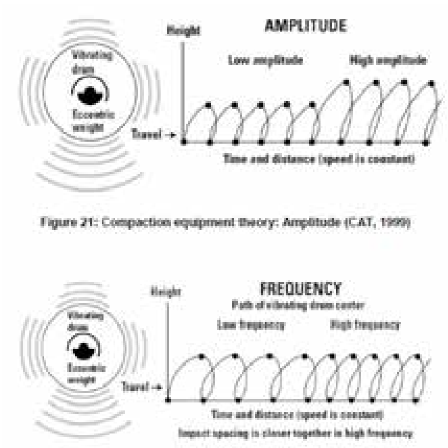
- Correlation with material's mechanical (modulus) and physical properties (density),
- Validity during decoupling when a drum loses contact with the compacted body,
- Capability to allow performance analysis of the compacted body,
- Applicability to obtain layer-specific mechanical and physical properties of the compacted body,
- Capability to be enhanced by advanced technology such as Artificial Intelligence.

Other smart compaction techniques include the control of compaction water on site:

- Compactive efforts: It is critical to establish the amount of roller passes to achieve a required density. To achieve the best results, laboratory and field compaction must be carefully correlated. Figure 3 highlights compaction equipment theory and potential for further research.
- Dynamics of vibratory compactors: In a vibratory compactor, centrifugal force is created by an eccentric weight or weights rotating inside a drum. Centrifugal force is frequently used to rate machines.
- Efficiency: Directly related to the conservation of energy, is the efficiency of compaction equipment. The Army Field Manual [20] describes the efficiency of the equipment.
- The amount of required water: Normally, it is a good practice to adjust the desired moisture content to Optimum Moisture Content plus two percent, but this depends on the environmental conditions

(temperature and wind) and the soil type. Careful control of the moisture content and the application of the water distributor is critical to sustainability.

Figure 3: Compaction equipment theory: Frequency [5]



4.5. Limitations and drawbacks: Use of non-potable water

Netterberg [22] highlighted the impact and effect of salt damage in Namibia road construction in the Saline Materials Guideline. Typical distresses include:

- Disintegration
- Prime damage
- Loose shoulders and layers
- Salt crystallization
- Accelerated weathering
- Blistering
- Curling and cracking

5.0 Preliminary laboratory investigation of non-potable water

5.1 Use of seawater and treated wastewater in pavement construction

Preliminary laboratory testing was conducted at the CSIR Advanced Material Testing Laboratory and included the use of seawater and treated wastewater on granular sub-base material.

- Dolerite, tillite, and sandstone aggregate were used. The material was sampled from local quarries of G5 and G6 standards (subbase). The parent rock type and location of the quarry is given below:
  - G5 Tillite (Ridgeview – Durban)
  - G6 Sandstone (Qala – Durban)
  - G6 Dolerite (Rooikraal – Johannesburg)
- The seawater was obtained from Blythedale Beach in KwaZulu Natal. And followed the South African Water Quality Guidelines for sampling. The treated wastewater was collected from the Rooiwal Wastewater Treatment works in Pretoria.
  - The seawater samples were collected where the depth of the water was less than 0.5 metres. The water was collected from 15 – 30 cm below the surface. Water was collected on the seaward side of a recently broken wave.
  - The treated wastewater sample was collected before being released into the Apies River. It was noted that 150 ML of treated wastewater is released daily from the surrounding treatment works in Pretoria.
- The material was washed, dried, and sampled before testing could continue. Quarries positioned in Kwa-Zulu Natal (KZN) were primarily sampled due to their end-use and proximity to the sea. Approximately 300 kg of material from each quarry was collected.
- A material testing program was developed to test the impact of seawater on material properties. Normal tap water (Pretoria) was used as a control (baseline) for the testing program. The testing includes material grading, Electrical Conductivity, Atterberg Limits (plasticity), Maximum Dry Density (MDD), Optimum Moisture Content (OMC), and CBR (strength of materials) (Table 1 and Figure 4).

Table 1: Material Testing Programme
Figure 4: Mixing and compaction of sandstone samples with non-potable water

Description	Test	Test Method
Control Tests	Grading of aggregate	SANS 3001 GR1
	Bulk Density	TMH1 B9
	Atterberg Limits	SANS 3001 GR10
	Maximum Dry Density	SANS 3001 GR30
	California Bearing Ratio	SANS 3001 GR40
	Electrical Conductivity	TMH1 A21T
	pH of Water Samples	-
Impact of seawater and treated wastewater	Variations in MDD and CBR	SANS 3001 GR30 / 40

5.2 Results and Discussion

The Advanced Material Testing Laboratory at the CSIR completed the testing of samples. The results and discussion of the testing are depicted.

Figure 5 highlights the aggregate testing. The materials were described as well-graded coarse gravel.

The Grading Modulus (GM) indicated that the materials are of relatively good quality and meet the Colto specifications [6] for G5 and G6 gravel. A maximum Electrical Conductivity of 0.15 S/m (or 0.10 depending on drainage) at 25^{0}C is usually specified for untreated road and other pavement base courses [22]. The Electrical Conductivity was between 0.01 and 0.09 S/m. Netterberg [22] specifies a pH between 6.0 and 8.5 for use on untreated materials. The results for all samples were between 7.1 and 8.2. The tap water, seawater, and treated wastewater all met the specifications (Table 2).

Table 2: pH of water samples

Water used in sample	Tap water (control)	Seawater	Treated wastewater
Dolerite	8.2	8.1	7.1
Sandstone	7.6	7.9	7.6
Tillite	7.6	7.9	7.6
Target [22]		6.0 – 8.5	

Atterberg Limits are empirical tests that are used to indicate the plasticity of fine-grained soil by the differentiation of highly plastic, moderately plastic, and non-plastic soils. The material specifications for G5 and G6 material follow [6]:

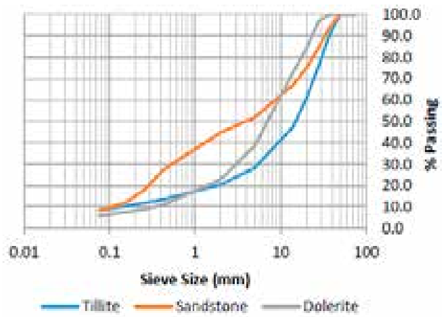
G5 material: The Liquid Limit shall not exceed 30, Plasticity Index shall not exceed 10, and Linear Shrinkage shall not exceed 5%.

G6 material: The Plasticity Index shall not exceed 12 or a value equal to 2 times the Grading Modulus plus 10, whichever is the higher value, and the Linear Shrinkage shall not exceed 5%.

All samples met the Colto [6] specification for Atterberg Limits of the material. The G6 Sandstone Material was described as non-plastic. The Liquid Limit and Plastic Limit depicted a small deviation (at most 3.7% deviation) whilst the greatest deviations can be seen in the Linear Shrinkage.

The California Bearing Ratio (CBR) test is a strength test that compares the bearing capacity of a material with that of a well-graded crushed stone (thus, a

Figure 5: Aggregate material grading (left) and properties of subbase material (right)



Parameter	Tillite	Sandstone	Dolerite
	Properties of Subbase Material		
Relative Density	1.380	1.356	1.801
Relative Density (Compacted)	1.558	1.508	2.017
Electrical Conductivity (S/m)	0.03	0.01	0.09

high-quality crushed stone material should have a CBR @ 100%). TRH 14 [23] specifies the criteria for G5 and G6 material.

G5 Material: The material should have a CBR after soaking of not less than 45 percent at 95% Mod AASHTO density and a maximum swell of 0.5 percent at 100% Mod AASHTO density.

G6 Material: The minimum CBR at 93% Mod AASHTO density should be 25.

G6 Dolerite was the only material, which met the target criteria for its specific material classification (seawater and treated wastewater).

Compaction testing was completed according to SANS 3001 Method GR30. Colto [6] specifies that the maximum swell at 100% modified AASHTO shall not exceed 1.0% for G6 and 0.5% for G5. Table 5 depicts the results of the compaction testing.

- All samples met the maximum swell criteria
- A lower OMC is required for Sandstone and Dolerite (seawater and treated wastewater).
- A higher MDD is achieved for Tillite, Sandstone, and Dolerite using treated wastewater.
- The MDD deviated at most 2.0% from the control and OMC deviated at most 10.5%.

Table 3: Atterberg Limits

	Tillite			Dolerite		
Parameter	Tap Water (control)	Seawater	Treated Wastewater	Tap Water (control)	Seawater	Treated Wastewater
Liquid Limit	15.94	16.13	16.08	19.51	19.21	19.74
Plastic Limit	12.85	13.23	13.32	17.43	17.31	16.88
Plasticity Index	3.08	2.90	2.76	2.08	1.90	2.88
Linear Shrinkage (%)	1.67	1.33	1.33	1.62	0.65	1.94

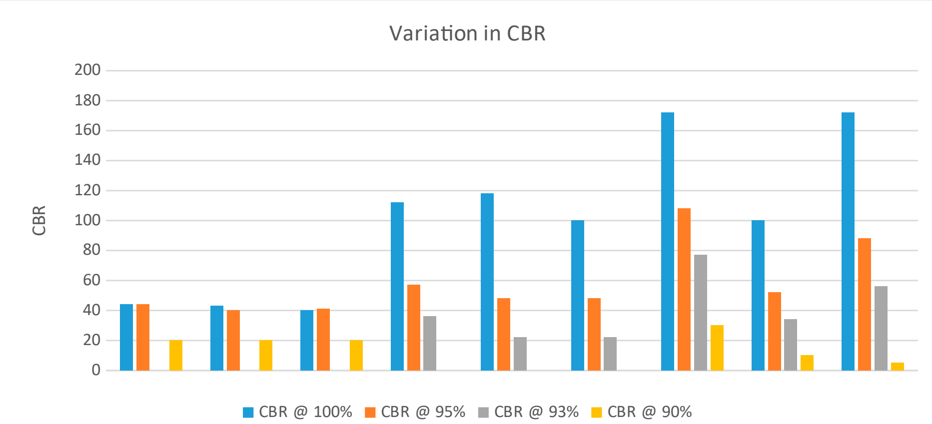


Figure 6: Variations in CBR

6.0. Conclusions

Promising results are shown in the laboratory testing and further research should be required going forward. Areas of expansion of the research include variations in non-potable water, use of different sub-base or base material, and establishment of experimental test sections for long-term pavement performance monitoring.

There is great potential for using seawater and treated wastewater as a non-potable source for pavement construction based on the preliminary laboratory results. Due to the state of available water in Southern Africa and the impact of climate change on road construction, there is a need for further investigation. Laboratory, as well as in-field studies, have been reviewed in this chapter with quantifiable outputs.

Alternate methods to using non-potable water and conventional compaction techniques in pavement construction were investigated in this chapter such as dry compaction and smart compaction techniques (energy-efficient

Table 4: CBR Test Results

	G5 Tillite			G6 Sandstone			G6 Dolerite		
CBR	Tap	Sea	TWW	Tap	Sea	TWW	Tap	Sea	TWW
CBR @ 100%	44	43	40	112	118	100	172	100	172
CBR @ 95%	44	40	41	57	48	48	108	52	88
CBR @ 93%	-	-	-	36	22	22	77	34	56
CBR @ 90%	20	20	20	-	-	-	30	10	5
Target	Not Met			Not Met			Target Met		

Tap: Tap Water, Sea: Seawater, TWW: Treated Wastewater

Table 5: Compaction results of tap, sea, and treated wastewater

	G5 Tillite			G6 Sandstone			G6 Dolerite		
Compaction	Tap	Sea	TWW	Tap	Sea	TWW	Tap	Sea	TWW
MDD (kg/m^3)	2232	2243	2238	2108	2119	2151	2421	2379	2437
OMC (%)	2.7	6.3	5.6	6.8	6.6	6.6	4.2	3.3	3.9
Swell (%)	0.0	0.0-	0.0	0.0	0.1	0.1	0.1	0.0	0.0

compaction equipment). Limitations and drawbacks of each technique were also investigated in this chapter.The use of non-potable water and smart compaction techniques both contribute to the "zero waste" theme.

7.0 Way forward

The study showed promising results in the field of non-potable water in pavement construction. Further research is, however, required with the following recommendations:

- Use of smart compaction and construction techniques to increase sustainability in the industry
- Analysis of a wider range of aggregate materials as well as base layers in a laboratory setting using seawater and treated wastewater.
- Chemical and variability analysis of different sources of seawater and treated wastewater.
- Economic variability of using non-potable water due to transportation.
- Long-term pavement performance monitoring of constructed as well as trial (experimental) sections, which use non-potable water.
- Analysis of other non-potable water sources for pavement construction such as greywater.
- Dry compaction of pavement sections.


Photo by Raphael Brasileiro from Pexels

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The Use of Plastic Waste in Road Construction

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1.0 Introduction

PlasticsSA's annual review estimated that 1 841 700 tons of plastics (including 337 700 tons of recyclate) were converted into products in 2019, with an input recycling rate (collected waste as a percentage of available plastics for recycling) of 45.7 per cent (PlasticsSA, 2019/2020). This indicates an estimated 18 per cent recycle content of plastic products made in South Africa, with significant material leakages into the environment still occurring. According to Jambeck et al. (2015), unrecycled plastic materials usually end up being disposed of in landfills, through self-help or by littering. The study by Jambeck et al. (2015) ranks South Africa among the top 20 contributors to ocean plastic, with around 0.09-0.24 million metric tons of plastic waste ending up in the ocean annually.

The development of the local end-use market for waste plastic is crucial to increasing South Africa's plastic recycling rates, especially for low-value, problematic plastic fractions, such as polyolefins consisting mainly of polyethylene and polypropylene. The use of recycled and/or alternative materials such as plastics in road construction is beneficial not only in terms of sustaining the environment, since naturally occurring materials will be conserved but as a means of reducing construction costs.

Recycled plastics are being investigated worldwide not only as a green investment, but also for improved pavement durability (Milad et al., 2020). The objectives of the study were to screen, evaluate and implement existing international technologies in line with South African design standards and specifications for materials in road construction.

The main research question was whether low value waste plastics can be optimised as alternative road construction materials in South Africa. The approach to answering this research question was to review the international literature on this topic and identify the best practices that could be effectively localised in South Africa. A secondary research question investigated existing asphalt road standards and specifications to determine whether they should be modified to facilitate the use of plastics as alternative

Figure 1: Methodology adopted during the research project

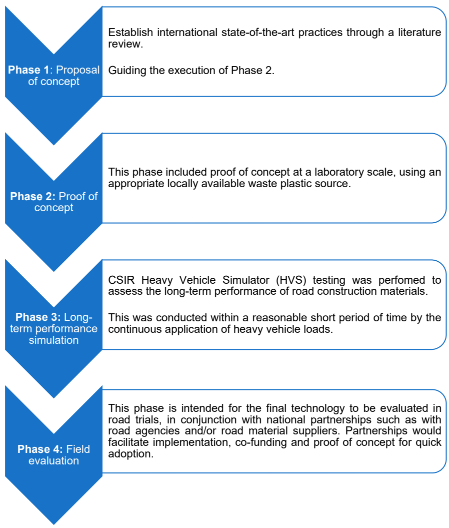


FIGURE 1

materials that could improve overall pavement performance and sustainability.

2.0 Methodology

The methodology implemented for this study consisted of the following phases shown in Figure 1. Only the first three phases were completed during this study.

3.0 Review of the literature

3.1 Approach

The aim of the literature search was to summarize the effect of the addition of waste plastic to asphalt mixes in terms of performance. This, in turn, served as a guide for the laboratory phase whereby bitumen or asphalt mix was modified with waste plastic.

In the literature review, a two-pronged approach was adopted based on the two asphalt modification methods, commonly known as the 'wet' and 'dry' methods:

- Reports of the low-cost, low-tech 'dry' modification of asphalt were investigated. The method consisted of adding various unsorted plastic waste to hot mix asphalt (HMA) aggregates prior to adding bitumen (Vasudenvan et al., 2010).
- In the second approach, waste plastic is added directly to bitumen and is commonly known as the "wet" method. Due to the use of a consistent source of modifier, the "wet" method results in a more controlled outcome.

3.2 Dry Modification of Asphalt Mixes Using Plastic Waste

During the dry method, the plastic is softened to adhere to the aggregate, forming plastic coated aggregates (PCA). To date, more than 5,000 kilometres of roads with plastic waste have been laid in at least 11 states in India (Suaquita, 2019). Researchers who participated in the development of this method claim that the roads constructed using this technology are of better quality and do not require maintenance for the first five years. However, in many cases, these claims are difficult to confirm (Mturi et al., 2021). Other claims (Suaquita, 2019) are that this technology results in:

- no toxic gas emission,
- Cost savings,
- Better binding property,
- Higher softening points of the binder, and therefore the asphalt mix can withstand high temperatures and higher loads, and
- Improved waterproofing.

Apart from India, there are experiences elsewhere in the developed world. In 2015, MacRebur, a company based in Scotland, initiated a commercial plastic waste recycling project (McRebur, 2017).

MacRebur has developed and trialled three products (MR6, MR8 and MR10) made from plastic waste materials originating from domestic and industrial plastic waste sources. The trials have been carried out mostly in developed countries (e.g. Canada, US and Australia) (White and Reid, 2018; Mturi et al., 2021).

3.3 Wet Modification of Asphalt Mixes Using Plastic Waste

Modification using proprietary polymers such as styrene-butadiene-styrene (SBS) or ethylene vinyl acetate (EVA) exhibits superior performance compared to asphalt mixes modified with waste plastic (Casey et al., 2008). However, the cost of polymer modified bitumen (PMB) manufactured with virgin or proprietary polymers can be up to 30 per cent higher compared to unmodified bitumen in South Africa. Polyethylene waste, on the other hand, is generally available in large quantities with different mechanical properties and at low cost, making them good candidates as modifiers (Polacco et al., 2005).

Unfortunately, polyethylene is almost completely immiscible with bitumen due to its non-polar and non-aromatic nature (Behnood and Gharehveran, 2019). As a result, polyethylene-modified bitumen is a multiphase material with a tendency to phase separate (Ait-Kadi et al., 1996). This single fact has severely limited its use as a bitumen modifier for the "wet" method (Mturi et al., 2021). However, compatibility enhancement techniques exist; and employing multi-polymer and/or chemical modification of polymers are examples of techniques used to enhance the compatibility of the PMB blend. Various chemical modification techniques have been suggested in the literature, such as (Mturi et al., 2021):

- Grafting (reactive monomers are grafted onto polymers).

- Functionalization of the polymer with epoxy groups, acrylic acid, carboxylic acid, glycidyl methacrylate (GMA), etc.
- Chlorination of the polymer (this will increase its polarity and thus increase the compatibility between the polymer and bitumen) to result in better dispersion of polyethylene particles in bitumen (Behnood and Gharehveran, 2019).

4.0 Results and Discussion

International studies were found to lack consistency regarding the use of plastic waste in asphalt road applications. Key findings from the literature review include the following:

- Plastic modification of bitumen and asphalt was limited compared to conventional modifiers. It was concluded that this was a direct consequence of the poor compatibility between bitumen and plastic material (Polacco et al., 2005).
- There was a lack of consistency in the approach to investigating plastic as a bitumen modifier. Therefore, the results obtained by the researchers were only applicable to the relevant methodologies applied in their investigation (Mturi et al., 2021).
- Insufficient evidence is often presented to support research claims, environmental sustainability, and the establishment of a consistent source of plastic waste where the composition remains the same over time. Therefore, the experimental results were generally relevant to the modifier as received at a given time (Mturi et al., 2021).

The findings of the literature review informed three key decisions on the way forward for this study, namely:

- Both the wet and dry methods were to be investigated.
- The plastic waste to be investigated would be limited to polyethylene waste. In South Africa, polyethylene waste represents a considerable source of low value waste, being underutilized and easily accessible for recycling.
- Consistency in the characteristics of the modified asphalt mix was the goal of the plastic waste modification process. Hence, the following requirements of the waste plastic product for modifying bitumen were deemed necessary (Mturi et al., 2021):
- A handling criterion to ensure the product is not too fine that it ends up in the environment at the asphalt plant, and not too coarse to further complicate the blending/manufacturing process.
- A composition criterion was needed to ensure the waste product is consistent; therefore, properties such as densities, melting temperatures and purity criteria needed to be specified.
- A homogeneity criterion to guarantee a good mixture of the different waste plastic components to avoid poor blending, where properties could span the range of each of the components or even lower.
- Asphalt in-service criterion to prevent adverse effects at the in-service temperatures of South African asphalt roads.
- An environmental criterion to prevent leaching of waste plastic material beyond national limits/thresholds. Additionally, the waste product for the asphalt road industry needed to be processed through an environmentally friendly recycling chain.
- A performance criterion to ensure consistency of the effects produced by the plastic waste source towards asphalt modification, considering that the effects of modification depend not only on the properties of the waste plastic but also on the properties of the base bitumen.

The recommended requirements for the waste plastic product used for this study have been summarised in Table 1 (Mturi et al., 2021).

Photo by Sarah Chai from Pexels

Table 1: Requirements for the waste plastic material used to modify bitumen.

Table 1: Requirements for the waste plastic material used to modify bitumen.

Property	Test Method	Units	Requirement
Recycling Material	-	-	Low-value waste stream[1]
Recycling Process Chain	-	-	ISO 14001 accredited (or equivalent)
Bulk Apparent Density[2]	ASTM D1895	g/cm^3	0.5-0.6
Purity (plastic: non-plastic)	See Note below[3]	per cent	>99
Macro Waste Polymer Homogeneity[4]	ISO 1183	g/cm^3, per cent	Variation in density between 4 random samples must be less than 2 per cent
Density	ISO 1183	g/cm^3	0.918-0.958
Melting Temperature, T_m	ASTM D 3418	°C	109-133
Glass Transition Temperature, T_g	ASTM 7028	°C	<-22
Leachable Concentration[5]	AS 4439.1-3	mg/L	<LCT

[1] Currently non-recycled (or not fully recycled) so as not to create competition with current high value end markets or with plastic waste stream having high recycling rates.

[2] Apparent density figures are not comparable except for materials having the same specific gravity after moulding or forming.

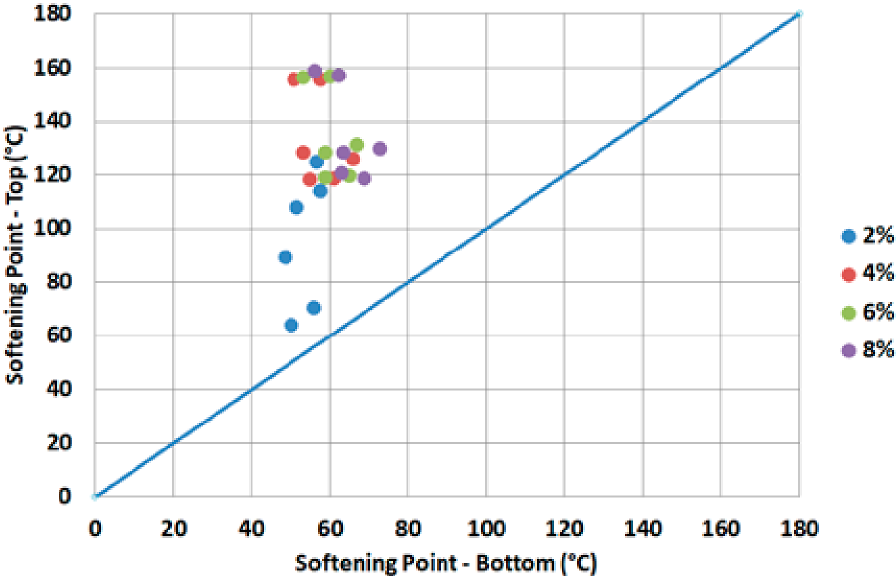
[3] The purity of recycled plastics is not easy to determine due to the different parameters that define a plastic material. Typically, a combination of techniques, including differential scanning calorimetry (DSC) and Fourier-Transform Infrared spectroscopy (FTIR) may be used to qualitatively ascertain whether a batch of recycled material is from a single family of plastic, e.g. HDPE. Since the sorting processes are inefficient, it is typical to find traces of a different type of plastic in recycled pellets, for example, recycled PP (rPP) in recycled HDPE (rHDPE), and vice versa.

[4] This refers to individual pellets. To achieve the required level of homogeneity, consider mixing with a twin-screw extruder as opposed to a single screw extruder or using an appropriate compatibiliser. Note: with poor blending (i.e. poor mixtures), the properties of the waste plastic could span the range of each of the individual components or even lower.

[5] As per National Environmental Management: Waste Act, 2008 (Act No.59 of 2008) and the Waste Classification and Management Regulations, 2013: Regulation 8(1)(a).

For the wet modification process, the following recommendations were made for the modified bitumen with the waste plastic product (Mturi et al., 2021):

- Given that bitumen and the waste plastic product were found incompatible (Figure 2), the waste plastic material needed to be purposely reacted to the bitumen backbone to improve storage stability. To cross-link the waste plastic to the base



bitumen, modifications were required to introduce reactive sites.

Figure 2: Storage Stability results for different percentages of polyethylene waste in bitumen.

- Provided compatibility is achieved, the following approach can be explored:
- Plastic waste material can be used to improve the rutting resistance properties of bitumen and act as a warm mix additive.
- The composition of the waste plastic and the dosage levels need to be controlled to avoid affecting bitumen performance properties.
- The waste plastic modified bitumen should always use a 70/100 penetration grade bitumen as the base binder.
- A 'TG1 (SABITA, 2015) plus' classification criteria be introduced prior to performance grading as per SATS 3208 (2021). Two grades be used for classifying the modified products: the current A-P1 grade for waste plastic modified binders exhibiting both rutting and fatigue properties, and a new A-P2 grade for less trafficked roads (e.g. rural roads) where improved rutting properties are needed without compromising fatigue properties. The recommendations are shown in Table 2.
- For the industry to adopt this process, the following issues will need to be addressed: (a) compatibility with other asphalt additives (warm mix additives,

Table 2: Properties of polymer modified binders for hot mix asphalt.

Table 2: Properties of polymer modified binders for hot mix asphalt.

Property	Blend Test Results	Unit	Test Method	Class*	
Before Ageing				**A-P1**	**A-P2**
Softening Point	56.6	°C	MB-17	63-73	53-73
Elastic Recovery @15°C	30.3	per cent	MB-4	30-50	5-30
Dynamic Viscosity @165°C	0.238	Pa.s	MB-18	≤0.55	≤0.55
Storage Stability @180°C	0.2	°C	MB-6	≤5	≤5
Flash Point	≥230	°C	ASTM D92	≥230	≥230
After Ageing (RTFOT)					
Mass Change	+0.0324	per cent	MB-3	≤1.0	≤1.0
Softening Point (min)	61.8	°C	MB-17	61	61
Elastic Recovery @15°C	-	per cent	MB-4	-	-
Stress Sensitivity ($J_{nr,diff}$; 3.2kPa)	28 per cent (58°C) 37 per cent (64°C) 45 per cent (70°C)	per cent	ASTM D7405	<75	<75
After Ageing (PAV)					
Strain Tolerance (CTOD)	12.9	Mm	LS-299	>10	≥Base Binder

*A refers to hot mix asphalt and P refers to plastomer

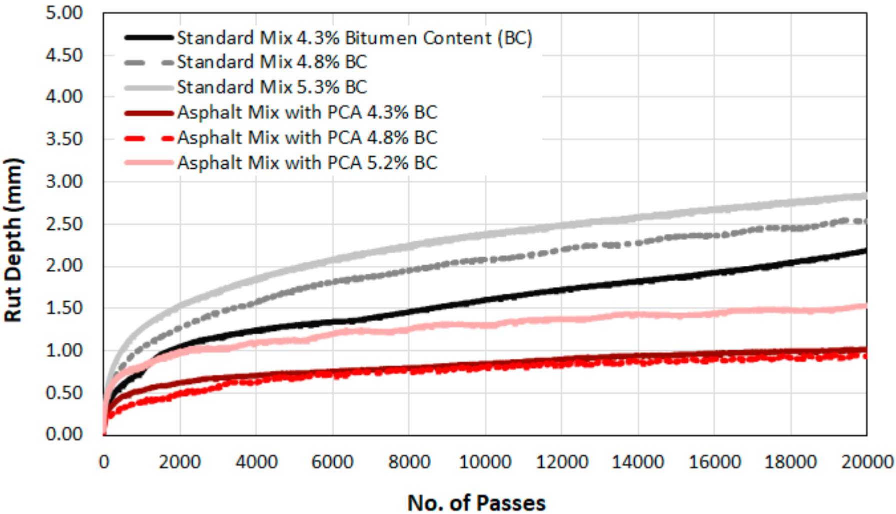
There is potential to use low-density plastic waste to design rut-resistant asphalt mixes

adhesion agents, etc.), (b) insolubility of polyethylene in solvents used for binder content and recovery analysis, and (c) recycling of asphalt mixes with waste plastic.

For the dry modification process, it was concluded that there is potential to use low-density plastic waste to design rut-resistant asphalt mixes due to the following findings (Mturi et al., 2021) as per the tests stipulated in SABITA Manual 35/TRH 8 (SABITA, 2019):

- The volumetric properties of the asphalt mix with the waste plastic met the criteria specified in SABITA Manual 35/TRH 8 (SABITA, 2019).

Figure 3: Rut depth vs. number of passes using the Hamburg Wheel Tracking Test.



- The results of the Hamburg Wheel Tracking Test (HWTT) indicated a higher maximum rut depth for the standard mix without PCA after 20,000 passes at 50°C, compared to the asphalt mix with PCA (Figure 3). This was based on the asphalt mix with PCA exhibiting more elastic behaviour and greater stiffness at these temperatures.
- The Black Space diagram (Figure 4) of the two mixes showed that at low temperatures, the two mixes exhibit similar stiffness and elastic behaviour. The Black Space diagram therefore predicts similar low cracking performance for the two mixes.
- Having similar stiffness and elastic behaviour at intermediate temperatures (at loading frequencies greater than 1Hz), the fatigue cracking performance of both the asphalt mix with PCA and the standard asphalt mix without PCA were comparable based

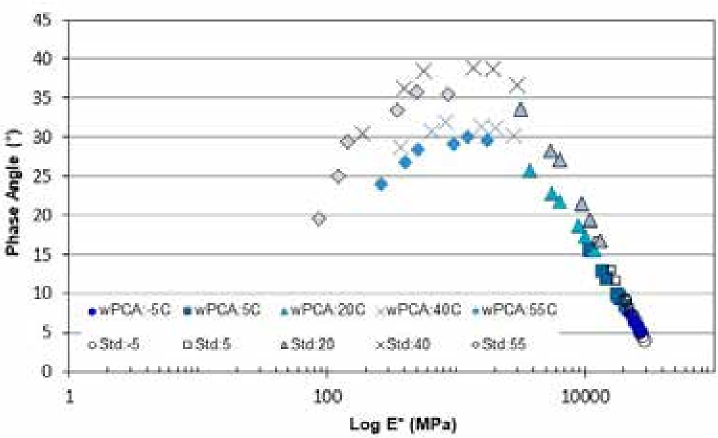
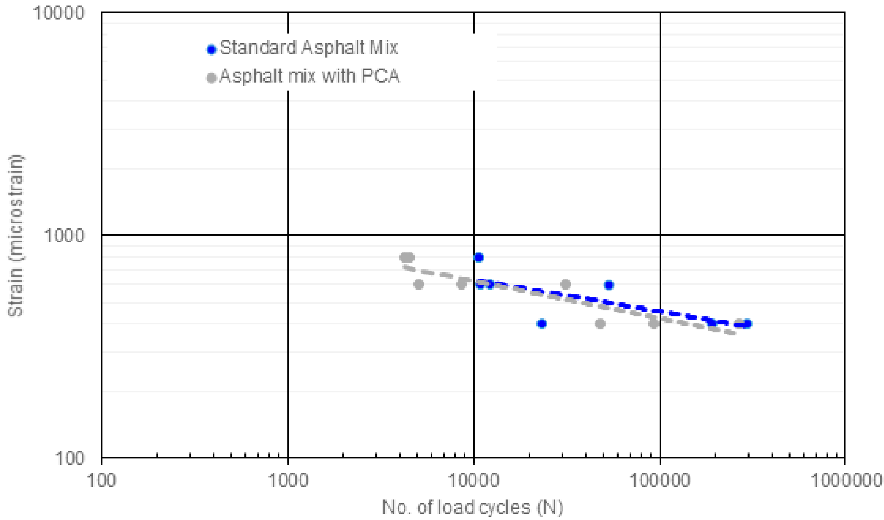


Figure 4: Black Space diagram for standard mix (Std) and asphalt mix with PCA (wPCA).

Figure 5: Fatigue life at a temperature of 10°C and a frequency of 10Hz.



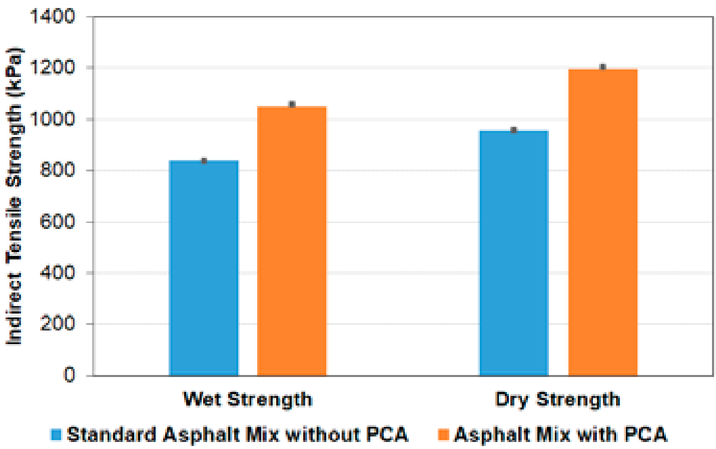
on the results of the four-point bending beam test (Figure 5).

- The asphalt mix with PCA met the workability criteria specified in SABITA Manual 35/TRH 8 (SABITA, 2019). This was based on the evaluation of the compaction data, where the voids of the asphalt mix with PCA after 45 gyrations did not exceed the design voids by more than 3 per cent.

For specific asphalt mix designs, the characterisation of asphalt performance indicated that waste plastic can have an extra binding effect in an asphalt mix.

This was observed with improved bitumen-aggregate adhesion and resulted in an increase in the tensile strength as determined from the Modified Lottman test (see Figure 6).

Figure 6: Indirect tensile strength results of a standard asphalt mix without PCA and an asphalt mix with PCA.



The constructed asphalt overlays (Figure 7) were designed for a total traffic loading of between 3 and 30 million equivalent standard axles (MESA) of 80kN (E80's) and were trafficked for a total of 476,294 HVS repetitions, which equates to 4.79 million E80s (using a damage coefficient of 4.2) under channelized trafficking (or 8.59 million E80s using equivalent comparable wandering traffic) at standard and non-standard loads on both sections (Akhalwaya et al., 2021).

The following HVS load applications were applied using a constant tyre pressure of 740kPa:

- 158,564 channelized repetitions of a 40kN dual wheel load (simulating a standard 80kN axle load);
- 93,210 repetitions of a 60kN dual wheel load (simulating a 120kN axle load);
- 186,796 repetitions of an 80kN dual wheel load (simulating a 160kN axle load) in the dry state; and
- 37,724 repetitions of an 80kN dual wheel load (simulating a 160kN axle load) in the wet state.

Figure 7: Construction of the HVS sections on road P159/1 (R80) in Gauteng, South Africa.

The comparative evaluation of performance test results from HVS testing was based on the following:

- Construction of two test sections consisting of a 50mm asphalt mix with PCA compared to a 50mm standard mix without PCA.
- Both test sections were constructed on a standard existing South African pavement structure containing unstabilized granular layers.
- The test sections achieved acceptable quality control for the HVS testing, even though higher percentages of voids were observed for the asphalt mix with PCA.

Based on the initial long-term performance simulation using a single wet HVS test, it was concluded that there is potential to use low-density plastic waste to design rut-resistant HMA mixes due to the following results:

- For the pavement structure paved with the standard mix without PCA, the true rut was physically measured in the post-mortem HVS investigation and was recorded as 6.69mm. For the pavement structure paved with the asphalt mix containing PCA, the true rut as measured physically in the post-mortem HVS investigation was recorded as 4.63mm. This result indicated that the asphalt mix with PCA performed slightly better than the standard mix despite having a higher percentage of voids.
- The results of permanent deformation/rutting were significantly lower than the South African warning rut level of 12.5mm and the terminal rut level of 20mm, indicating acceptable performances in terms of permanent deformation for both test sections for the applied traffic and environmental conditions.
- Although only a single HVS test was completed, both test sections appeared to be relatively insensitive to the magnitude of the HVS wheel load, especially in the dry state. This implies that the pavement structures for both test sections will likely not be overly sensitive to overloading.
- Based on the selected aggregates, the use of plastic waste can also be used to improve moisture sensitivity performance. However, there is a need to provide handling guidelines to ensure that asphalt mixes with PCA are mixed, transported and compacted appropriately.

5.0 Conclusions

The findings showed potential in using specified waste plastic materials to design rut resistant asphalt mixes without compromising other asphalt performance requirements. The approach requires the adoption of the necessary criteria to establish a consistent source of plastic waste. The research also highlighted the need to understand the mechanism that improves rut resistance to ensure that this benefit is realized through the control of performance criteria and handling of the asphalt mix. Furthermore, the research identified requirements for measuring additional asphalt properties that would quantify the contribution of the asphalt layer to safety, health and environmental sustainability.

Feedback originating from this research was directed at the South African government and industry stakeholders. The purpose was to encourage the use of plastic waste for environmental benefits, as well as for improved performance of road surfaces. Industry adoption of the technology will require the development of guidelines that will provide guidance in assessing use of waste plastic, and standard documents that will identify mechanical properties, application and impact potential of the developed waste plastic-based materials in road construction. This will lead to a better understanding of the suitability of plastic-based waste materials in road projects and therefore lower the risk of premature failure of roads.

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Wind energy industry gearing up for massive growth

The recent announcement of the preferred bidders for the Fifth Bid Window (BW5), October 2021, under the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), will see 1 600MW of new generation capacity being developed by onshore wind Independent Power Producers. This is in line with the government's intention to increase generation capacity and ensure the security of energy supply to society.

This is a huge step towards rolling procurement, which is what the country and the wind power sector both need for renewables to be able to deliver adequate energy to the country and help shift the economy onto a positive trajectory. Furthermore, the sector views the closing of policy gaps as a clear direction in terms of plans to procure new generation capacity on an ongoing basis, in line with the energy roadmap, which brings 14.4 GW of new wind power online over the next decade.

Consecutive bidding rounds will enable local manufacturing facilities to be re-established and facilitate the potential expansion of already operating manufacturers, which is crucial in creating long-term sustainable jobs.

With supporting policy and smooth procurement rounds expected to include the announcement of Bid Window 6 during Q1/2022, the renewable power sector certainly has a key role to play in re-building the country as a significant catalyst of economic growth, and investors have a big role to play in making that a reality.

Bid Window 5 facts:
- R50bn investment into the South African economy.
- 49.2% South African-owned projects.
- 34% black-owned projects.
- 44% commitment to local manufacturing targets during construction will be achieved.
- R2.7bn committed to local development.
- Bidding attracted 7% ownership of projects by black women.

Decarbonisation

Working in collaboration with its global counterparts, SAWEA continues to urge key stakeholdersi ncluding governments, economies and communities to put policies in place that will raise ambition and remove barriers to the massive scaling up in investments in wind power, in order to reach Net Zero targets.

The global wind manifesto for COP26 calls for wind energy to be a lead contributor to global decarbonisation strategies and for a commitment to decommissioning schedules of coal-fired power stations. This manifesto has proven to be aligned with the SA governments ambitions at COP26, following the commitments to move away from coal during the COP26 proceedings.

The latest CO2 emission targets released by the Presidential Climate Commission (PCC), which aim for a 350-420 Mton CO2e reduction by 2030 as part of our Nationally Determined Contributions (NDCs), show the state's increased commitment to decarbonisation. We acknowledge this symbolic commitment to mitigating the global climate emergency.

SAWEA's role is to safeguard industry's alignment with the global agenda and ensure that it continues to advocate for the necessary policy shifts.

Noupoort Wind Farm consists of 35 turbines with a total output of 80MW. When operating at full capacity, it generates around 304 800MWh of clean renewable energy per year and is expected to supply electricity to power up to 91 835 South African homes.

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- 33 operational wind farms
- 3.6 million SA households are powered by wind each year
- Wind power investment into communities in 10 years: R5.6 billion committed to local communities
- Water savings 25,2 million Kilolitres
- Carbon emission off-set: 28.8 Megatons
- 3 366MW of wind power has been procured through, from 36 wind projects

POWERING SA's ECONOMY

- Wind Power adds capacity to the power grid: fast, reliable and cost effective
- Investment of an estimated R40 billion, per year, for the next decade, if smooth procurement and policy will deliver in line with the country's 2019 Integrated Resource Plan
- The energy transition delivers thousands of new jobs each year

STIMULATING THE LOCAL VALUE CHAIN

- Wind energy production is an excellent vehicle for direct infrastructure investment and a positive multiplier of economic effects
- Manufacturing facilities deliver new job creation and skills to area's that will lose coal jobs, as decommissioning starts to take place in these areas
- Specialised components and skills development are stimulating the local economy: tower manufacturer; component transportation; steel sector; construction industry; engineering and logistics

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SAWEA
South African Wind Energy Association

Responses to Climate Change: A household-level case study from Johannesburg

Daniel Limpitlaw

1.0 Introduction – Carbon Dioxide Emissions and Climate Change

The link between carbon emissions and climate change was identified at the end of the 19th century (Arrhenius, 1896) but was largely ignored until the 1960s when reliable measurements from Mauna Loa in Hawaii first showed a consistent rise in atmospheric carbon dioxide (CO2) (Weart, 2008). By the early 1980s the risks posed to society by climate change had also been recognised and, since then, the arguments put forward by climate sceptics have gradually been overturned. Today, anthropogenic climate change is acknowledged as one of the greatest threats to our society.

Responses to this threat have been debated at the highest levels with many governments undertaking to meet emission reduction goals. Still, in the 50 years between 1960 and 2010, anthropogenic emissions of CO2 quadrupled (Weart, 2008) and the expected feedback loops that release more CO2 from natural reservoirs are now evident.

As with most problems, it is dissatisfying to passively wait for help and the old slogan of Friends of the Earth: "Think Globally, Act Locally" provides some inspiration, hence this paper – a report on measures adopted at a suburban house in Johannesburg, South Africa, in 2017/18, and the impacts they have had on the household carbon budget.

Householders who have adopted measures to lower their emissions have typically done so for a combination of cost-saving, energy-saving and environmental reasons (Caird, Roy, and Herring, 2008), (Yoo, Park, An, Al-Ammar, Khan, Hur, and Kim, 2012). In spite of these good intentions, uptake of household-scale renewable energy projects has been impeded for several reasons, including unrealistic marketing claims (Martinot, Cabraal, and Mathur, 2001), lack of access to capital and the presence of perverse policy environments (Caird et al., 2008), (Alstone, Gershenson, and Kammen, 2015). Most critically, a lack of information prevents uptake: data from the UK shows that householders have typically assumed that the cost of installing home energy efficiency measures far exceeds the expected energy savings (Caird et al., 2008).

This paper is primarily intended to provide insight into the strengths and weaknesses of a household photovoltaic (PV) and solar water heating (SWH) system.

The measurements presented in this paper are crude and calculations rely on estimates and assumptions, but provide an indication of the orders of magnitude of change in carbon emissions achieved. The assessment presented here is intended to assist other households in reducing their carbon footprints. While the specific household energy breakdown in other countries will be different, the approach to assessing emissions and making choices that minimise them remains applicable. It will take a concerted effort by the majority of countries to reduce their emissions to reverse the trajectory of climate change, so the idea of household-level change is one that should be extended globally.

1.1 The South African Setting

In a recent publication, a group of academics (Scholes, Scholes and Lucas., 2015) provided some insight into the causes and effects of climate change from a Southern African perspective. They noted that, with a per capita emission rate of just over 7 t/annum CO2e1, a South African emits half the greenhouse gases of the average person in the USA and is around the global average of 6.8 t/capita. This performance is worse than it may appear as it places South Africa among the top twenty global emitters and, on a per capita basis, and is far above the average for sub-Saharan Africa (4.5 t/a). Grid power in South Africa is largely generated using coal-fired thermal power stations and the grid emissions factor is commensurately high – 30% higher than that of Saudi Arabia2.

The global average temperature has increased by about 1 °C since 1900 (Wolff, Shepherd, Fung, Shine, Hoskins, Solomon, Mitchell, Trenberth, Palmer, Walsh, Santer and Wuebbles, 2020). This increase has not been evenly spread across the globe and South Africa has heated at nearly twice the global average rate recorded to date: in South Africa annual temperature has increased by 1.2 °C over the period of accurate records (Scholes et al., 2015).

2.0 Taking Action

While there are many ways in which our society releases additional carbon into the atmosphere, energy use dominates South Africa's carbon footprint and was responsible for 79% of the country's CO2e emissions at the last assessment (DEA, 2014). Consequently, reducing energy use and using cleaner forms of energy are key to reducing the impact of the country on the global weather system.

The household is key in debates on environmental sustainability (Lane & Gorman-Murray, 2011). Additionally, the familiar scale of households provides a way of communicating environmental sustainability imperatives to the broader population.

While billions of people have had their standard of living greatly improved through connection to grid electricity, the resulting emissions are a key driver of climate change (Alstone et al., 2015; IPCC, 2014). That we have come to rely on electrical power in our homes is unsurprising given the correlation between human development and the consumption of energy (Lloyd, 2017). The proliferation of electronic appliances in households has increased the residential sector's electricity demand. By 2009, between 30 and 40% of electricity generated globally was consumed by the residential sector (Lior, 2010).

The obvious ways in which individuals contribute to a country's carbon footprint include transport, cooking, heating water for washing and space heating. While some sacrifices may be required, technologies exist that allow us to reduce our impact without forgoing too many of our comforts.

Replacing old, energy intensive appliances and light bulbs is easy and relatively inexpensive, especially if replacement coincides with the end of an appliance's useful life, but tackling those appliances used for heating is where the real gains are to be made.

According to Ahmad, Khan, Javaid, Hussain, Abdul, Almogren, Alamri, and Niaz (2017), solar PV household renewable energy systems are the most likely to be installed due to their abundant energy source and low maintenance costs.

2.1 Heating Water

Water, one of the most difficult everyday substances to heat, requires 4.18 kJ to heat one litre by 1°C – compare this to carbon steel which requires only 0.49 kJ to heat one kilogramme by the same amount (Engineering Toolbox, undated). Given the high solar radiation levels in most parts of South Africa (including Gauteng) it follows that the sun should be harnessed for water heating instead of coal-fired grid electricity. Gauteng Province receives an average shortwave solar radiation of around 220 W/m2 (Donev, van Sark, Blok, and Dintchev, 2012) more than twice that received by the UK (100 W/m2) (Burnett, Barbour and Harrison, 2014).

In an attempt to encourage the uptake of solar water heaters (SWHs) the City of Cape Town, circulated a memo (City Energy, undated) showing the possible savings achieved through using a SWH. Assuming an average ambient water temperature of 20°C and a requirement to heat the water to 60°C, the City of Cape Town calculated that a 300 L electric water heater (EWH) would require around 15.5 kWh per day (assuming a usage of 250 L per day and an average standing loss of 3.89 kWh/day).

This is approximately 5 580 kWh annually. Using temperature data from a 300 L system, which only heats water at 17:00 each day (in a household where hot water is primarily consumed at night), the total energy required is 2 790 kWh annually (see Table 1). This suggests that judicious use of hot water and use of a timer on the system can halve energy consumption.

Table 1. Data used to calculate grid energy consumption for a standard electric water heater (EWH)

Temperature increase daily (°C) (from – to)			Delta (°C)	kJ	kWh (daily)	Total kWh (quarterly)
Winter	28	60	32	40 166	11.2	1 004
Spring	35	60	25	31 380	8.7	785
Summer	48	60	12	15 062	4.2	377
Autumn	40	60	20	25 104	7.0	628

Installing a SWH can dramatically reduce consumption of grid electricity. The system assessed here was retrofitted to an existing EWH. If the water temperature in the tank is less than 60°C at 17:00, the system heats the water electrically. In summer, the tank water drops to around 48°C (after use of hot water the previous evening) in the morning and the SWH raises the temperature to over 60°C over the course of the day. Under summer conditions, the system does not draw current from the grid. In winter, the temperature drops to around 28°C in the mornings and is heated to around 48°C by late afternoon. The grid-powered heating element then increases the temperature to 60°C. In spring, the water temperature drops to 35°C and increases to around 50°C. In autumn, it drops to 40°C and increases to around 55°C. In these instances, the element increases the temperature to 60°C. With the SWH, the household draws around 850 kWh from the grid and relies on solar heating for the other 1 945 kWh annually (see Table 2).

Table 2. Data used to calculate grid energy consumption for a solar water heater (SWH)

Temperature increase daily (°C) (from – to)			Delta (°C)	kJ	kWh (daily)	Total kWh (quarterly)
Winter	48	60	12	15 062	4.2	377
Spring	50	60	10	12 552	3.5	314
Summer	60	60	0	0	0.0	0
Autumn	55	60	5	6 276	1.7	157

Using a grid emission factor of 0.94 kg CO_2e/kWh (MAC Consulting, 2013), the SWH option shown in Figure 1 emits 15% of the CO_2e of the always-on, grid powered EWH (796 kg/a versus 5 245 kg/a). If liquified petroleum gas (LPG) is used to heat the water once a day (i.e. 2 790 kWh required annually), the emissions would be even lower than the grid/SWH option presented above: 600 kg/a CO_2e (using an emission factor of 0.215 kg CO_2e/kWh (DEFRA, 2018)).

Figure 1. Energy consumed for heating water: always on (base case) versus timer and solar heating assisted

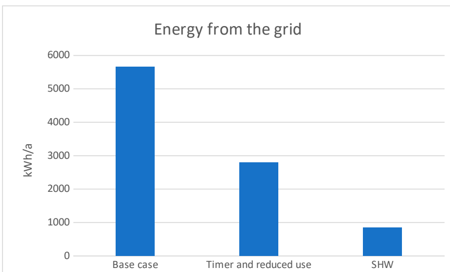


Photo by freestocks.org from Pexels

2.2 Space Heating

In winter, many homes in Johannesburg are heated by electric space heaters. The south-facing house considered here needs heating from May until mid-August. Several parts of Johannesburg have a significant infestation of black wattle (Acacia mearnsii) and, in this case study, the garden (and neighbouring vacant lots) have been cleared of this invasive, alien tree.

The wood is used in a stove for space heating, in combination with electric heating. The woodburning stove has nominal power rating of 4 kW, with a maximum of 9 kW. Typical use (as per the manufacturer3) is 7-8 kW, enough to heat a 135 m2 standard height room.

On a normal winter week day, the stove is lit at around 17:00 and allowed to burn out at around 22:00. Over weekends the stove burns between 14:00 and 22:00. Making some gross approximations, this equates to 108 days of burning, split 5:2 for week days versus weekends. The stove thus generates just over 3 000 kWh/a to heat the house. New stoves are reported to have efficiencies ranging upwards of 75%, but as this one is more than a decade old, an efficiency of 70% is applied, thus requiring a wood energy input of just less than 4 300 kWh.

To check this, wood burned between 5 July and 9 August was measured (no. of burning days = 14). A total of 124 kg of wood was consumed with a daily minimum of 3.5 kg and a maximum of 18 kg (average: 8.9 kg/day). Applying this average to the estimated 108 burning days per year, yields a consumption of 960 kg of wood annually. Assuming an energy content4 of 4.5 kWh/kg, this is equivalent to 4 310 kWh annually, thus tying in with expected stove energy input.

The question then arises: is this better than using electricity from the grid? To provide an answer, the emission factors shown in Table 3 were applied.

Table 3 Emission factors and resulting emissions from a wood burning stove (Transition Culture, 2008; Robinson, 2011)

Gas	Emission factor (kg of CO_2e per kg wood burnt)	Annual emissions (in kg CO_2e)
CO_2	1.9	1 821
N_2O	0.2	192
CH_4	0.07	67
CO	0.38	364

The stove thus emits 2.4 t of CO_2e annually to heat the house. The grid energy used by additional space and underfloor heaters is part of the global house energy consumption figure discussed later.

Is this good or bad? How good is wood as a fuel? Johnson (2009) provides some insight into emissions from various fuel types (Table 4).

Table 4 Unit emissions for various fuels used for space heating (Johnson, 2009).

Emission (kg CO_2e/t)	Charcoal (incl. production emissions)	LPG	Wood
CO_2	3 584	2 928	2 240
CH_4	147	5	138
N_2O	9	1	24
Total	3 741	2 935	2 402

Applying these slightly different factors to the wood loaded into the stove: 0.96 t of wood x 2402 kg CO2e results in 2 306 kg CO_2e—close enough given the approximated input data.

Using a grid emission factor, determined by (MAC Consulting, 2013) for South Africa, of 0.94 t CO_2e/MWh, an electric space heater5 with an output of around 3 000 kWh would generate just under 3 t/a CO2e. An LPG heater: (based on the output kWh) would release nearly 650 kg/a CO2e – LPG has a higher emission rate per unit mass than wood, but one kilogramme of LPG contains about three times more energy than one kilogramme of wood (log wood: 14.7 GJ/t; LPG: 46.3 GJ/t) (Forest Research, 2019).

Comparing a bio-fuel, like wood, to a fossil fuel like LPG is inherently complex. There are a number of arguments around the regenerative capacity of wood and leakage of hydrocarbons into the atmosphere during the production and transport of LPG (Scholes, pers. comm., 2019). There are also land cover change arguments to be considered when using wood from virgin forests and woodlands (Johnson, 2009). These intricacies are beyond the scope of this case study.

2.3 Outdoor cooking emissions

In many South African households, a braai (barbeque) is an important social event. In the case study, a braai is held on average once a week in the warmer weather, starting in September and ending in March – approximately 28 in total. On average 2 kg of charcoal is used and is ignited with 500 g of wood and paper (no chemical firelighters are used). On this basis, approximately 70 kg of charcoal is burned annually. Bhattacharya, Albina and Abdul Salam (2019) provide emission factors for unimproved charcoal cooking stoves. The emissions factors for a mid-range performer (of the stoves assessed by those authors) have been applied here (kg/kg charcoal burnt6) (see Table 5).

Table 5 Emission factors and resulting emissions from charcoal cooking stoves (Bhattacharya et al., 2019).

Gas	Emission factor (kg/kg charcoal burnt)	Emissions (kg/a gas)	Emissions (kg/a CO_2e)
CO_2	2.4360	170.5	170.5
CH_4	0.0078	0.55	15.3
N_2O	0.0003	0.02	5.57
CO	0.1750	12.3	23.3

This is a total of just under 215 kg CO_2e annually.

It is difficult to compare a charcoal braai to other forms of cooking as charcoal needs to burn for some time before it is ready for cooking and then continues to burn after cooking is complete. An LPG barbeque is turned on when needed and off immediately thereafter.Considering the energy content of the charcoal and wood combusted annually in braaing, the process produces around 510 kWh/a. For 30 minutes of effective cooking, we can assume that we first need 30 minutes of burning to produce adequate coals and after cooking, a further 30 minutes are wasted burning down. We can crudely assume that an LPG or electric grill would require around 170 kWh to achieve the same amount of cooking (i.e. 30 minutes).

For an LPG grill, this emits around 37 kg/a of CO2e. An electric grill (connected to the South African grid) would emit around 160 kg/a CO_2e. It thus appears that using charcoal for cooking is a poor choice from a carbon perspective as even a grid-powered grill is a better alternative (see Figure 2).

There are two mitigating aspects to consider: 1) the assumptions used to calculate the charcoal emissions, especially the 1:3 ratio of effective cooking time to total burn, may be conservative—according to Atlantic Consulting (2009), charcoal used for cooking will typically emit three times more CO_2e than LPG grilling (a factor of nearly 6 is reported here); 2) charcoal is (theoretically, at least) a renewable fuel source and so should be more sustainable than either coal or LPG.

2.4 Indoor Cooking

In the case study, a gas hob is used for cooking and it has consumed an average of just over 17 kg of LPG annually over the last decade. Using an emission factor of 2.94 kg CO2e/kg LPG (DEFRA, 2018), stove-top cooking thus emits just over 50 kg CO_2e annually. The oven in this case study is a 4 kW electric unit and so any oven cooking is included in the overall household electricity consumption figure. 17.3 kg of LPG is equivalent to around 240 kWh. An electric stove using this amount of energy would emit just less than 230 kg CO_2e annually.

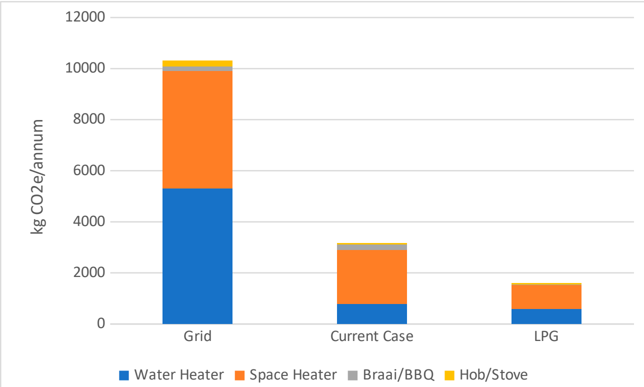


Figure 2 Emissions from household processes amenable to optimisation.

Does this change the overall footprint of the house significantly? The energy consumption base case for the house is 23 140 kWh per annum, sourced from the grid. This results in emissions of just under 22 t of CO2e. Replacing 3 000 kWh of electric space heating reduces the emissions by 720 kg/a but making use of a charcoal braai instead of an electric griller increases it by 55 kg/a. The contributions made by these and other interventions7, can be seen in Figure 3. The photovoltaic (PV) system is a 3.36 kW solar array with an inverter/controller and battery backup. The reduction in carbon emitted is based on the total energy generated by the PV system in 2018 (4 233 kWh). The average sun-hours received in Johannesburg for the period 1961-1990 is reported to be 3,124 (NOAA, 2015). In 2017, Johannesburg received 3 504 sun-hours and in 2018, 3 446 sun-hours (World Weather Online, 2019). Accordingly, it would appear that 2018 was a relatively good year for solar energy generation, but not exceptional.

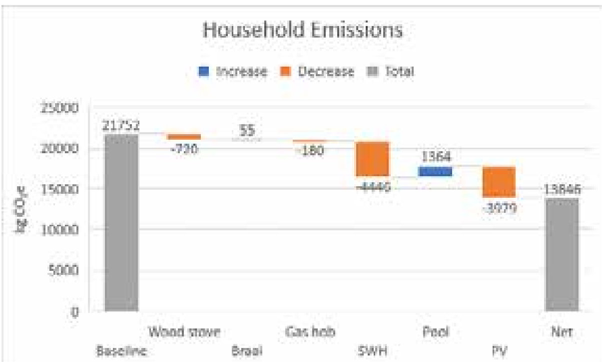


Figure 3 Impact of options on the annual household carbon emissions.

2.5 Transport

In addition to household-related emissions, most people generate CO2e from transport. In this case study, for the decade ending 2017, a distance of 257 000 km was driven using nearly 25 000 L of petrol and 7 700 L of diesel. This resulted in 77.5 t of CO_2e emissions. To reduce this, a petrol vehicle, primarily used for urban commuting, was replaced with an electric vehicle (EV). EVs are not yet able to undertake long journeys between cities, and so the diesel vehicle was retained for this purpose. The EV has an onboard backup generator which can be used to top up the batteries, but in 17 months of operation, it has consumed less than 10 L of petrol and so this can be disregarded. The EV is almost exclusively charged at the case study house and so shares the hybrid grid/PV carbon footprint of the house. The baseline emissions are thus those of the house, plus the petrol and diesel vehicles: 21 800 kg/a + 5 700 kg/a + 2 050 kg/a = 29 550 kg/a (CO2e).

Over the course of 2018, the EV was found to consume a net of 13.9 kWh/100 km. This takes the effect of recuperative braking into account. Applying this to the average distance travelled in the petrol vehicle (19 000 km/a), results in an energy supply requirement of approximately 2 600 kWh/a. if this was supplied exclusively from the grid (with an emission factor of 0.94 kg CO2e/kWh), the resulting emissions would be 2 480 kg/a CO2e – less than half the emissions of the petrol vehicle. Given that the EV is charged at the case study house, the effective emission factor for the house can be applied. The PV system was installed in September, 2017, resulting in a reduced emission factor for the house. This was calculated by applying the grid emission factor to energy supplied from the grid and a zero-emission factor to energy supplied by the PV system, summing the energy and the dividing by the grid-related emissions. The resultant factors are shown in Figure 4 (note the decreasing PV generation in winter results in more grid energy being used).

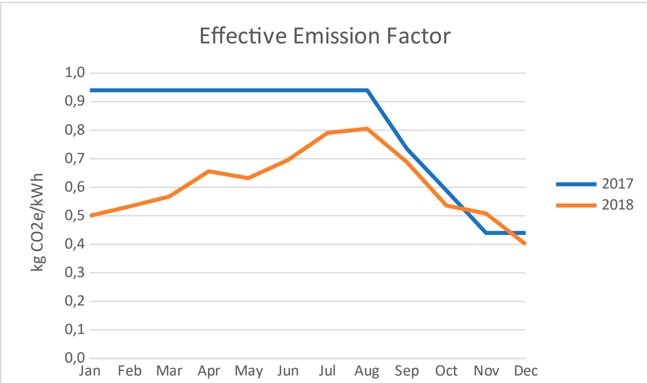


Figure 4 Effective emission factor after the installation of a PV system.

Applying the average 2018 house emission factor, 0.61 kg CO2e/kWh, to the EV energy consumption results in annual emissions of 1 610 kg CO_2e. The reduction in carbon emissions is shown in Figure 5.

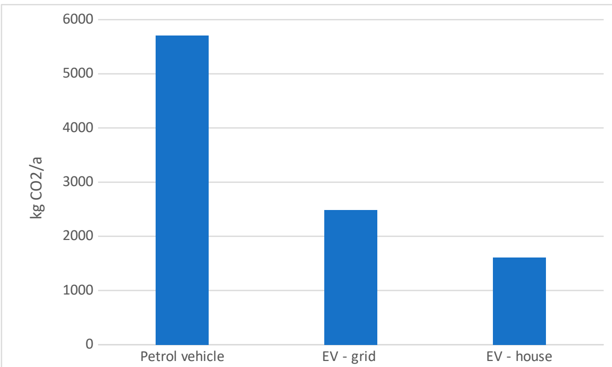


Figure 5 Emissions resulting from a petrol vehicle and EV driven 19,000 km annually.

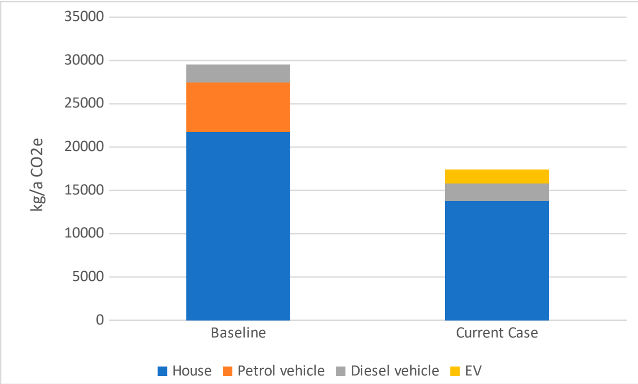
The resulting overall carbon footprint is shown in Figure 6.

Figure 6 Reduction in carbon emissions achieved.

3.0 Discussion

The Climate Action Tracker (2019) reports that South Africa emitted 575 Mt CO_2e in 2016. To meet the most aggressive target of the country's reduction pledge range, annual emissions must be reduced by 160 Mt/a by 2020 (i.e. to a total emission of 415 Mt CO_2e in 2020). The domestic sector is South Africa received 19.1% of electricity supplied in 2006 (Tait & Winkler, 2012). Applying this percentage to the reduction target, the domestic sector needs to reduce its emissions by around 30 Mt/a. The 12 t/a saving achieved for the household described in this paper would thus need to be replicated in 2.5 million households across South Africa. Not all households in South Africa are energy-intensive and so this extrapolation may not be feasible.

Economically, the savings generated through investment in this household PV system do not off-set the costs. A proposed carbon tax in South Africa is currently set at ZAR 120/t (USD 8.75/t)



electricity consumption by approximately 6 200 kWh/a. In 2019, the utility bill for the case study house reflected a charge of ZAR 1.19/kWh (USD 0.09/kWh) for grid power (excluding network and service charges) – an annual savings of ZAR 7 300 (USD 530) in electricity charges, assuming that the house remains connected to the grid after implementing the changes. This is nearly ZAR 150 000 (USD 10 940) over the twenty-year life of the PV and SWH systems, so they almost pay for themselves. Electricity charges in Johannesburg have increased at around 11% annually over the past 12 years, and if this continues, the payback time will shorten, but this analysis is beyond the scope of this paper.

(DEA, 2018), valuing the annual carbon reduction achieved here at around ZAR 1 440 (USD 105) – a payback period of nearly 680 years8. An alternative way of looking at the value of the reduction is to consider the cost of purchasing carbon offsets. An offset currently available for air travel is priced at USD 27.88/t9 (ZAR 390/t). This values the reduction achieved at around ZAR 7 400 (USD 540) annually: a payback period of 208 years. The PV and SWH reduce

It is instructive that nearly twenty years ago, one of the barriers identified to the widespread uptake of solar-based home energy systems was "high first cost and affordability" (Martinot, Chaurey, Lew, Moreira, and Wamukonya, 2002).

4.0 Conclusion

It is possible to reduce carbon emissions at a personal level with little or no impact on lifestyle. An impediment to this improvement is the cost associated with the technologies that are required.

This case study shows that switching from electrical heating appliances to LPG appliances is probably the cheapest and most effective intervention that can be made to reduce carbon emissions at a household level. The carbon emissions associated with LPG heating are consistently lower than the hybrid solar/grid options assessed (although, in the case study, LPG is delivered in bottles and transport emissions have not been included in the analysis). LPG is derived from fossil fuels and is therefore less sustainable than solar power, despite its clear advantage over the grid-solar hybrid system in terms of emissions. In countries with lower grid emission factors, a grid-solar hybrid may have lower emissions than LPG. It must also be stressed that any leakages in the LPG transport/storage systems could erode the relative advantage of this energy source. An analysis of this (and potential health impacts of indoor gas burning) is beyond the scope of this paper.

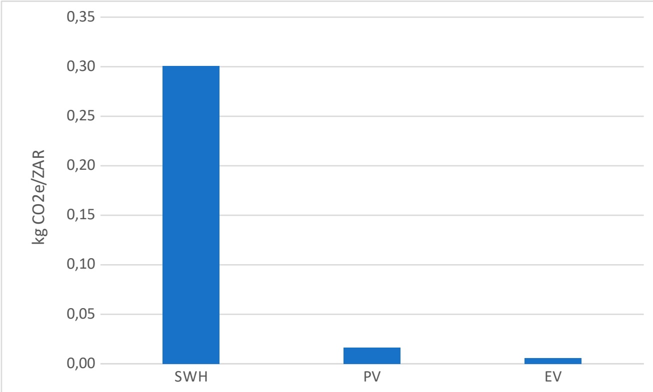


Figure 7 Mass of annual carbon emission by spending ZAR 1.00 (USD 0.07).

Of the interventions made, the solar water heater is the best value for money with a cost of R3.33/kg CO_2e/a (0.24 USD/kg CO_2e/a) (see Figure 7). This is clearly the most sensible intervention to be made and all homes in South Africa, especially in the sunny interior, should have one. The photovoltaic system and the electric vehicle allow further reductions to be made, but until the costs associated with these technologies reduce drastically, they will remain beyond the reach of most and unjustifiable for the remainder.

Photo by Vivint Solar from Pexels

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- 1 Tonnes of CO2e, or carbon dioxide equivalent, is a convenient way of reporting net global warming potential. The net climate forcing effect of each of the gases emitted to the atmosphere by human processes is related to the forcing effect of CO_2. The emitted mass of gas is thus multiplied by its forcing factor: CO_2 has a factor of 1; methane (CH_4), a factor of 28; nitrous oxide (N_2O) a factor of 265. There are a number of other gases that may be included, but these are the most significant emissions from a household perspective (see IPCC (2013) for more details).
- 2 Saudi Arabia has an emission factor of 0.65 t CO_2e/MWh (CDM, undated) while South Africa's is 0.94 (MAC Consulting, 2013).
- 3 This is a Morsø 1710 stove.
- 4 The Sustainable Energy Development Office (SEDO), part of the Government of Western Australia states that the energy content of wood is 16.2 MJ/kg (4.5 kWh/kg) (Akinola & Fapetu, 2015) – wood from Australian trees (black wattle) is generally used in the stove considered here.
- 5 Electric space heaters and LPG heaters are considered 100% efficient – they convert all of the energy supplied in to heat (CSE, 2013).
- 6 Note: these are kilogrammes of the actual gas, not CO_2e as in the previous calculation.
- 7 A swimming pool with two pumps, 0.75 kW and 1.1 kW was installed. The first is run for an average of 5 hours daily and the second for around 10 minutes.
- 8 Based on a capital investment of approximately ZAR 980 000 (USD 71 500) for the SWH, PV and EV.
- 9 Based on the offset cost for a return flight from Johannesburg to Cape Town (My Climate, undated).

WASTE

Fibre Circle
PRODUCER RESPONSIBILITY ORGANISATION

Paper. A natural fit for the circular economy and greener packaging.

Paper has a fascinating history. Developed centuries ago, it has been through the mill—literally and figuratively—in terms of how it is made. There are also many interesting side stories: one that often goes untold is how paper actually stores carbon, making paper, and the wood it comes from, good for the planet.

"Nobel Prize-winning physicist Richard Feynman said that trees don't grow from the ground, they grow from the air," says Jane Molony, acting CEO of Fibre Circle, the producer responsibility organisation for the South African paper and paper packaging sector.

Many of us first learned about photosynthesis in primary school: how plants absorb sunlight and carbon dioxide (CO_2) to make food. Trees take in CO2 from the air, and water from the ground—which also came from the air at some point—and convert this into growth (trunks, roots and leaves). Oxygen is returned to the atmosphere. This carbon cycle is why trees of all kinds are such a vital part of keeping our planet regulated, offsetting greenhouse gas emissions and mitigating climate change.

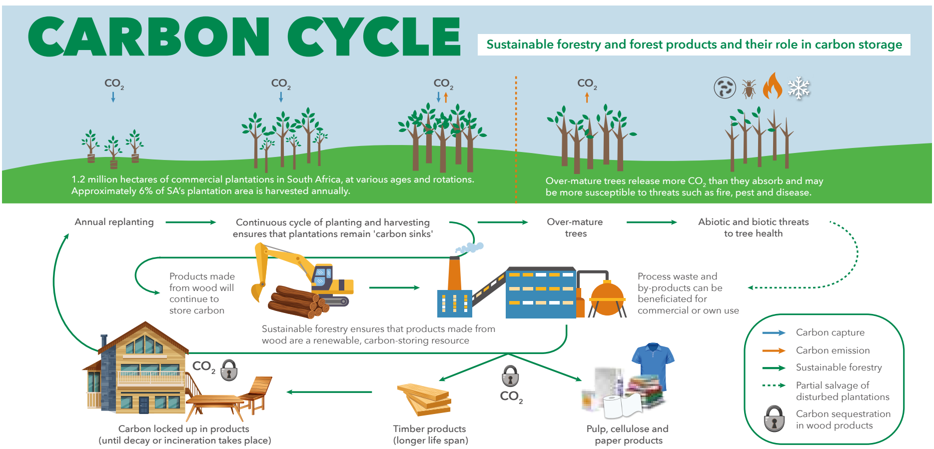
It is also why sustainably produced harvested wood products—like paper—are a greener option.

"In South Africa, trees can be divided into two groups—indigenous trees in natural forests and commercially farmed trees in plantations. The latter were introduced some 100 years ago to protect natural forests, by providing wood for industrial purposes such as building and fuel," says Molony.

Essentially, plantation trees are crops; planted and replenished in rotations, with only 9% of the total tree count being harvested in any given year. This means that there are always trees growing, at different stages of maturity, and these trees are contributing to the carbon cycle, not to mention the economy and the livelihoods of thousands of people.

Even when planted trees are harvested for their wood—for construction or for paper, packaging and tissue—the carbon remains locked up in the wood fibres and stays there for the lifecycle of those products.

It's just one of the reasons paper recycling is important—it keeps the carbon locked up longer.



Innovative and technological waste management practices: The awareness of Joe Slovo Township residents

Sibongangani Mngomezulu, Ayo Adeniran, Sijekula Mbanga and Winston Shakantu

1.0 Introduction

The modern urban world is currently faced with the challenge on how to offer basic infrastructure to its rapidly growing population while reducing waste management problems. Bundhoo (2018) disclosed that in most developing countries, the efficiency of waste collection and disposal remains deplorably low despite the daily increase in the production of waste. Ukoje (2016) argued that waste management in metropolitan regions is critical since the majority of waste created in these locations is typically transported to the urban-fringe, low-income, and rural areas for disposal, and this comes with disastrous long-term consequences. Bras et al. (2009) observed a significant difference in waste practice between low, middle and upper income groups in Port-au-Prince, the capital city of Haiti, which is the poorest country of the Caribbean and reported that about eighty-eight per cent of low income households eliminates their waste on roadsides, rivers and other open spaces in the city, resulting in significant environmental and health problems.

Horn (2020) claimed that this global challenge is particularly acute in cities of the global South, where low-income dwellers typically reside in unserved or underserved communities which are usually in the periphery of the urban areas. Rasmeni and Madyira (2019) recorded that municipal solid waste management is a serious environmental problem in South Africa's growing city townships, and the incorrect waste management endangers residents. Various studies such as Association for Water and Rural Development, AWARD, (2019) and Nyika and Onyari (2021) reveal that about 90 per cent of MSW is disposed of in open dumps and landfills and lack of access to basic services such as sewage and refuse removal and running water are common problems in South African townships. In the same vein, Scarlat et al. (2015) indicated that in the whole of Africa, less than half of the solid waste generated is collected in urban centres and 95 per cent such collected waste is neither reused nor recycled but disposed at dumping sites polluting the air and nearby water sources. Waste-to-energy plants, on the other hand, will greatly contribute to achieving the goals of waste management, sustainable development, and environmental protection by reducing greenhouse gas emissions and conserving resources (Monni et al., 2006).

At first glance, the introduction of innovative technologies may appear to be a solution for the global provision of standardized access to sustainable services because it allows the extension of basic infrastructure to urban populations located in inaccessible parts of the city without significant increases in emissions; for providers, it facilitates service-delivery at the highly localised scale typically required in low-income settlements; while for low-income households, it offers financial savings and immediate access to services that can meet growing demand (Simelane and Mohee, 2012). This paper is motivated by this and hence sought to evaluate the awareness of inhabitants of Joe Slovo Township, Port Elizabeth, South Africa on innovative waste management practices.

The paper begins by introducing and exploring works of waste literature as well as the theoretical underpinnings of innovative waste management systems. This is followed by the research methodology and case study contexts, which employ quantitative data to investigate residents' awareness of novel waste management technology. The case study, Joe Slovo Township, is a low-income housing community where the rapid demographic expansion outweighs service provision.

2.0 Municipal solid waste management

This section will deal with literature on waste types, disposal, zero waste and innovation and technology in waste management practice.

Municipal solid Waste Management (MSWM) systems typically comprise the collection, transportation, processing, disposal and monitoring of waste materials produced by human activity so as to prevent or reduce their negative effects on health and the environment (Adeniran, Adewole and Olofa, 2014). Amo-Asamoah et al. (2020) highlighted that classification of waste is vital as it enhances the processing technique which will be employed by stakeholders and Gandy (2014) argued that collection of waste by its type is a basis for proper waste management which could aid recycling. It is, hence, important that for innovative and technology aided waste management system, waste separation at source must done and stored separately for each waste typology (Akon-Yamga et al., 2021).

The Basel Convention categorised waste into two main namely hazardous and non-hazardous or solid waste (See Figure 1) (Awasthi, Li, Koh and Ogunseitan, 2019). Hazardous waste is generally regulated at the national level, while non-hazardous is the mandate of the regional and or municipal government (Kollikkathara, Feng and Stern, 2009).

Figure 1: Waste Types - Adapted from the Basel convention

Table 1: Types of waste and their sources

Table 1: Types of waste and their sources

Types	Sources
Glass	Bottles, broken glassware, light bulbs, coloured glass
Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles
Organic	Food scraps, yard (leaves, grass, brush) waste, wood, process residues
Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, telephone books, shredded paper, paper beverage cups. (*Strictly speaking paper is organic but unless it is contaminated by food residue, paper is not classified as organic).*
Plastic	Bottles, packaging, containers, bags, lids, cups
Other	Textiles, leather, rubber, multi-laminates, e-waste, appliances, ash, other inert materials

Source: Hoornweg and Bhada-Tata (2012).

The focus of this paper is on municipal solid waste and the composition of such waste and their sources as identified by Hoornweg and Bhada-Tata (2012) is presented in Table 1.

As observed by Stoeva and Alriksson (2017), households in developing countries lack proper conditions for waste separation and they lump all of it together. Bharadwaj, Rego and Chowdhury (2017) specified that collection of waste is by means of municipal trucks or their appointed waste company and if not collected, Friedrich and Trois (2011) observed that although prohibited, the practice of, illegal dumping, littering and open burning of waste is practiced in developing countries. Also, over 90 per cent of the collected waste is however disposed to landfill sites as documented by AWARD (2019).

The South African Waste Information Centre (SAWIC, 2015) listed thirteen pieces of legislation as currently governing waste in the country and the most recent of which is the National Environmental Management: Waste Amendment Act, 2014 (NEWMA) (Act 26 of 2014). The Act encourages the adoption of waste reduction techniques to ensure that such waste is reused, recycled and recovered in an environmentally sound manner before being safely treated and disposed of (Department of Environment, Forestry and Fisheries, DEFF, 2020). A waste management hierarchy which is embedded in the national policy and presents a list of waste management approaches for solid waste, explicitly indicating the most environmentally preferred approach with waste reduction, reuse, recycling, and recovery as the best waste management practices while the disposal of waste at landfill sites is the least preferred option (Adeleke, Akinlabi, Jen and Dunmade, 2021). The NEMWA Act also specifies institutional and planning matters, as well as the licensing and control of waste management activities and issues of environmental management compliance and enforcement (Mohale, 2021).

Municipalities are required under NEMWA to exert executive responsibility in delivering waste management services such as garbage removal, waste storage, and waste disposal while assuring access to such services for all communities. To give effect to the implementation of NEMWA, a number of mechanisms which include norms and standards, integrated waste management plans, industry waste management plans, extended producer responsibilities, and priority wastes have been introduced with the National Waste Management Strategy (NWMS) (Department of Environmental Affairs, DEA, 2011). Strydom and Godfrey (2016) however observed that not much had been achieved with regards to waste management as the challenge keeps growing.

Shekdar (2009) observed that solid waste management has been an integral part of every human society. The revolution of solid waste management now involves waste technologies which are more energy-efficient as well as protective of human health and the environment (Weitz et al., 2002). Shekdar (2009) asserted that sustainable solid waste management involves 3Rs (reduce, re-use and recycle) while Olukanni and Oresanya (2018) indicated that it is 4Rs to include recover energy. This will be discussed in the next section.

3.0 Theoretical underpinning

The theoretical underpinning for this study is based on the waste management hierarchy, which is an internationally recognised guide for waste management methods with the goal of deriving maximum benefits from products before they are disposed while minimizing negative environmental impacts (Dlamini, Rampedi and Ifegbesan, 2017). The waste management hierarchy depicted in Figure 2 includes five waste management categories: prevention-reuse, recycling, waste treatment, energy recovery, and disposal (DEFF, 2020). The following are brief descriptions of the waste hierarchy's primary components:

(a) Waste Prevention: Waste prevention measures include using less packaging and repurposing products and materials.

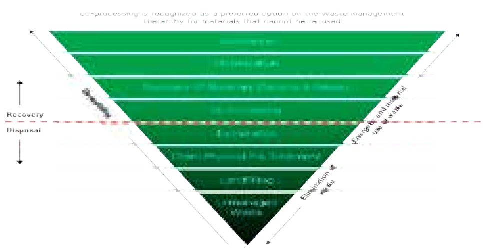


Figure 2: Waste management hierarchy (Source:)

(b) Recycling and composting entail the collection, reprocessing, and recovery of waste materials in order to create new materials.

(c) Waste Disposal (land filling and combustion): These actions are employed to dispose of garbage that cannot be avoided or recycled. Landfills that are properly built and equipped with existing technology can be used to create electricity by extracting methane (Nanda and Berruti, 2021).

4.0 Research methodology

The population of the study area was estimated to be around 6,500 households, and the study used Krejcie and Morgan (1970) and Smith's (2013) approach to arrive at an acceptable sample of 361 possible research participants from the case study. With 95 per cent confidence level and using random sampling, the opinions of the three hundred responding households out of the three hundred and sixty one households approached during the physical questionnaire administration were retrieved with the 5-point Likert Scale questions. The Likert type Scale was chosen as the ideal scaling system for suitable statements / questions since it allows for the usage of concealed attitudes and produces a very trustworthy scale (Abdullah, Razak & Pakir, 2011). Ethical clearance was received for the study which was carried out in 2019 from the Nelson Mandela University. The questions sought to identify the education level of the respondents, the items of waste generated by them, their ranking of waste disposal methods and their awareness around innovative and technological waste management practices. Some of the respondents did not respond to all the questions posed to them hence the data was cleaned after coding and subjected to statistical analysis for the frequency and mean scores using Statistical Package for Social Sciences (SPSS V21 for windows), and the results and findings are provided in a variety of formats including text, tables, and charts.

5.0 Description of the Study Area

Joe Slovo township, the area under consideration is situated 25 Kilometres away from Gqeberha (Port Elizabeth), CBD. The township which is halfway between Uitenhage and Gqeberha is a Mecca of sorts attracting new populations of people migrating from the nearby rural areas in the hope of finding a better life in the city. Joe Slovo , from this vantage point, can be viewed as a transitional space toward absorption into the metropolitan system. The township's continual and rapid growth is overwhelming the municipality, and as a result, the township faces a variety of issues, including solid waste management. The area is made up of low-income inhabitants with heavy reliance on government subsidies and grants to survive (Guérin et al., 2015).

Department of Human Settlement (2017) documented that Joe Slovo is in Ward 41 and the RDP houses built in this area are the component of the Zanemvula Megaprojects which was created in 1995 and started as informal settlements used as a reception project accommodating residents from Veeplass, Soweto on Sea and other flood plain areas. The area has however grown over the past 25 years from informal settlement to semi-formal settlements and currently has more RDP houses than informal housing structures. The township has 4 sections named Phase 1, Phase 2, Phase 3 and Phase 4 or Hillside. This location started with 1942 RDP houses, but now it has 6500 housing units. Phase 1 to 3 has a total of 2500 housing-units, and Phase 4 (Hillside) has a total of 4000 housing-units. Figure 3 illustrates the spatial location of Joe Slovo Township in Gqeberha, within the Nelson Mandela Bay Metropole.

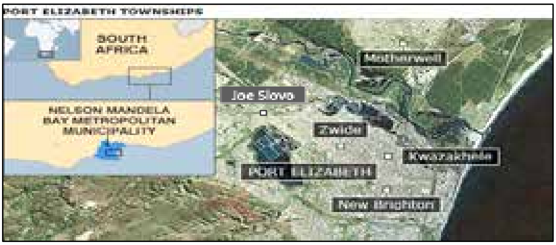
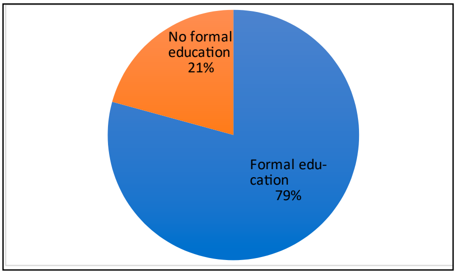


Figure 3: Gqeberha *(Port Elizabeth) Townships showing the location of Joe Slovo Source:* Straton, 2016/BBC:Online.

6.0 Findings and Discussions

6.1 Education level of respondents

The empirical findings in Figure 4 revealed that of the 276 that respondent to this question, two hundred and eighteen representing 79 per cent have no formal



education (i.e. did not attend school at all) and it has been observed by Guérin et al. (2015) that

Joe Slovo is inhabited by poor and low-income groups who rely on government support for survival and that their focus is on earning an income to survive, and they do not see the value of acquiring skills and education. Peerson and Saunders (2009) also opined that literacy skills among adults in developing countries are generally below average.

[**Figure 4: Education status of the respondents**

6.2 Frequency of generation of items of solid waste by the inhabitants

The respondents' were asked to indicate the frequency of their generation of waste materials and the result of the descriptive statistics is presented Figure 5. Two hundred and thirty-four (234) respondents indicated that they never had food remains as waste and this can be as a result of the income level of the respondents. in terms of waste polythene bags and other plastic materials, one hundred and fifty (150) respondents revealed that they never generated such waste.. Figure 5 further showed that ninety (90) respondents indicated that they never generated newspaper and other waste papers and with regard to old clothes, two hundred and forty (240) respondents disclosed that they never have old clothes as part of the waste.

The results further portrayed that one hundred and fifteen (115) the respondents never produce waste bottles while one hundred and seventy-nine (179) respondents indicated that they sometimes generate waste cans and other metals.Furthermore, one hundred and ninety-five (195) respondents indicated that they never generated human waste/pampers and regarding household's hazardous waste, two hundred and seventy-six (276) respondents indicated that they never generate this waste item. Lastly, two hundred and ninety-five (295) respondents indicated never to produce old appliances.

The literature reveals that municipal solid waste includes recyclable wastes, food wastes, garden wastes, hazardous wastes and others (Nelson Mandela Bay Municipality- Integrated Waste Management Plan, NMBM IWMP, 2016). Although with varying generation frequencies, the identified wastes, as indicated by the respondents are cans and other metals, newspaper, bottles and plastic materials in order of ranking. This finding validates Joel and Fansen (2013) who opined that although waste composition differs from place to place and for different income groups, the bulk of the waste generated by inhabitants in developing countries is recyclable and can therefore bring an economic benefit, particularly for low-income groups. However, the findings of this study contradict the observation of Sujauddin, Huda and Hoque, (2008) that in the composition of waste, food remains usually high. This contradiction can be adduced to the general income level of the inhabitants of Joe Slovo . This finding suggested that the type of waste generated could be a function of income level.

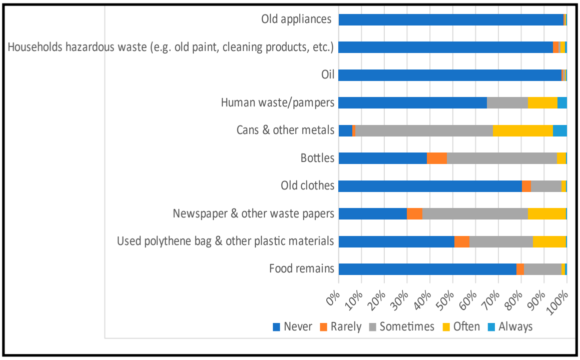


Figure 5: Type of solid waste generated by the inhabitants

6.3 Ranking of waste disposal methods

A supplementary analysis of the ranking of the types of waste disposal methods used by

Table 2: Ranking of waste disposal methods

Waste Disposal	Ranking	N	Mean	Median	Std. Deviation
Municipal waste trucks	1	300	3,55	3,00	0,982
Empty plots	2	300	1,68	1,00	1,010
Recycling facilities	3	295	1,03	1,00	0,278
Community bins or municipal drums	4	296	1,03	1,00	0,200
Landfill sites	5	299	1,02	1,00	0,200
Abandoned houses	6	300	1,00	1,00	0,000

Source: Researcher's analysis of data, 2019

inhabitants, as shown in Table 2 demonstrated that the respondents indicated that the commonly used method of disposal is by disposing waste in the municipal waste truck.

This has a mean value of 3.55, and it ranks at number one (1). However, the other disposal means all have mean values of below two (2), with disposing of waste in abandoned houses ranking the least, with a mean value of 1.00.

The present study was designed to identify the methods that respondents use for waste disposal, and the respondents stated that they do so primarily via municipal waste trucks.

The work of Ogola, Chimuka and Tshivhase (2011 specified that collection of waste is by means of municipal trucks the finding implies that the municipal infrastructure is essential for the waste disposal and management system.

The bulk of the waste generated by inhabitants in developing countries is recyclable and can therefore bring an economic benefit

6.4 Awareness of the Community on Innovative and Technological Waste Management Practices

Table 3 illustrates the awareness of communities on innovative and technological waste management practices. The findings show that the majority of the one hundred and seven (36.1 per cent) respondents disclosed that they have very poor knowledge regarding recycling and ninety-two (31.1 per cent) of the respondents have a poor understanding of

Table 3: Awareness of the community on innovative and technological waste management practices

Waste Disposal	Ranking	N	Mean	Median	Std. Deviation
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Abandoned houses	6	300	1,00	1,00	0,000

Source: Researcher's analysis of data, 2019

recycling, as an innovative method of improving waste technology and services. Seventy-six (25.7 per cent) of the respondents indicated that they have a fair knowledge of recycling as waste innovation. Eighteen (6.1 per cent) of the respondents revealed that they have a good understanding of waste innovation and technology and only three (1 per cent) of the respondents indicated that they have excellent knowledge of recycling as a solid waste management practice.

One hundred and twelve (37.8 per cent) of the respondents disclosed that they have very poor knowledge on reuse which is part of innovative and technological waste management practices and ninety-one (30.7 per cent) respondents indicated that they have a poor understanding of the term reuse as used for innovative and technology practices for effective waste management. Seventy-one (24 per cent) of the respondents indicated that they a have fair knowledge of reuse as a waste management practice. Eighteen (6.1 per cent) of the respondents revealed that they have a good understanding of reuse as waste innovation and improvement of technology and only four (1.4 per cent) of the respondents indicated that they have excellent knowledge of reuse as solid waste management practice.

Furthermore, the results indicated that one hundred and sixty-three (55.1 per cent) of the respondents disclosed that they have very poor knowledge regarding reducing which is an essential part of waste management practice, whereas eighty-two (27.7 per cent) respondents revealed that they have a poor understanding of the term reduce used in regard to the practise of waste management and thirty-eight (12.8 per cent) of the respondents indicated that they have fair knowledge regarding reducing as a waste management practise. Eleven (3.7 per cent) of the respondents revealed that they have a good understanding of reducing as waste innovation and technological improvement, the minority two (0.7 per cent) respondents indicated that they have excellent knowledge of reducing as a process applied to solid waste management practice.

Lastly, the survey revealed that two hundred fifty (84.5 per cent) of the respondents disclosed that they have very poor knowledge on recovering energy, which is part of waste management practice and twenty-eight (9.5 per cent) respondents revealed that they have a poor understanding regarding how recovered energy can be used in the practice of waste management. Seventeen (5.7 per cent) of the respondents indicated that they have a fair knowledge of recovering energy as a waste management practice. Only one (0.3 per cent) of the respondents revealed that they have a good understanding of the recovering of energy and no respondents indicated that they have excellent knowledge on recovering of energy as a waste innovation and a technological practice for optimal solid waste management.

An additional analysis ranked the awareness of the community on innovative and technological waste management practices.

The findings shown in Table 3 illustrated that respondents have a poor knowledge regarding innovative and technological waste management practices using recovery of energy, scoring the lo mean of 1.22 and recycling scoring the highest mean score of 2.05. This result supports Sinthumule and Mkumbuzi (2019) who observed that there is a lack of awareness and/or knowledge regarding waste technology. The indication of the results is that there is a need for mass education and awareness on these issues.

7.0 Conclusion and recommendations

The residents of Joe Slovo township generally are not aware of the innovative and technological practices of reducing, reusing, recovery and recycling of energy from waste. This study hence recommends the need for formal education and literacy programmes in the study area. This should be geared towards enhancing adequate public awareness as well as the encouragement of community participation in the planning and implementation of solid waste management programs. In addition, this will help increase the citizens awareness on environmental and waste-related issues. It is also recommended that while the public and private sectors complement their efforts by ensuring adequate collection, safe and effective transportation, recycling, and disposing of wastes, the structures for the implementation of the concepts Reduce, Reuse, Recycle and Recover energy should be instituted.

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Barriers to closing the loop on nutrient recycling–a case study on phycoremediation of domestic wastewater in South Africa

Maronel Steyn and Paul Oberholzer

1.0 Introduction

In 2015, the United Nations published the 2030 Agenda for Sustainable Development. Achieving the 17 Sustainable Development Goals (SDGs) would guarantee a balance between environmental, economic, and social aspects of development. Sustainable Development Goal (SDG) 6 not only focuses on drinking water and basic sanitation, but also includes the sustainable management of water, wastewater, and ecosystems. This goal specifically focuses on the essential role of water in addressing those challenges (e.g., poverty, education, and health) linked to water scarcity, water pollution, degraded water-related ecosystems, and cooperation over transboundary water basins (UNEP 2018b; United Nations 2020; UNEP, 2021; UN-Water, 2021). As part of SDG6, specific goals / targets have been identified to achieve sustainable development. One such goal (Target 6.3 of SDG 6) is to half the proportion of untreated wastewater released into water bodies globally (UN-Habitat and WHO, 2021). According to UN-Water (2021), an estimated 44% of household wastewater is not treated by secondary or higher treatment processes or treated to meet the relevant effluent guidelines or standards globally.

Africa's sanitation and wastewater infrastructure challenges are exacerbated by uncontrolled population growth and urban migration. While 38% of the African population is currently living in urban areas, rates of urbanisation growth are highest in Sub-Saharan Africa (5.8%) and predicted to double by 2030 (Bahri, 2007). Over 63% of South Africans are already living in urban areas (PMG, 2020). This implies that the existing sanitation and wastewater treatment and management challenges will likely also increase, giving rise to additional water security challenges. Given this reality, the World Bank in 2018 launched an initiative that called for a paradigm shift towards the circular economy, where wastewater is increasingly viewed as a valuable resource instead of a waste product. Figure 1 depicts how sustainable wastewater management can allow for resource recovery in the form of energy, reusable water, biosolids and nutrients, adding to economic benefits.

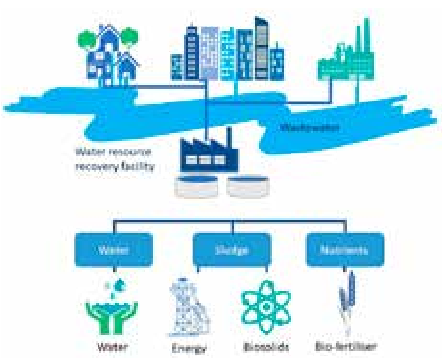

FIGURE 1

Figure 1: Economic benefits from resource recovery resulting from sustainable wastewater management (adapted from Rodriguez et al., 2020).

In addition to the great potential to close the nutrient recycling loop, the circular economy can support cost recovery within the waste sector and can even help to create viable businesses. Nutrient recovery from organic waste streams is high on the development agenda and is also of great importance in view of diminishing non-renewable resources, such as phosphorus (Shaddel et al., 2019; Renuka et al., 2021). Furthermore, nutrient recovery from domestic wastewater extends beyond direct economic benefits to that of ecosystem and human health benefits. Following biological treatment or physicochemical separation, phycoremediation is one of the main practiced routes for capturing nutrients from wastewater (Shaddel et al., 2019) and provides an alternative low-cost green solution to nutrient recovery from wastewater streams in developing countries (Oberholster et al., 2019; Oberholster et al., 2021).

The use of algae for the removal of nutrients is not a new phenomenon and was first described in 1953 by Oswald and co-authors. Olguin, in 2003, described phycoremediation as "the process whereby macroalgae or microalgae bio-transforms or remove pollutants, including nutrients and xenobiotics, from wastewater and carbon dioxide (CO_2) from waste air". Internationally, phycoremediation has been successfully applied to different industrial wastewaters for example sugar processing effluent (Sailaja and Meti, 2014; Zewdie and Ali, 2020), paper and pulp effluent (Sasi et al., 2020), tannery waste (Hanumantha et al., 2011), and distillery effluent (Khrisnamoorthy et al., 2019). Similarly, phycoremediation has reportedly successfully decreased or eliminated heavy metal content of wastewaters (Kwarciak-Kozłowska et al., 2014; Koul et al., 2021), reduced antibiotic resistance (Michelon et al., 2021) and absorbed other emerging contaminants (e.g., endocrine disrupting chemicals, Personal care products and pesticides) (Gupta et al., 2015).

The photoautotrophic nature of the algae, which allow them to use CO_2 as their carbon source (Guldhe et al., 2015), makes phycoremediation an attractive low-cost alternative solution as the addition of an organic carbon source is not needed (Rao et al., 2011; Koul et al., 2021). The nutrients, phosphorous and nitrogen, which are readily available in domestic wastewater are essential for the growth of algae (Emparan et al., 2018; Bansal et al., 2018; Goswami et al., 2021; Koul et al., 2021). To date, various microalgae species (e.g., ***Chlorella*** spp. and ***Scenedesmus*** spp.) have been described to successfully remove nutrients from wastewater by several authors (Bansal et al., 2018; Queiroz et al., 2007; Rao et al., 2011; Renuka et al., 2021;). These species have high nutrient removal capabilities combined with a fast growth rate, making them good candidates to treat wastewater. At the same time, due to their high capacity for inorganic nutrient uptake (Bolan et al., 2004; den Haan et al., 2016) microalgae could produce potentially valuable biomass (Al-Jabri et al., 2021). Some of the multiple benefits that can be derived from microalgae biomass include amongst others, biofuel (Alam et al., 2012; Hannon et al., 2010), biogas (Debowski et al., 2013), and biofertilizer (Baweja et al., 2019; Guo et al., 2020). Since microalgae contains valuable compounds (e.g., fatty acids, and proteins), Fernandez et al., (2018) highlighted the increasing importance of microalgae for agriculture and animal feed (Saadaoui, et al., 2021).

Figure 2 provides a simplified process flow diagram for the circular movement of nutrients resulting from phycoremediation. Green microalgae are introduced into the domestic wastewater whereby it improves the domestic effluent through the uptake of nutrients (nitrates and phosphates) from the wastewater. The improved domestic wastewater effluent is subsequently used for irrigation of agricultural crops (pending general and special effluent and reuse standards). Simultaneously, the green microalgae biomass cultivated in the domestic wastewater can be harvested and subsequently (pending quality, quantity, and a risk assessment) be used for products such as biofertilizer or animal feed. In turn, the nutrients from the crops produced or animals that were fed, would again reach domestic wastewater via agricultural waste and surface waters.

FIGURE 2

Figure 2: A simplified process flow diagram showing the circular movement of nutrients resulting from phycoremediation of domestic wastewater.

The use of phycoremediation as treatment method is gradually increasing globally (Sivasubramanian, 2016; Priyadharshini et al., 2021) but are often implemented as highly technically advanced treatment facilities with controlled environments and dedicated, specifically designed and built infrastructure, such as the high-rate algal ponds (Van der Merwe and Brink, 2018). Back in 1996 already, the Belmont Valley WWTW in Grahamstown, South Africa first introduced phycoremediation in combination with wastewater treatment in what is known as an integrated algae pond system (IAPS) (Momba et al., 2014). This system has been operating for several years and while also incorporated with the wastewater treatment, it makes use of much more technical advances and dedicated infrastructure (Momba et al., 2014).

For the current study, phycoremediation was instead acknowledged and implemented with the main aim to: 1) introduce a self-sustaining system that could operate within the existing municipal wastewater infrastructure, 2) would be cost-effective to implement and maintain, 3) would increase the lifespan of the existing waste stabilisation pond system in rural areas, 4) needed to operate without any electricity, and 5) to improve ecosystem services by removing some of the nutrients (nitrates and phosphates) responsible for widespread eutrophication in the surface waters of our country.

Phycoremediation was first implemented at Motetema WWTW in the Sekhukhune District of Limpopo Province of South Africa in 2016 (Engineering News, 2016; Oberholster et al., 2017) and thereafter in 2017 at Brandwacht WWTW in the Western Cape Province (Mossel Bay Advertiser, 2018; Oberholster et al., 2021). Phycoremediation was implemented as part of the daily operation of these waste stabilisation pond wastewater treatment systems in South Africa, making use of existing infrastructure.

The aim of this paper is to 1) describe the phycoremediation process that has been implemented at the Brandwacht WWTW in the Western Cape, 2) explain the main findings of the research done to date in relation to closing the nutrient loop, and 3) to highlight the main barriers and learning associated with implementing the phycoremediation technology at domestic wastewater treatment plants in South Africa, as these are often not discussed in literature.

2.0 Methodology

2.1 Study site

Brandwacht is a small rural community close to the towns of Friemersheim and Great Brak within the Garden Route District of the Western Cape Province of South Africa. The Brandwacht community consists of 1 470 people living in 398 houses. Just under half of the community have access to safe piped drinking water. More than 88% of the community have access to flush toilets and 96.7% have electricity. Only 1.8% of the community has a tertiary education (Stats SA, 2017).

Phycoremediation has been implemented as part of the everyday treatment and operation at the Brandwacht wastewater treatment works (WWTW) since March 2017. Brandwacht WWTW (34.0493°S and 22.0573°E) is categorised as a micro-sized treatment works as it treats up to 0.5 Mℓ of domestic wastewater daily. The Brandwacht WWTW consists of 7 gravity-fed ponds and is managed by the Mossel Bay local municipality (Figure 3).

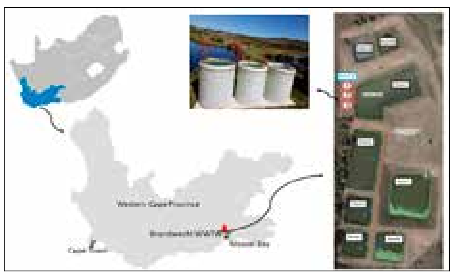

FIGURE 3

[**Figure 3: Location map of Brandwacht Wastewater Treatment Works in Brandwag. The WWTW is managed by the Mossel Bay local municipality. The Google Earth image of the Brandwacht WWTW shows the 7 ponds and indicates the three bioreactor tanks (1- 3) as well as the pipeline to dose Pond 3 – Pond 6 with algae.**

2.2. Phycoremediation technology implementation

2.2.1 Algae selection

Following a literature review (Barros, et al., 2015; Martínez, 2016; Zhu et al., 2018) and laboratory scale studies (Oberholster et al., 2017; Oberholster et al., 2021), it was found that a consortium of the microalgae *Chlorella protothecoides* and *Chlorella vulgaris* (Figure 4) had (1) the potential to take up maximum phosphates (b) the fastest exponential growth rates, and (c) can grow at the largest temperature range. The latter species were mass cultured and inoculated at the wastewater treatment works as part of the field study. Before and after introduction of these cultured microalgae species at the wastewater treatment works, natural algal species were closely evaluated and changes after inoculation, monitored (Oberholster et al., 2017; Oberholster et al., 2021).

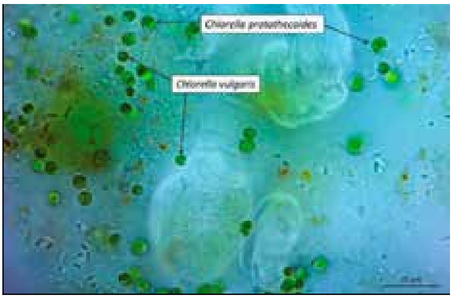

FIGURE 4

Figure 4: Microscope image (600X magnification) of the inoculated algae, *Chlorella protothecoides* **and** *Chlorella vulgaris***.**

Oberholster et al. (2021) recently published the changes in the algae assemblages before and one year after mass inoculation of the selected algae consortium at Brandwacht WWTW. The dominant natural algae before introducing the consortium of algae to the final effluent pond at Brandwacht changed from *Microcystis aeruginosa* (40%) and *Micractinium pussillum* (24%) to *Clorellaprotothecoides* (52%) and *Chlorella vulgaris* (36%). Continuous dosing of the maturation ponds waste ponds with the cultivated microalgae, allowed the *Chlorella* spp. to dominate and become a self-sustaining system, outcompeting some of the natural species.

2.2.2. Climatic conditions

Serra-Maia et al. (2016) reported optimum growth temperatures for *C. vulgaris* between 20°C and 28°C in bioreactors, while Fei et al. (2015) observed maximum biomass and lipid production by *C. protothecoides* at 25°C. Growth of both species is however significantly inhibited at 35°C. Climate data (average rainfall, humidity, cloud cover, UV index and temperatures) are summarised for the 2017 study period for Brandwacht WWTW, Mossel Bay (Figure 5). Oberholster et al (2021) recently discussed the impact of the minimum air temperatures of 11°C at Brandwacht (Figure 5A) from June to August as below optimum for the microalgae and that a reduction in algae growth and subsequent biomass could be expected. Huisman et al (2002) reported *C. vulgaris* to have a lower light intensity, therefore not requiring a lot of light to grow. Similarly, Brandt (2015) found *Chlorella* a good competitor and an ideal species for cultivation in lower light locations. The cloudy days in the study area are therefore less likely to impact the algae growth than the temperature changes. As explained in Oberholster et al. (2021), the constantly lower temperatures during the colder winter months, required a change from a 4-week cultivation (Figure 6A) to a 5-week growth period in order reach the required chlorophyll-a level (250 mg L^{-1}) and corresponding rich green colour on our simplified algae readiness chart 1 (Figure 6B). Release of the algae at this concentration, as well as weekly manual mixing of the algae in the bioreactors, prevent overshadowing and suspension in the reactor tanks.

FIGURE 5

Figure 5: Climate conditions during 2017 in Mossel Bay. (A) shows the temperature ranges, (B) indicates the average UV index, (C) summarises the % cloud cover as well as the humidity, while (D) depicts the average rainfall (mm) and rainy days. (Source: Weather data obtained from https://www.worldweatheronline.com/)

2.3 Water Quality Sampling and Analyses

2.3.1 Physicochemical Analyses

Random water samples were taken before (n=2) and after (n=3) the phycoremediation treatment was implemented at the Brandwacht WWTW as described in Oberholster et al. (2021). The physicochemical water quality analyses of the final effluent (Pond 7) were performed by the accredited water analytical laboratory of the CSIR in Stellenbosch. Analyses were done by means of approved analytical methods detailed in the "Standard Methods for the Analysis of Water and Wastewater" (APHA, AWWA, and WPCF, 1992).

2.3.2 Microbiological Analyses

Microbiological water quality analyses of the water were performed monthly over 6 months (including Summer and Winter conditions) after implementing the phycoremediation technology. Water samples were collected and transported on ice to the CSIR Stellenbosch microbiology laboratory for analyses within 6hrs after sampling. The Colilert-18/Quanti-Tray method for simultaneously detecting total coliforms and *Escherichia coli* (*E. coli*) in water, was employed to determine the log reduction of *E. coli* at each outlet of the 7 Ponds of the Brandwacht WWTW. The *E. coli* count of the final effluent was compared to the Department of Water Affairs and Forestry (DWAF) general and special authorisation standards for discharge of wastewater effluent to a water source (DWAF, 1999), as well as the DWAF (1996) agricultural irrigation guideline for wastewater effluent.

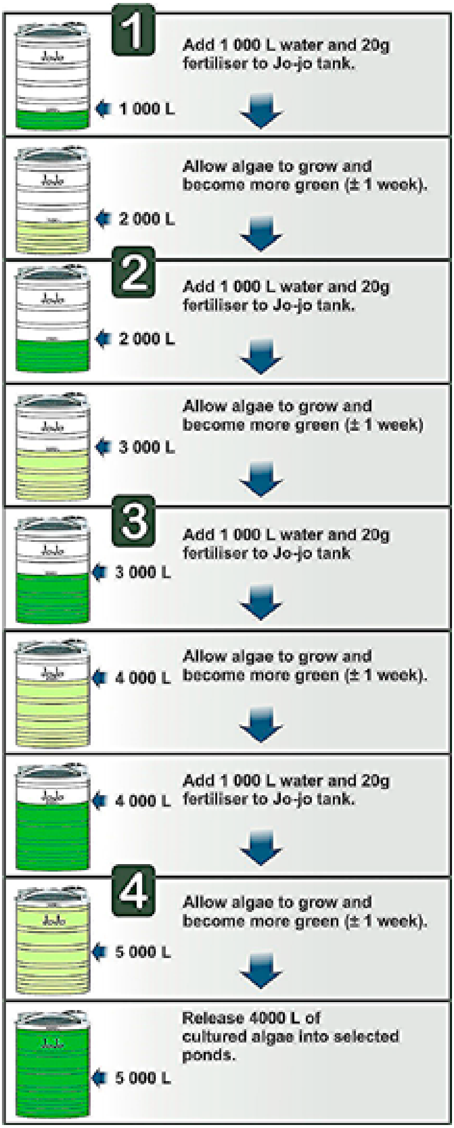

FIGURE 6

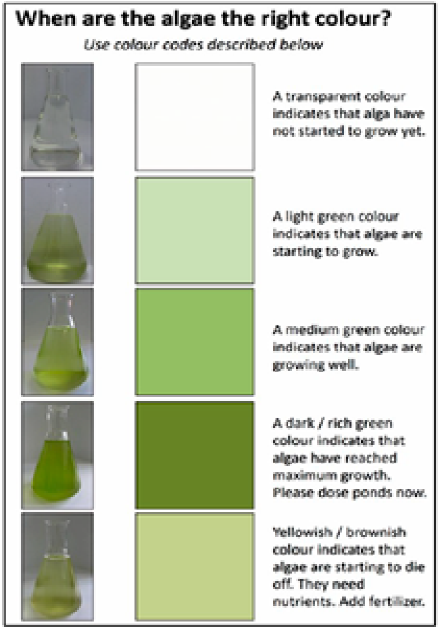

FIGURE 6B

Figure 6: Cultivation process of green microalgae (A) over a 4-week period is shown and (B) algae readiness colour chart. The algae are cultivated in 3 – 5 bioreactors (each 5000L in size). Every week, 20gram fertiliser is added with every 1000L water added to each bioreactor tank. The colour chart (B) allows un-trained or semi-skilled plant operators or maintenance staff to understand the algae readiness level for dosing of the waste ponds.

2.3.3 Statistical Analyses

Water quality data were captured in Microsoft Excel Spreadsheets. Simple error bar graphs for the water quality parameters were created in SigmaPlot (Version 14), and statistical analysis was performed using SigmaStat 14. The Mann–Whitney Rank Sum test was used to determine statistical significance for each parameter in the final effluent (Pond 7) of the Brandwacht WWTW. Where data was normally distributed, the Students' t-test was performed to determine significance. In all tests, the level of significance was adopted at $p < 0.05$.

2.4 Algae Biomass Harvesting

Following a laboratory assessment on the harvesting of algae biomass from Brandwacht WWTW (Van den Berg et al., 2020), a field assessment was done to test biomass harvesting at pilot scale. A small-scale pilot plant (Figure 7) was installed to test the potential removal and harvesting of the algal biomass for beneficiation, while considering costs and potential future upscaling to derive benefits from the biomass for job creation. The volume of biomass that can be harvested from the ponds, depends on various factors (e.g., climate, size of WWTW), and largely decides the feasibility of beneficiation and potential product development.

FIGURE 7

Figure 7: Pilot plant to harvest algae biomass at Brandwacht WWTW. The upper volume of water was pumped from the waste pond to the pilot plant to flocculate and harvest the algae.

To harvest the algae biomass, flocculation is needed and depending on the end-product and to increase the shelf life of the product, drying of the biomass might be required (Viswanathan et al., 2011). For the paper, Zetag 7557 (provided BASF, Germany), a commercially available synthetic cationic polymer was used as it is currently used by the Mossel Bay local municipality in their day-to-day water treatment activities. Pugazhendhi et al. (2019) recorded a 98% removal efficiency of algae from marine water with this product.

For the current study, Zetag 7557 was mixed with the water as it was pumped from the final oxidation pond into the water troughs (200 L) (Figure 7) to a final concentration of 20ppm (optimal concentration according to Lam et al., 2015). Once flocs formed at the surface, sieves were used to manually collect the algae biomass and allow the excess water to drain.

3.0 Results and discussion

3.1 Water Quality

Figure 8 summarises the physicochemical water quality of the final oxidation pond effluent. It highlights the removal efficiencies of the different parameters before phycoremediation and one year after phycoremediation treatment at Brandwacht WWTW. Phycoremediation resulted in an increase in the pH of the final effluent. Acien et al. (2016) cautions that high pH values can impact the performance and growth of both bacteria and microalgae, thereby impacting their capacity to remove contaminants from the wastewater. The pH increase at Brandwacht was in line with what has been described in literature as it relates to CO_2 depletion with increased growth of the algae (Al-Jabri et al., 2021).

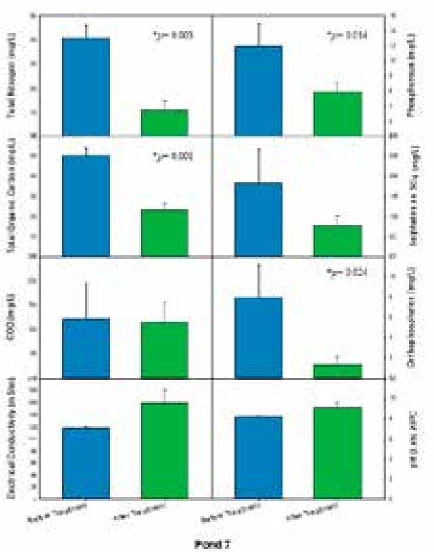

FIGURE 8

Figure 8: Water quality of Pond 7 before and after phycoremediation. Significantly different results indicated (*p< 0.05).

In a controlled laboratory assessment, Singh et al., (2017) recorded rates of up to 87.9% and 98.4% for total nitrogen and total phosphorous removal by *C. vulgaris*. During field trials, Rao et al (2011) found that nitrites and nitrates were reduced by *C. vulgaris* by 48% and 24% respectively, while a 99% phosphate reduction was achieved in high-rate algal ponds. At Brandwacht, the reduction in total nitrate (73.1% removal) and total phosphorous (50% removal) was significantly different before and after the phycoremediation treatment. These results contrasted with what we found at the first pilot plant in Limpopo (Oberholster et al (2017) where 74.4% of the total phosphorous were removed and only 35.4% of the total nitrogen. Oberholster et al (2021) reported much less cloudy days and warmer temperatures at Motetema. Motetema also had far larger total nitrogen concentrations to start with compared to total phosphorous concentrations. Acien et al (2016) stated the importance of the N/P ratio in wastewater as excess nitrogen cannot be removed if phosphorous content is insufficient to allow such removal. The N:P ratio at Brandwach WWTW was 3.4:1 before and 1.8:1 after treatment respectively (Oberholster et al., 2021). There was an increase in electrical conductivity after treatment, exceeding the South African effluent discharge standards of 150 mg L^{-1}. Even though COD levels were reduced by 6.6% from 122 mg L^{-1} to 114 mg L^{-1}, Oberholster et al (2021) noted that the COD still did not meet the South African effluent discharge standard (75 mg L^{-1}) after treatment.

The removal of microbial pathogens from domestic wastewater by means of phycoremediation has been described in literature (Rath, 2012; Emparan et al., 2019; Koul et al., 2021). The microbiological water quality in terms of log ***E. coli*** numbers in the effluent of each of the 7 ponds at Brandwacht WWTW is depicted in Figure 9. From the inlet of raw sewage (***E. coli*** = ~6.84 x 106) to Pond 1 to the final effluent of Pond 7 (***E. coli*** = ~69), there is more than a 5-log reduction in ***E. coli*** numbers. Prior to implementing the phycoremediation treatment technology, the Brandwacht WWTW already achieved the DWAF General Standard (red line at 1000 ***E. coli***/100mL) for effluent discharge into a water source. Since implementation however, a further two log reduction was seen from Pond 3 onwards and improved water quality was achieved earlier on in the treatment process. The microbiological quality of the final effluent is such that it can be used for irrigation of sports fields or specific crops (DWAF, 1996). The phycoremediation technology therefore contributed to improved microbiological water quality of the effluent and improved the potential for reuse of the effluent. The phycoremediation technology did not improve the microbiological water quality to that of the target water quality range (0 ***E. coli***/100mL) or special standard (DWAF, 1999) for unlimited reuse and irrigation (DWAF, 1996) indicated by the blue line.

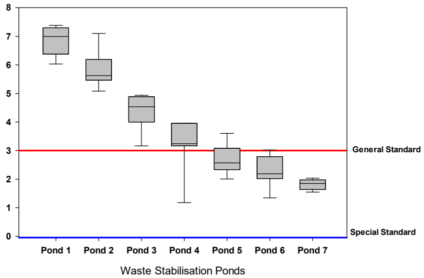

FIGURE 9

Figure 9: Log reduction of *E. coli* and compliance to DWAF effluent discharge standards (DWAF, 1999).

3.2 Biomass harvesting

Barros et al. (2015) reviewed some of the main advantages and disadvantages of the technologies available to harvest microalgae. Flocculation, depending on the flocculant used, adds to the cost and can also be toxic to the end-product or final effluent thereby limiting its re-use (Branyikova et al., 2018; Zhu et al., 2018). Chemical flocculation by means of Zetag 7557 was performed under field conditions. The algae started forming large flocs on the surface of the water troughs within 5 minutes of contact with wastewater (Figure 10).

Wang et al. (2010) reported that microalgae biomass concentrations are usually low (range of 0.5–3.0 g L^{-1}), because of light limitations. This, together with the small cell size of microalgae, renders biomass harvesting costly and energy consuming. Low microalgae biomass concentrations of 0.5 g L^{-1} were associated with open pond reactors, while photobioreactors could have concentrations up to 5g L^{-1} (Vandamme et al., 2013). Few studies reported in-field results from open ponds only using flocculation. Ghayala and Padayaa (2013) reported microalgae concentrations of 10 mg L^{-1} (day 7) after growing microalgae in 10 L bioreactors, making use of centrifugation during harvesting. A total mass of 625mg +/- 50mg of wet algae biomass was collected from every 1000 L of wastewater at Brandwacht. However, this was the results of the first trial and should be repeated, possibly under summer conditions. In-field trials of different flocculants or other harvesting methods should be investigated.

FIGURE 10

Figure 10 Photos of the in-field flocculation and harvesting of algae biomass at Brandwacht WWTW.

3.3 Barriers to phycoremediation at the pilot sites

Increasingly, phycoremediation is successfully implemented to remove pollutants from wastewater, while simultaneously harvesting beneficial biomass for various end-products. The advantages of phycoremediation and closing the nutrient loop is clear and well documented in literature (Rao et al., 2011; Renuka, et al., 2020). The technology can be implemented as a low cost, green solution that does not require high energy or an additional carbon source (Whitton et al., 2015; Oberholster et al., 2019). In fact, the algae use CO_2 as its carbon source, which has further positive impacts for sustainability with regards to reduction in greenhouse gas emissions (Ghayala and Pandyaa, 2013; Singh et al., 2019). However, the success of the phycoremediation technology is directly linked to various aspects such as microalgae selection, closed versus open culture systems, climate-related aspects, as well as harvesting techniques ((Whitton et al., 2015; Koul et al., 2021).

Climate variations can negatively impact the growth rate of the selected microalgae and overall performance of the treatment making use of open ponds (in our case, existing waste stabilization oxidation ponds), causing delays in system turn-around times as was seen at Brandwacht WWT. The study area frequently experienced >30% cloud cover for 80% of the time which resulted in a changed Winter cultivation framework of 5 weeks instead of 4. Even after careful selection of the microalgae consortium, ***Chlorella vulgaris*** and ***Chlorella protochoides***, for their large biomass potential and wide optimum growth temperature range, low biomass concentrations were retrieved.

Considering the high pH of the water and the temperature fluctuations, as well as the fact that the algae was cultivated in open waste stabilisation ponds, the low microalgae concentrations retrieved is not surprising. Subsequent research showed that the flocculant supplied by the local municipality, is best used in marine waters and might not have retrieved efficient concentrations of the ***Chlorella*** spp. The algae biomass, in contrast to most studies, was not centrifuged nor concentrated, or dried as these costs or infrastructure would not be available to rural municipalities in South Africa. While the technology improved the physicochemical and microbiological water quality, and obtained good nutrient removal efficiencies, the treatment failed to improve the water quality to comply with the South African effluent discharge standards. This limits some of the reuse options in terms of reuse of the water for irrigation and the type of crop (e.g., sports fields or food crops) that could be irrigated. Based on the low microalgae biomass concentration harvested, feasibility of the technology and further initiatives to improve the low-cost system, should be investigated. The costs and need for solar-/ wind turbines connected to a mixer in the bioreactor or the addition of an extra bioreactor to increase algae cultivation and subsequent biomass, should be interrogated. This might assist in improving the effluent quality to within the guideline limits. Harvesting of the algae biomass requires further research in terms of flocculant and harvesting technique. The environmental impact of the flocculant used for harvesting algae biomass should be carefully selected based on the end-product envisaged.

4.0 Conclusion

Even though large-scale production of microalgae is an emerging technology, it shows great advantages, also for rural areas of developing countries. Domestic wastewater of improved quality could be obtained at very low cost, reducing the selling prices of irrigation water for agricultural production. Harvested biomass can be exploited as algal bio-fertilizer in African countries with an agriculture dominant sector. With the nutrient recovery by microalgae growth, potential pollution of the wastewater can be dramatically reduced to prevent eutrophication in waterbodies. There are however several barriers and disadvantages, especially when trying to keep the costs to the minimum. Cultivation of the microalgae in open waste stabilisation ponds, render them sensitive to climate fluctuations or low biomass concentrations. Cost-effective ways to harvest enough microalgae biomass for producing bio-fertilisers and allow for small scale job creation in developing countries are needed.

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- 1 In some rural areas of South Africa, wastewater treatment plant operators or workers are semi-skilled or do not have the infrastructure to measure the chlorophyll-a level in the tanks. The project team therefore developed a colour chart indicating the algae readiness level for release into the waste ponds.

Photo by Pok Rie from Pexels

The Preparedness of Master of Architecture Graduates for the Fourth Industrial Revolution (4IR)

Kevin Bingham and Ginny Porter

Introduction

The Fourth Industrial Revolution (4IR) has transformed the way we live and work with AI, the Internet of Things (IoT), virtual reality (VR) and robotics, according to a definition by Rouse (2017). The Internet's Big Data has grown exponentially, and the prospect of robots performing many more human jobs is of concern to workers from diverse disciplines. The profession of architecture is not spared. According to Reif (2018), writing for the World Economic Forum (WEF), by 2020 creative thinking will be third on the list of the most important skills needed for people to survive and thrive in the 4IR world. Therefore, the discipline of architecture's demise is not foreseen to be imminent for at least another decade. Reassuringly, as reported by David and Cope (2015:2) in The Guardian, Michael Osborne, Associate Professor in Machine Learning at the University of Oxford says, "creativity is arguably the most difficult human faculty to automate. Robots are unlikely to be fully creative any time soon." Nevertheless, academics will be compelled to reformulate numerous curricula and reassess their content to ensure that students obtain employment when they graduate and that their skills are valued.

The South African Architectural Professions context

Taking into account that a Professional Architect1 has, in most instances, completed eight years of training before practice, and accepting that architects and Architectural Learning Sites (ALS) are validated cyclically by the South African Council for the Architectural Profession (SACAP) and that M.Arch. programmes currently meet the international Canberra Accord (CA) on architecture education standards of substantial equivalency; Professional Architects should be well-equipped for the world of practice.

Introduced in 2008, the CA considers the portability of university degrees amongst the accreditation agencies that signed the Accord. Countries subscribing to the CA include China, Mexico, South Africa, Canada, Korea, the USA and selected universities validated by the Commonwealth Association of Architects (CAA). The Canberra Accord recognises the substantial equivalency of accreditation/validation systems in the architectural education of its signatories. These equivalencies are reviewed cyclically by international validation boards appointed by the CA.

The dawn of the 4IR has been a progressive one for architects. Architectural practice has, for some decades, addressed the computerisation of drawing production and three- dimensional (3D) visualisation through life-like renderings and fly-through animation. More recently, portable viewing devices such as 'goggles', enable viewers to immerse themselves within a computer-generated constructed space and navigate within a representative virtual reality world. Building Information Management (BIM) has also in recent times added to the efficiency of the consultant teams' access to information, with the possibility of simultaneously sharing a computer model at a variety of remote locations. BIM is a collaborative technological tool, which enables multiple stakeholders to work on the design, planning and construction of a building project. As an example, the United Kingdom (UK) Government mandates that BIM is utilised for all construction contracts from 2016 to deliver more sustainable buildings faster and more efficiently.

The progression to and engagement of architectural practitioners with computer tools is a natural process. A variety of computer graphic programs is introduced to architecture students at most ALS, but with limited tuition. The access to such programmes is determined by the willingness of computer suppliers to offer free or limited licences to students or the ALS, which may also purchase some licences. These software tools require extensive tutorials, and frequently the features are not fully explored, but they are worth the commitment to keep skills at the cutting-edge. As CO Architects' principal, Eyal Perchik, commented in Kilkelly's (2017) article, not everyone can read drawings, but everyone can relate to virtual reality. Exploring a concept model enables architects and clients to experiment with different options before the expense of printing large-scale drawings.

Traditionally, expertise in technology was reserved for the Architectural Technologist, and university studies focused more on the theories of architecture and its implications on design. However, because of the cross-disciplinary opportunities provided by BIM, these technologies are now used by architects, engineers, construction managers, quantity surveyors and project managers.

Figure 1, acquired with permission from SACAP, illustrates the qualifications and professionalisation pathways from NQF Level 5 needed as a draughtsperson, to those at NQF Level 9 needed as a Professional Architect. The requirements for progression are shown. Beyond these levels is the NQF Level 10 for a Doctorate in Architecture.

A Candidate Architectural Technologist will have studied at a tertiary institution for at least three years at NQF Levels 6 or 7 and will have gained the required competency to practise in the built environment after a supervised internship of two years as specified by SACAP. Those who have completed the fourth year of architectural study, resulting in an accredited Bachelor of Technology (B. Tech) Degree or an Advanced Diploma, will be at NQF Level 7, while the fourth year Honours Degree is set at NQF Level 8. The NQF Level 8 qualification is seen as the stepping-stone to the Master's programme at NQF Level 9. Should the appeal of academia be relevant, students could move up to NQF Level 10 for doctoral studies.

According to Wood (2017:2), Nick Bostrom, an Oxford academic and philosopher, believes that the world is at the cusp of an AI explosion, which will drive the design industry. Wood asks: "Will the Internet of Things create a socially adaptable and responsive architecture?"

Creating a socially adaptable and responsive architecture would entail considering the population growth and its effect on the environment, as an example. Wood spoke to Michael Bergin from the Computer-Aided Design (CAD) software supplier, Autodesk, who suggests that the architect would be less involved in drawing, and more in specifying and problem- solving. This is a key critical cross-field outcome (CCFO) used daily by practising architects. The Internet of Things (IoT) is an ideal tool to gather information and Mahsa and Mohammed (2017) explain how, by using information received via BIM's connectivity, construction challenges such as crisis management, energy management and disaster prevention can assist in the efficient management of these issues. Wood (2017) comments how 3D printing and AI can offer architects a new aesthetic language and with AI-driven robots on

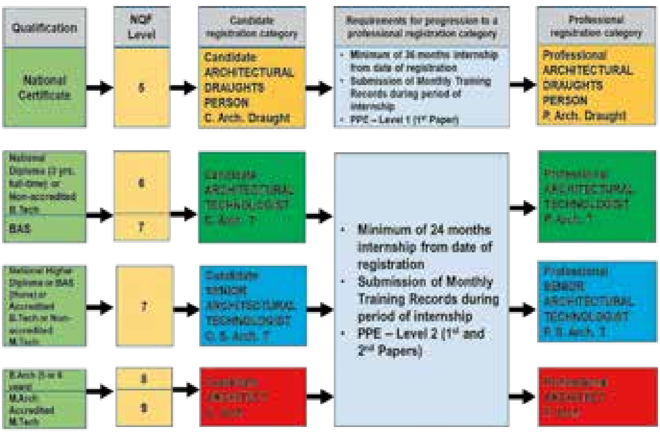

Figure 1: Qualifications and professional development for Architectural Professionals (Source: SACAP, 2020)2

construction sites soon expanding into bricklaying, welding and other tasks, the architect's role will dramatically differ. A paradigm shift in revising the curricula is required to remain relevant in practice.

Peerutin (2019), Chair of the South African Institute of Architects' (SAIA) Practice Committee, cautioned that only a fraction of the power of BIM is utilised due to a lack of expertise and that there will have to be fundamental changes in the course content of the architecture curriculum to take advantage of the offerings of technology such as BIM.

Also, he stresses that "… the importance of developing a BIM strategy (BIM Execution Plan and Employers' Information Requirements) on a project-by-project basis cannot be overstated" (Peerutin, 2019:5).

Focus of the study

The study on which this paper is based aimed to describe how particular CCFOs are necessary for recently graduated students in architecture during the 4IR. These are important at all NQF levels and include those found in the essential part-qualifications (unit standards) as per the South African Qualifications Authority (SAQA) guidelines. The research proposed suggestions for the development and implementation of an informed architectural pedagogy that will require a paradigm shift if graduates are to compete in the context of the 4IR.

Research objectives

The research objectives, which considered the preparedness for M.Arch. graduates for the 4IR, guided the development of the quantitative questions, headed under issues concerning technology, CCFOs, entrepreneurship, social awareness and cultural responsiveness in the curriculum, and commitment to lifelong learning.

Many academic disciplines in South Africa and abroad address the universal issues raised by Finch and Melvin (2017). These issues have been gleaned from the United Nations Educational, Scientific and Cultural Organisation's (UNESCO's) Sustainable Development Goals (SDGs) (UNESCO, 2019). Particularly relevant is the link between social justice and climate change because of the move to green technologies by architect designers.

Literature review

Is a machine able to create an iconic masterpiece such as Le Corbusier's Notre-Dame du Haut at Ronchamp and evoke feelings of reverence in people from all spiritual backgrounds? Although an old source, this quotation is relevant to the discussion–Cotterill (1989:23) comments, "I would defy even the most hardened criminal to sit alone in Le Corbusier's masterpiece and not feel the presence of something larger than man." We ask, in this paper, "Do polymathic architects need to be developed and encouraged for similar creations to occur?"

Cramer (2012), the founding editor of Design Intelligence and co-chair of the Design Futures Council, feels that communication skills and business leadership should be taught before graduation. He stresses the importance of keeping the curricula current and enabling interactions with industry professionals. He recommends an experiential, cooperative, educational approach where students learn first-hand about building procedures with on- site supervision and day-to-day project management challenges.

Etherington's (2011) provocative title "Will architects exist in 2025?" which was posed at the Royal Institute of British Architects' think tank, Building Futures, provided feedback after a year-long study where the key questions of who will design our built environment, how will practices change by 2025, and what role architects will play in these changes, were addressed. Financial literacy and problem-solving were focus areas where the architect was recommended to be client-savvy and see beyond the building. According to Etherington (2011), a time is envisaged when practices will be known as 'spatial agencies' or 'design houses' with the name 'architect' no longer used. Etherington's view omits to consider the full suite of training afforded to the architecture student and its importance in ensuring an environment well suited to human habitation, and the sustainability of the planet.

Historical background

Polymath Sir Christopher Wren (1632–1723) is regarded as one of the greatest English architects in British history (Curl, 2005:742). He was a recognised architect, mathematician- physicist, astronomer, scholar, anatomist, astronomer, and geometer. Wren gained a reputation as an architect through his creation of the Sheldonian Theatre in Oxford. The design is based on the classical design of the Roman Theatre of Marcellus. Wren is best known for his restoration of buildings in London after the Great Fire in 1666 that put paid to his reconstruction of St. Paul's Cathedral in London, which then had to be rebuilt. Wren's English Baroque design, with its distinctive dome, is said to be his greatest achievement (Curl, 2005:742). Wren designed and supervised 51 uniquely different city churches. According to Tinniswood (2001), Wren's success lay in his involvement in each stage of the work. He was pedantic about workmanship, insisting on the finest of materials. A polymath such as Sir Christopher Wren may not be readily available today in many architectural firms but, certainly, soft skills such as problem-solving, communication, project management and systems thinking are essential for Professional Architects today. Also, innovation and creativity, with a solid foundation in theory, will enable graduates to compete in the ever- changing 4IR.

Modern-day polymaths

Dickinson (2018), an architect for more than 45 years, believes that architects should be polymaths and not just specialists. He discusses the work of polymath Michelangelo and believes that, because of the avalanche of technology, which we are compelled to master, we are losing touch with reality because of the "CAD Monkeys"3 the architect has to now contend with. He believes a 'Balkanisation' of architecture has emerged with many architects splitting off into areas of specialisation.

There are a number of modern-day polymaths. Gerfen (2018), for example, discusses David Benjamin, and how his architectural practice, The Living, blends the topics of biology, computer science, and design, intending to augment architecture. During an interview with Benjamin, Gerfen commented on how the discipline had been defined in academia and in professional practices, which may be outdated, and the increasing pressure to take a more interdisciplinary approach.

It cannot be disputed that world-renowned entrepreneurs such as Elon Musk, Mark Zuckerberg and Bill Gates are polymaths who take full advantage of technology offerings in the 4IR. Further, according to Simons (2018), several research studies have revealed that people who enjoy broad interests are more likely to succeed in life.

Not everyone can become a polymath, but there are opportunities for joint research studies where multi-disciplinary contributions lend a polymathic approach to the study. Simmons (2018) reports how researcher Professor Brian Uzzi from Northwestern University in the United States (US), for instance, examined copious papers going back hundreds of years. He found that when teams collaborated, their output was more impactful and attracted numerous citations. In building construction, people from a variety of disciplines work together as a team, each bringing their skills to the collaborative work. Graduates in architecture are predominantly trained to be generalists within their fields.

The issue of social justice was championed by polymath architect, Michael Sorkin, who recently died of the Covid-19 virus. Smith (2020) explains that Sorkin's forthright manner sometimes caused conflict, but his insights into social justice and the influence of politics in architecture will always be remembered.

Charles Jencks (1939-2019), a prodigious polymath, was known for his skills in "breathing life into buildings". He launched a second career in landscape architecture where he incorporated ideas on mythology, cosmology, symbolism and science. He used the land to explore subatomic physics and chaos theory.

Social skills

Reif (2018), President of the Massachusetts Institute of Technology (MIT), advises that to survive in the 4IR, social skills need to be developed and improved. He explains that it is important for people to be proactive in reinventing the future of work.

According to Deming (2015), computers are poor at simulating human interaction and, therefore, communication skills are another key CCFO in the 4IR context. His research

found an increasing emphasis on the importance of social skills which technology cannot emulate with ease. This emphasis he said is particularly relevant in high-paying jobs. Deming (2015:1598) explains, "this literature shows a clear link between the computerisation of the labour market and the decline of routine work. Yet the link between the increased variability of workplace tasks, team production, and social skills has not previously been explored." Deming (2015) cites Heckman and Kautz (2012) who discuss the importance of non-cognitive or soft skills and, in particular, the ability to work with others.

Tucker and Neda (2019), writing for The Architectural Science Association (ANZAScA), explain how they found a clear knowledge gap in terms of the inclusion of teamwork in the curriculum of architecture and related design disciplines. This knowledge gap could be easily addressed by closer interactions with government, academia and practising architects. Osman (2018) feels that cross-disciplinary communities are crucial in the 4IR, and spaces should be created for conversations across community, industry, social and academic precincts.

Soft skills, according to Cimatti (2016), indicate personal transversal competencies like teamwork, communication and language skills, and social aptitudes. A blog team with broad- spectrum skills and commitment to collaboration used the social media platform, LinkedIn to analyse 50,000 professional skills most in demand by employers. The number one skill being sought in 2019 was creativity. LinkedIn indicated that creativity is the single most important skill in the world for all businesses today to master.

Predictions from the World Economic Forum (WEF) and futurists

Schwab (2016), Founder and Executive Chairman of the World Economic Forum (WEF), has been at the centre of global affairs for over four decades. He is convinced that the world is at the beginning of a revolution that is fundamentally changing the way people live, work and relate to one another, which he explores in his new book, The Fourth Industrial Revolution. Schwab (2016) points to real evidence that technologies are having a major impact on businesses and roles, as robots replace people. One technology that has become accessible is the 3D printer, which is said to be replacing some employees formerly in the production/assembly line.

In a WEF online article (2020:1), Erik Brynjolfsson, Director at the Massachusetts Institute of Technology (MIT) Initiative on the Digital Economy, commented that "The future is not preordained by machines. It's created by humans." The late Stephen Hawking, rated as one of the world's greatest physicists, and whose views on the future of the world are highly regarded, once commented in an interview with Wired that robots could, with the help of AI, supersede humanity. Brynjolfsson (2020) does, however, say that it would be best to not compete with machines, but rather to outdo them. He believes that creativity in schools is being stamped out and that schools should consider investing in this skill. Other 'soft skills' he mentions are leadership, teamwork and interpersonal skills.

Preparedness of architecture graduates for 4IR innovations

The SACAP registers architectural practitioners across four categories viz. Professional Draughtsperson, Professional Architectural Technologist, Professional Senior Architectural Technologist and Professional Architect. As shown in Figure 1, to attain registration as a Professional Architect, the current South African model requires five years of full-time tertiary study. This sees the graduate attain a Master's degree (NQF Level 9), and after an additional two years of Internship as well as successful navigation through professional practice examinations, SACAP registration is enabled.

Architecture programmes are offered in traditional universities as well as in Universities of Technology (UoTs) in South Africa. SACAP has annual Continuing Professional Development (CPD) requirements for the Professional Draughtsperson, the Professional Architectural Technologist, the Professional Senior Architectural Technologist as well as the registered Professional Architect. The registered Professional Architect has full licensure to tackle any projects of all complexities. Until the advent of the Covid-19 pandemic, most CPD courses were offered by building suppliers, attempting to promote their wares. The pandemic has brought to life daily online CPD offerings, made available internationally and in some cases, collaboratively. The topics are wide-ranging, including the Sustainable Development Goals and architecture after Covid-19.

The role of education in the 4IR

In the current fast-changing world, what is taught will soon become obsolete, and to address this, inter and multi-disciplinary learning opportunities should be offered at the tertiary level.

The South African Qualifications Authority (SAQA, 2018) in its NQFpedia Glossary of Terms4 defines CCFOs as "the generic outcomes that inform all teaching and learning" (2017:19). Qualification and part-qualification developers must consider CCFOs in the development of qualifications. Such skills are not simply 'nice-to-have', but essential to prepare students for their future roles in fast-changing environments.

Hattingh (2016) believes that the Sector Education and Training Authorities (SETAs)5, the government, and other policymakers, need to plan for the eventuality of changes arising from the 4IR. No education system can keep up with these changes and curricula need to be reformulated to include topics such as creativity, problem formulation (rather than problem-solving), economic citizenship, emotional intelligence (empathy, intercultural sensitivity etc.,) and the ability to adapt. Creative skills are useful in careers that are complex, fragmented, ever-evolving and collaborative and should be a requirement at any NQF level.

> Marr (2018:4), who wrote for Forbes, advises that any jobs requiring true creativity are probably safe for the foreseeable future. He commented that,
> Many jobs require additional and very human qualities like communication, empathy, creativity, strategic thinking, questioning, and dreaming. Collectively, we often refer to these qualities as 'soft skills', but don't let the name fool you; these soft skills are going to be hard currency in the job market as AI and technology take over some of the jobs that can be performed without people (Marr, 2018:4).

Webber-Youngman (2017) lists ten skills, other than those previously mentioned in this article, highlighted by the WEF (2017) as namely, emotional intelligence, service orientation, negotiating, and judgement/ decision-making.

Educators are not spared from being replaced, as according to Dvorsky (2017), the host of massive open online courses (MOOCs), Apps, and computer-aided instruction will soon eliminate teaching positions. VR technology is useful in the studio environment, where, according to Powers (2001), the constructivism ideology teaches students about built environment challenges without real-world repercussions. Webber-Youngman (2017) feels that Inquiry-based Learning (IBL) is a crucial component in getting projects completed. This theory has the locus of control with the student who is encouraged to ask questions. IBL emphasises constructivist learning, first put forward by David Kolb (1984), who introduced experiential learning from a constructivist viewpoint. Essentially this means "learning by doing" from people, incidents and resources, reflecting and building on prior knowledge. In the architecture studio environment, the lecturer is the Master, and there is a longstanding tradition of learning-by-doing (Moore, 2001) where the apprenticeship model is in place.

During the third year of the Bachelor of Architecture degree at the University of KwaZulu-Natal (UKZN), students engage with environmental and social influences in architecture, preparing them for their internship year. This concept embraces Vygotsky's (1978) social- cultural theory, which conceives of human learning as a social process. After graduating, what Kolb (1984) refers to as experiential learning in the internship year takes effect where environmental factors, cognition and experiences influence the learning process, better-preparing students for their Master's degrees. During the Honours and Master's programmes, urban design and community engagement are emphasised and therefore, should their experiential learning have been effective, this would benefit students' ultimate progress. Also, elective courses from other disciplines, as well as interactions with established local communities with intrinsic issues, ensure a multi-disciplinary approach and the continuance of experiential learning.

Built environment higher education programmes at all NQF levels have traditionally encouraged experiential learning with a hands-on approach through visiting building sites and interacting with professionals in this field. This approach has blended with the studio- based pedagogy and the encouragement of reflective practice. As observed by professors of architecture education, Kolhe and Tarar (2017), experiential learning has a key role to play in the education of the builders of the future and these include planners, architects and engineers. They commented on how this theory of learning moves away from the traditional "chalkboard" approach leading to change and the enhancement of communication and teamwork skills, ultimately encouraging lifelong learning.

In architecture tertiary studies, studio work also exemplifies this theory of experiential learning as students learn by experiencing and experimenting with different materials and theories. Kolb's (1984) experiential theory, and constructivism, where students construct their understanding of the world with real-world problem-solving, applies in the studio as well.

This theory of learning by doing has its historical roots in the work of Dewey (1929) and Bruner (1961) as well as Vygotsky (1978) and is still relevant in many paradigms of education. However, a reassessment of how these theories work in the 4IR should be considered.

Entrepreneurship and innovative thinking

The SAQA Unit Standard Identity (ID) 114600 at NQF Level 4 applies to the development of innovative thinking in small businesses. Accredited providers who offer this unit standard include training companies, filmmaking organisations, consulting engineers and transport firms.

Figure 2 illustrates the importance of creative skills as part of the soft skills to be developed for business management and is pertinent, as many architecture graduates will establish their own businesses. Figure 2 also illustrates how creativity in business management links with other soft skills such as problem-solving and its importance in innovative practices.

Figure 2: Creativity in business management (Source: Adapted from SAQA Unit Standard Identity [ID] 114600)

Creative problem-solving is key for the development of skills, and rote learning is a thing of the past. Robots are ideal for handling repetitive tasks. Gleason (2018) reports that experiential and problem-based learning are essential components of higher education pedagogy in the 4IR. Singapore's institutions of higher education, for example, aim to upskill and educate their citizens by shifting the population's skill sets.

An example worth emulating

Singapore is well-known as a country that embraces technology. Gleason (2018), in referencing Singapore, believes that humans will always drive innovation and creativity and should learn to work alongside robots, which have been referred to as 'cobots'.

Collaboration with government and business is recommended and, according to Gleason (2018), both should provide finance, with the former being committed to up-skilling its citizens. Adaptable and flexible mindsets mean cognitive agility that enables people to keep current in fast- changing environments.

Singapore has two large-scale initiatives, SkillsFuture and Smart Nation, which work alongside their institutions of higher education to prepare the population to live and work in the 4IR. The beneficiaries of these ventures include citizens of all age groups and the nation's economy.

The Smart Cities in Singapore, with the IoT and Wi-Fi-enabled devices, will see communication enhancing lifestyles for city residents. However, these citizens need to become digitally literate to take full advantage of these technologies. Gleason (2018:165) states "In preparation of 4IR, Singapore is deploying a multi-faceted strategy that merits rigorous appraisal by other countries and institutions of higher education". Perhaps, this example from Singapore is worth emulating by countries such as South Africa.

South Africa in the 4IR

During the 2020 budget speech, Mr Tito Mboweni, South African Minister of Finance and former Governor of the South African Reserve Bank, spoke of South Africa's commitment to 'not being left behind' as far as 4IR is concerned (SA Parliament, 2020). He advised that schoolchildren, particularly those from disadvantaged communities, should learn robotics and coding skills.

Smart cities, he said, are developing, and two examples are Oliver Tambo Airport and King Shaka International Airport – the international airports in two of South Africa's nine provinces. Education was given high focus in the budget, and there are plans to build a new university of science and innovation in the Ekurhuleni region of Gauteng, South Africa's most populous province.

Lifelong learning

Architectural studies do not stop at tertiary level, as CPD ensures that architectural professionals are kept at the cutting-edge of technology and has become essential for each professional's career requirements. Vestburg (2018) commented that 4IR needs to embrace the concept of lifelong learning:

There's something else we need from a Fourth-Industrial-Revolution education system: the full embrace of the concept of lifelong learning. I realise I'm hardly the first to espouse the lifelong-learning ideal, but we need to be more emphatic about making it a reality. Rather than a nice add-on to our current formal education system, it should be the concept around which the entire system is understood and organised.

Teamwork or group work is mentioned repeatedly by academics and practitioners as being advantageous in the workplace. Teamwork provides informal, formal and non-formal learning opportunities. The latter also includes social media. However, students are frequently resistant to teamwork where, for example, uneven workloads are experienced, as commented in the study on which this paper draws. As architectural professionals practise in multi-disciplinary environments, the groundwork for these aspects should take place at tertiary level although such skills are honed throughout the course of life. Peerutin (2019) comments that it is puzzling that more practices have not taken advantage of outsourcing highly skilled experts to form teams. Collaboration and communication are key CCFOs, and conflict management and cross-cultural awareness are important considerations in the built environment.

Methodology

The quest was to examine how, by the introduction of CCFOs, architects can become multi- skilled, multi-disciplined and possibly even polymaths (whose knowledge spans a variety of topics).

An empirical, longitudinal combined research methodology was used for the study on which this paper draws to derive benefit from both the rich, interpretative, in-depth qualitative approach and the more scientific, generalisable quantitative approach. The rigorous and persuasive mixed methods project enabled insights from graduates from four tertiary institutions in South Africa in the discipline of architecture. Responses were evaluated from an architectural and an educational perspective.

Two instruments were formulated. The core considerations for assessing the CCFOs were addressed by a quantitative approach using a questionnaire submitted via email with Likert scale responses of 'Yes', 'No', and 'Sometimes', analysed in Microsoft Excel. Ethical considerations were adhered to as respondents were advised that all data would be kept confidential.

A sample of M.Arch. graduates from UKZN, University of Cape Town (UCT), University of the Free State (UFS), and Nelson Mandela University (NMU) participated in the study. The years in which the sample had graduated ranged from 2014 to 2018. The data were acquired from 17 graduates with M.Arch. Degrees.

The qualitative questions were devised using the broad, universal issues deemed important for the future of architectural practice, namely climate change, water security, an ageing population, social identity, an ethical and empathetic understanding of diverse perspectives, social justice, smart cities, building technologies, reuse of materials and virtual worlds, mentioned in Finch and Melvin's (2017) article concerning their vision for the architecture profession for the next 10 years.

Student feedback on the march 2020 curriculum

There were 17 responses to 45 requests made to the four educational institutions. The respondents highlighted the lack of guidance in their curriculum on the topics of new building technologies such as nanotechnology, smart cities and virtual worlds, all issues raised as important for future architects by Finch and Melvin (2017). The data revealed that M.Arch. graduates would thus be under-prepared, in terms of 4IR readiness, for practising as architectural professionals.

All responding students commented that their CAD skills were mostly acquired during their working experience and that their exploration of virtual space was self-taught. One student regretted the emphasis placed on hand-drawn work, as expert CAD skills were expected in the marketplace. She commented, "Viscom6 ended in undergrad and while I was studying the course never went into computer graphics, rendering/3D software and only focused on hand-sketching–a major stumbling block I now find in the workplace."

Presentation skills were emphasised in the summative assessment stages of the architecture learning programmes, as this is where the students graphically display their design creations. Students print out large-scale drawings, sketches and 3D-rendered imagery. One student commented, "Well presented schemes often masked their underlying architectural flaws." Another said, "Sometimes people passed because their presentations were flashy. But virtual worlds are important in the workplace where the cost savings using this technology are considered essential. One student commented on how presentation skills were expected from students to communicate their design work, but no formal instruction on this aspect was received.

Another area needing development emerged, of curriculum coverage regarding running an architectural practice. Some Respondents pointed to a lack of understanding of the current metrics in finance, marketing, professional services and operations. One student said, "Only the bare minimum was covered within certain courses." Another commented, "This would be highly beneficial if added to the curriculum." However, in one institution, a module entitled Simulated Office Practice does aim to introduce some of these skills. A graduate from another institution said, "It was covered to a minor degree in a specific module." Considering the importance of entrepreneurship, it is something that should be addressed in greater detail in the curriculum.

Teamwork

Teamwork in the 4IR is essential, particularly as some projects are complex in concept, requiring multidisciplinary skills. Responses regarding the inclusion of teamwork in the curriculum were varied but it appeared that the students did not like it. One respondent said, "Not everyone contributed equally to the team." Another said, "Mine was one of the very few teams that got along and worked together effectively, personalities were complementary, and this allowed me to enjoy it more than some of my classmates."

Conflict resolution is something that frequently arises in the built environment profession, and teamwork, even if disliked, gives students insight into what could happen when they start working. For instance, one graduate said, "A team's success or failure depends entirely on the individuals that make up the group. So, when one or two let you down, it constantly creates tension."

Concluding observations

Graduates in architecture can evolve into polymaths if exposed to wide-ranging learning opportunities and collaboration with stakeholders in business and government. The development of the architecture curriculum should be an ongoing exercise to ensure that students' skills are current and relevant in the context of the 4IR. Opportunities for multi- disciplinary relationships between Architecture, Information Technology (IT), Environmental Science, and Engineering would assist universities with the costs involved in obtaining suitable resources such as those required for 3D printing, smart cities, robotics, material fabrication and others.

A key question is, "Can universities endure the fluidity of these changes?" In this study, although the sample was very small, a key finding was that the responding graduates reported being ill-equipped to run architectural practices. A greater emphasis on the administration and solving of entrepreneurial challenges in architectural practices will address this issue. Furthermore, creativity and communication skills are emphasised in the literature, and such skills should not be neglected in the formulation and modification of curricula to prepare architecture students to work cooperatively in the context of the 4IR. Further research on other issues also described in the Finch and Melvin (2017) list need to be explored if future architects are to be viewed as polymaths in the true sense of the word, and again take their rightful places as project leaders.

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- 1 The professional designations of the SACAP are capitalised.
- 2 BAS means Bachelor of Architectural Studies and PPE means Professional Practice Examination.
- 3 CAD Monkey is a programme created by an Architect and a Programmer to automate key processes. The "CAD Monkeys" term used by Dickinson typically refers to people who have gone through years of difficult and strenuous education in engineering, architecture, or a similar field only to end up with a repetitive job where they do one task on a computer drafting program over and over again.
- 4 The NQFPedia was accessed at https://hr.saqa.co.za/glossary/pdf/NQFPedia.pdf#, on 06 August 2021.
- 5 The main purpose of a SETA is to improve and develop skills within its sector, to identify skills development needs, and to ensure that national standards are maintained.
- 6 Viscom stands for Visual communication, which is a module in architecture studies that uses a variety of computer software and hand skills.

Xylem – Championing water for a sustainable future

A purpose in water

Water is one of the most critical resources on our planet, if not the most critical of all. Even though it may seem abundant, one in three people still don't have access to safely managed clean drinking water – roughly 2.2 billion people. 4.2 billion don't have safely managed sanitation services, and 3 billion don't have access to basic handwashing facilities (WHO). Nearly 800 million people don't have reliable access to safe drinking water of any sort, 40% of whom are in sub-Saharan Africa (Global Citizen.)

Yet this does not need to be the case. Water is abundant—it's good management of this precious resource that we lack. This defines Xylem's purpose, proclaimed by our slogan: Let's Solve Water.

At Xylem, through combining technology, expertise and collaboration, we can help resolve water's most pressing issues. We invest heavily in technology to create new advantages, such as using ozone to treat water effectively in a self-contained approach. We gain valuable insights from our projects across the world, applying best practices to get the best results. And we work closely with the Public and Private sectors, non-profit groups and communities to establish water management and access that lasts.

If you are reading this supplement, you appreciate water's critical importance – especially in South Africa. Thank you for your interest, and prepare to discover how we can solve water together.

You will learn more about Xylem, our mission, our impact, and how we work to create water solutions for Africa. You will discover our origins, our corporate investment work through our CSI arm, Watermark, our successes on the continent, and why we are so focused on Southern Africa.

Water in South Africa

In terms of water, South Africa is a paradox. If measured by annual rainfall, our country sits in the middle of the global pack. Yet, in reality, South African qualifies as one of the more water-scarce nations on the planet. This situation is due to several factors, both natural and made by humans.

Water gathers primarily through catchment areas that capture rainfall and funnel the bounty into rivers, wetlands and aquifers. Half of SA's water is captured by only 10 percent of its surface area, the majority situated among the Drakensberg. Large parts of the country receive very little rainfall and, as we saw recently in the Western Cape and still currently in the Eastern Cape, is susceptible to severe drought. South Africa's largest city and Africa's economic powerhouse, Johannesburg, supplies nearly all of its water needs from the Lesotho Highlands.

Human activity and engineering impact South Africa's water in many different ways. Agriculture consumes roughly 60% of local surface water for irrigation, and 25% goes towards urban uses (Department of Water and Sanitation). Each South African consumes 235 litres of water per day, above the international average of 185 litres. Water even reflects South Africa's socio-political past: most water infrastructure focuses on urban and previously white areas, leaving rural and underprivileged areas historically neglected.

These are significant concerns, and some predict SA could run into a national water shortage by 2035. But at Xylem, we look for opportunities. All the above present many choices that can vastly improve access to water for communities and industry alike. Achieving these improvements is core to Xylem's mission as a pure water solutions provider.

Who is Xylem?

Xylem as a brand came into existence in 2011 when the ITT Corporation spun off its Water & Wastewater, Residential & Commercial Water, Analytics and Flow Control businesses to form a new entity, Xylem. Though an official brand presence for around ten years, Xylem claims a legacy that goes back decades. Some of our brands, such as Flygt, Godwin, Bell & Gossett and Goulds Water Technology, were established over a century ago.

Xylem derives its name from the vascular tissue in plants that conducts water. We are a world leader in water and wastewater technology. From collection and distribution to usage, recycling and returning to nature, we focus on the entire water cycle, investing in research and development, new product lines and technologies, new water conservation methodologies and smart infrastructure—always keeping the end-user in mind. Xylem is present on seven continents, employing over 16,000 people across 150 countries, and earned US$4.88 billion in revenue during 2020.

Xylem combines technology, communities and partnerships to tackle water issues. Our products

reflect our values. The Concertor wastewater pumping system saves 70% more energy than conventional pumps.

The acoustic free-swimming Smartball detects the smallest of leaks. Blu-X's wastewater network optimisation technology creates unprecedented visibility of wastewater operations, leading to substantial savings and highlights opportunities for improvements.

Sustainability is crucial to making water both accessible and commercially viable. To support this vision, Xylem invests considerably in developing water-related technologies. We spend US$ 191 million annually on research and development through 2,600+ engineers based across global R&D centres, delivering over 3,000 patents and a 25% vitality index. We work across all sectors—industrial, commercial and residential—and leverage a worldwide partner network to deliver results on the ground in local and relevant ways.

Winning through sustainability

It's easy to claim one cares about the environment, communities or the future. But at Xylem, it's a fundamental part of our mission. This commitment reflects in two areas: our sustainability goals and the word of Watermark, our CSI arm.

Xylem commits to sustainability through our 2020 sustainability report, "Water for a Healthy World." In this document, available online, we articulate several benchmarks that align us with our mission, including to:

- Save more than 16.5 billion cubic metres of water through the use of advanced technologies;
- Prevent over 7 billion cubic metres of polluted water from flooding communities or entering local waterways;
- Provide access to clean water and sanitation solutions for at least 20 million people;
- Ensure 100% of employees have access to clean water and safe sanitation at work, at home and during natural disasters;
- Give 1% of Xylem employees' time and 1% of company profits to water-related causes and education;
- Use 100% renewable energy and 100% process water recycling at its major facilities.

Technology is key to how we achieve such goals. Water infrastructure and usage are notoriously inefficient. For

example, South Africa loses 37% of its water through pipe leaks (Greencape). Other examples include chemical pollution while disinfecting water, energy-demanding pump designs for urban and industrial uses, and a lack of visibility of water supply chains.

Xylem's technologies address these critical areas affordably and with the impact that lasts. We deliver our solutions through collaborative partnerships, enabling local providers to design and execute projects that resonate with domestic requirements.

Our work ranges from the pumps that circulate water in the Burj Khalifa, the world's tallest building, to supporting Ghana's Safe Water Network. We participated in establishing the Thakadu Nickel Purification Plant in South Africa, Rwanda's KivuWatt methane power system on Lake Kivu, and pumping operations to keep SA's largest diamond mine going.

These projects reflect our focus on local collaboration and community enablement, carried further through Watermark.

Making the Watermark difference

Suitably, we save the best for last. Corporate social investment is not window dressing at Xylem but a reflection of our values. We demonstrate this commitment through Watermark, our CSI arm.

Watermark completes the cycle for a better water future. Through Watermark, Xylem employees can nominate and volunteer for water-related projects in their communities and elsewhere. We use Watermark to collaborate with NGOs across the world, such as the Planet Water Foundation, UNICEF and Earth Echo International. Watermark was instrumental in COVID relief projects, helping provide potable water, cleaning materials, masks and public education.

In South Africa, Watermark makes a difference by working closely with local communities and NGOs. Funding and volunteers from Watermark supported SOSNPO in rehabilitating parks for the Bloekombos informal community near Kraaifontein in the Western Cape, involving local community leaders and the services of Bloekombos artisans.

Earlier this year, Xylem Watermark and Community Chest provided the Hillwood Primary School in Lavender Hill, Cape Town, with a drip irrigation water supply system for the school's food garden. We additionally supported similar projects at Megatong Primary School and Dikgabane Primary School in Soweto with rainwater capture systems to support local food gardens to supplement the national nutrition program.

Watermark is an enabler of responsible and communal appreciation for water. We emphasise ongoing community involvement and education around water usage. For example, Xylem and Xylem Watermark partner with the Manchester City Football Club to drive education around water consciousness through the Water Heroes Academy.

Join Xylem to solve water

Water is everyone's concern. It may seem ample in some places, but like a desert mirage, it's easy to overestimate water's presence. Even countries regarded as water secure face uncertain futures: the UK could face drought in 20 years due to climate change (UK National Audit Office.)

We have the means to use water better, and our global partner network ensures water challenges are tackled in locally relevant and managed ways. The Xylem approach is not to drop down from high above but to build solutions from the ground up – be it through our commercial services or the incredible work of Watermark.

Xylem is proud to be a part of South Africa. It's a land of grit and opportunity, where natural beauty coexists with human excellence. We help make water part of that journey and invite you to join the Xylem vision of water for all. Together, we can solve water.

SUSTAINABILITY SUMMIT 2022

21 - 23 SEPTEMBER 2022

REFLECTING ON A SUSTAINABLE FUTURE !

The 12th annual Sustainability Summit will be brought to you as a live virtual event, thus offering both exponential global reach and accessibility by easily bringing the content directly to the audience.

In 2022 – the shift continues, from the way we work to our global vision.

As devastating as the impact of COVID-19 has been, in many ways it's also proved to be a revelation. Overwhelming evidence suggests that the pandemic is tightly bound up with environmental issues – climate change, biodiversity loss, air, water and soil pollution, among others.

As a result, governments, corporates, and citizens worldwide are looking for ways to work together to

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