Scoping of a Citizen Science Monitoring and Evaluation Platform for the State of Sanitation Services in South Africa

Report to the
Water Research Commission

by

L Duncker, M Wilkinson, T Kolisi
Sustento Development Services

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Obtainable from
Water Research Commission
Private Bag X03
Gezina
PRETORIA, 0031

orders@wrc.org.za or download from www.wrc.org.za

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EXECUTIVE SUMMARY

BACKGROUND

The world is facing unprecedented social, environmental, health, and economic challenges, specifically in the time of COVID-19. Tackling and resolving these challenges will require policymakers, the public and private sector, scientists, and citizens to collaborate and work together. Reliable, consistent and disaggregated health, environment and economic data will be essential to stimulate future political commitments, inform new policy-making and decision-making that will be required due to the global shift that have occurred as a result of the COVID-19 pandemic, and to trigger and inform effective and efficient investments towards.

Now, more than ever, data and information on the sustainability of our actions and activities is necessary. The 2030 Agenda for Sustainable Development, which incorporates the Sustainable Development Goals (SDGs), has elevated the need for scientific monitoring and reporting to track achievements related to the goals, targets and indicators in Agenda 2030. Monitoring, reporting and learning is critical to reversing the impacts of the global pandemic being experienced by the countries and people of the world.

Measures taken by governments to contain and mitigate the COVID-19 pandemic have led to widespread disruption in the provision and financing of essential services, including water supply, sanitation and hygiene (WASH). The pandemic has also impacted on where and how countries focus their limited fiscal resources, which could impact on the levels and types of WASH services provided and thus progress with the SDGs.

The lack of access to ongoing, real-time monitoring and information of the state of sanitation services in South Africa, at a national and local level, has a major impact on the fiscal and decision-making processes at local and national government levels. To be able to develop and implement sanitation interventions and appropriate solutions, particularly in this time of COVID-19, it is necessary to be sure that the actual, in real-time state of sanitation in the country is known, that the daily challenges experienced with sanitation (toilets and handwashing) are being captured and reported and real-time information on the safety, hygiene, accessibility, equitability and reliability of sanitation services is known, especially in peri-urban and rural areas of the country.

The Water Research Commission (WRC) recognises that Citizen Science tools have the potential to close the perceived gaps between government's role in service delivery and that of citizens in responding to and supporting different aspects of service delivery. Hence, the application of Citizen Science in the WASH sector is aptly placed to assist South Africa with effectively and efficiently collecting, storing, analysing and reporting data and information on the state of WASH, while at the same time contributing to national and international mandates of stakeholder participation, transparency, accountability, access to basic services and addressing basic human rights.

AIM

The aim of this study was to scope the application of Citizen Science in sanitation in the gathering, analysing and reporting data and information about the state of sanitation infrastructure in South Africa, utilising a scientifically reliable and inexpensive participatory technique through an existing technology. The focus of the study was thus on the SH in WASH – namely CS monitoring and reporting of the state of sanitation and hygiene in South Africa.

The project's objectives were the following:

1) Review the theory, practice and case studies of Citizen Science that has been applied in the sanitation sector and other related sectors, i.e. water sector.

2) Identifying the opportunities, risks, and challenges in applying Citizen Science to sanitation in South Africa. This will include a review of the challenges, drivers and barriers for success in using Citizen Science.
3) Scope the requirements, standards, components, indicators and measures necessary for gathering and analysing citizen-based information about sanitation.
4) Examine the possibility of linking with other Citizen Science monitoring that is already in use in the country and other sanitation monitoring and reporting systems.
5) Pilot the tools that will be developed to gather and analyse citizen-based information about sanitation.
6) Based on the outcomes of the above, the specifications for a real-time Citizen Science monitoring system for South Africa could be developed as a follow-on to this project.

METHODOLOGY

The methodology for the project was based, together with the theory of Citizen Science, on the principles of Participatory Action Research (PAR), which entails collectively diagnosing and defining a “problem”, planning a course of action to address the “problem”, taking action, evaluating the outcome, and reflecting and learning. Participatory methodologies recognise that people within communities – the citizens – are best placed to make decisions that affect their lives. Participatory approaches inherently believe in and build on the skills, knowledge, experience and culture of community groupings, in order to engage them in designing and implementing their own development goals.

THE SANITATION MONTORING CHALLENGE

The latest WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) report indicated that nearly half the world’s population lacked safely managed sanitation services in 2020 and that at current rates of service delivery the globe would only reach 67% coverage by 2030, leaving 2.8 billion people without safely managed services. Similarly, only 71% of the global population had access to a handwashing facility with soap and water, with the JMP projecting that at the current rate of progress this population will only increase to 78% of the population by 2030. The JMP was only able to report the above progress and projections due to the significant progress that had been made in collecting and supplying sanitation and hygiene data and information over the past 5 years. However, major data gaps exist, globally and from countries, related to safely managed sanitation from the perspective of whether an on-site sanitation system has been safely emptied and the content treated, with only 7 countries currently having these data available, and only 1 country having this data available for the rural areas.

Currently, South Africa is unable to report the percentage of the population that has access to a **safely managed** sanitation service, due to data gaps. South Africa’s progress with achieving universal and equitable access to a hygiene facility is well below the current global estimate of 71% of households, with the country reporting that only 44% of households had access to this basic service. The UNICEF ESARO report predicted that South Africa would only achieve the SDG6.2 indicators well after the 2030 target date. Even though South Africa does, through the General Households Survey, collect most of the relevant data required to report on SDG6, it is unable to report on the safe and hygienic management and treatment of human sanitation facilities, which is the key data that are required for the country to be able to report the levels of access to a safely management sanitation facility (as required by the SDG6.2).

Citizen Science offers an innovative and unique way to address some of the resource and data gaps in South Africa’s current SDG 6.2 reporting process, specifically for capturing sanitation and hand hygiene data for the rural and on-site, dry sanitation systems in the country. Citizen Science could make contributions in three types of sustainable development and SDG processes, namely providing input into defining national and sub-national targets and metrics, aiding invaluable inputs into monitoring progress and assisting with implementing actions required to achieve sustainable development and the SDGs.

It is important to recognise that the monitoring scale, method, approach and process for sanitation and hygiene, particularly rural sanitation, is unique. When monitoring water supply and ambient quality of water resource, many of the same methods and tools can be utilised, and the same process of taking a water sample, running analysis and interpreting the result can be utilised. Sanitation and hygiene cannot follow this same process. It is not possible to take a 'sample' for a rural sanitation facility or hand hygiene facility and test, analyse, interpret and report the results of the analysis. Hence, citizen monitoring of sanitation and hygiene needs to utilise very different tools, methods, process and procedures.

Noting these nuances and challenges in monitoring and reporting rural, on-site, sanitation systems, there is a need to design a system that can address these challenges in partnership with citizens and to encourage the citizens (i.e. households) to participate in monitoring and reporting their access to sanitation services and to monitor and report the state of their sanitation service on an ongoing basis.

FRAMEWORK FOR THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM

In the development of the framework, the principals of Citizen Science were applied to develop a framework for Citizen Science monitoring and reporting on the sanitation and hygiene SDG targets, international parameters, South African legislation and policy parameters, as well as being able to monitor and report the public's sanitation and hygiene imperatives.

In designing a Citizen Science sanitation and hygiene information platform (CS-SHIP) for South Africa, it is necessary to understand the top-down strategic objectives and intents that would form the higher levels of a hierarchical framework. The bottom-up citizen determined monitoring requirements for sanitation in the country would then be categorised to speak to each of the upper-level national sanitation strategic objectives/policy intents. The Citizen Science monitoring framework thus applies the bottom-up citizen driven monitoring priorities with the top-down international and national sanitation objectives and intents.

The key international indicators for realising the human right to sanitation are the following:

- Availability – everyone is entitled to sufficient and continuous water for personal and domestic use, and a sufficient number of sanitation facilities.
- Affordability – services must be affordable to all – they must not compromise the ability to pay for other necessities guaranteed by human rights, e.g. food or housing.
- Quality – water has to be safe and present no threat to health. Sanitation must be hygienically and technically safe. Access to water for cleansing and hand washing is essential.
- Acceptability – sanitation facilities must be culturally acceptable, often meaning gender-specific and ensuring privacy and dignity.
- Accessibility – water and sanitation facilities must be accessible to everyone within – or in the immediate vicinity of – households, health and educational institutions, public institutions and places, and workplaces. Physical security must not be threatened.

The international commitment and national policy review conducted for this study demonstrated the policy intents that will need to be monitored to be able to report progress with these. The policy intents also have a number of components that need to be monitoring and reported for each intent. Designing a sanitation monitoring programme that measures and reports these intents and components, should address international and national sanitation reporting obligations, i.e. to design a top-down sanitation monitoring system. Citizens would not be expected to contribute to or participate in the research behind such a system.

Participation of citizens in research or monitoring progress will be dependent on their interest in the subject (i.e. sanitation), the perceived benefits of participating and the ability of the monitoring system to encourage their inputs, participation and continued support. Hence, to ensure that citizens' needs inform a citizen

sanitation and hygiene monitoring programme, a survey of citizens perceptions, interest and priorities for sanitation was conducted. The following emanated from the citizen survey:

1. It is possible to gather sanitation information from citizens from an electronic platform.
2. Almost all citizen respondents were willing to participate in the survey – indicating a generally positive attitude to those that started the survey.
3. Citizen respondents could clearly inform the design of the monitoring systems through providing invaluable information on the following:
    a. What they consider important in their use of a sanitation facility. If these key priorities are utilised to design the Citizen Science monitoring programme for sanitation, one would expect greater participation in the study.
    b. What would motivate participation of citizens in such a Citizen Science monitoring programme. Again, designing a CS monitoring programme to consider these motivations should increase participation in the monitoring.
    c. What prevents participation of citizens in such a Citizen Science monitoring programme. Again, designing a Citizen Science monitoring programme to remove or minimise the barriers to participation should increase participation in the monitoring.
    d. The correct communication/Citizen Science tools for the monitoring programme. Designing a Citizen Science monitoring programme utilising the simplest, easiest and preferred communication tools should increase participation in the monitoring.

The above perceptions, interest and priorities were utilised to inform the specifications of the Citizen Science sanitation and hygiene information platform (CS-SHIP).

SPECIFICATIONS FOR THE CITIZEN SCEINCE SANITATION AND HYGIENE INFORMATION PLATFORM

The specifications of the CS-SHIP in South Africa merged the top-down international sanitation and hygiene commitment (i.e. SDGs) and the South African sanitation and hygiene policy intents with the sanitation priorities of the citizens. The CS-SHIP was designed so that Citizen Science could provide the relevant information and data on the sanitation and hygiene facility, and that this information and data would contribute to the national/international sanitation monitoring and reporting system. The CS-SHIP would also be able to monitor and report on the citizens' priorities for their sanitation/toilet and hygiene facility, thus providing them with information and insight into their sanitation facility and thus, report on the state of the sanitation facility. Citizens would also receive feedback from the CS-SHIP on the state of their sanitation facility and obtain potential corrective actions, if the status of the sanitation/toilet and hygiene facility is shown to be inadequate. In the CS-SHIP, the flow of data and information would occur between various stakeholders. The four crucial stakeholders required to operationalise the CS-SHIP are **the participating citizens** (the key source of data and the pivotal human component), **the scientist – ultimately the artificial intelligence (AI) system** (data storage, data cleaning, data analysis and reporting), **local government** (submit queries to the CS-SHIP to generate credible, up-to-date and scientifically valid data on sanitation and hygiene in their rural and peri-urban areas), and **national government** (submit queries to the CS-SHIP to generate credible, up-to-date and scientifically valid data on sanitation and hygiene in the country for policy and reporting on international SDG targets).

In order to collect data to report on the requirements and imperatives for sanitation in South Africa, two information gathering tools were designed for the CS-SHIP specific to South African conditions and cultures:

- Short electronic questionnaire – designed and developed on KoboToolbox to capture citizens needs for understanding the state of their sanitation and hygiene facilities (further review and refinements will be required in the development of the full CS-SHIP).
- Photography – manual analysis at this stage, which provided insight into the specifications required for the AI and image recognition software (still to be designed to be utilised in future for the CS-SHIP).

These tools focus on utilising existing hardware, i.e. computers, laptops, tablets and smartphones, that most people already have and use. Thus, there is no need to incur expenditure in terms of hardware to gather the data. The Internet of Things, improved access to internet, and smartphone technology have infinitely expanded the opportunities for Citizen Science as each household, no matter how remote, has at least one cell phone at some stage of the month.

In using this assessment tool, photos/images could be uploaded to assess the condition of a sanitation facility through image recognition/computer vision. The technological evolution in the quality of cameras on smartphones makes uploading photos/images an easy task. Any image recognition software may be applied for sanitation, however, the machine learning specific to sanitation and including the scoring and feedback loop will need to be built from the beginning. Image recognition is a sub-category of computer vision technology and a process that helps to identify the object or attribute in digital images. The CS-SHIP would be designed to capture 4 or 5 images of a household's sanitation and hygiene facility.

These images are expected to provide sufficient information for the AI to analyse the images and generate a score and report for each household's sanitation and hygiene facility. These two tools can be used by a household, but can also be used by an individual representing his/her community/settlement in the deep rural areas by taking photographs of toilets and administering the questionnaire for those who may be not have a smartphone, or may not be able to read/write. Different levels of assessment can be applied using images and photos:
Level 1, 'landscape assessment' relies on rough settlement-scale information, typically gathered through aerial photographs and stored in, or converted to, a geographic information system (GIS) format.
Level 2 is 'rapid assessment' at the specific site scale, using relatively simple, rapid protocols. Level 2 assessment protocols are to be validated by and calibrated to Level 3 assessments.
Level 3 is 'intensive assessment' and uses intensive research-derived, multi-metric indices. They are meant to give detailed information regarding how well a sanitation facility is functioning.

One of the key questions of the scientists in this study was what were the most crucial elements of a sanitation and hygiene facility that need to be assessed to provide a scientifically credible score for the state of a sanitation and hygiene facility at a household and community level. South Africa has conducted a number of expensive assessments of sanitation over the years, using a checklist to determine the presence or absence of elements that are required to meet SDG requirements and to comply with policy and national norms and standards for a basic sanitation and hygiene facility. Some of these checklists utilised assessments of over 40 elements to determine a score for the facility and for facilities with a community. A stepwise regression analysis was conducted using SPSS to determine the key elements for a VIP toilet (as example) to the score that was calculated for each of the facilities (in the 2008/9 dataset) and the programme (community) (in the 2007/08 dataset). The result of the regression provided the suite of elements that had the greatest impact on the score for the facility, with these elements assumed to be vital to include in any image/scientific assessment (using photo images) of the state of a sanitation facility. The regression analysis also provided an algorithm that could be utilised in future to estimate the score for the state of a household's sanitation facility by the AI in the CS-SHIP. The full range of these elements and the checklists will be finalised during the further design and development of the computer vision/image recognition software. The elements will be assessed according to the policy requirements, the building code, and the applicable water and sanitation norms and standards.

Once the information and photos/images have been collected, applying the assessment method will result in a sanitation facility receiving a score or a rating, which can be categorised and colour coded. The score and the rating can be reflected as a letter of the alphabet, which aligns with the ratings of the South African Institute for Civil Engineering (SAICE) Infrastructure Report Card. The score of the toilet can be used for corrective actions on household, settlement, local government, and national government levels. It focuses on the learning element where the feedback to the participants contains the score for the sanitation facility, as well as the corrective actions that can be taken. The scoring and feedback are case specific, each toilet's score per element will determine the feedback to the user through automatic triggers that will be developed as part of

the computer vision software. To report to local and national governments, the scoring will be aggregated from individual toilets to form a score per settlement. The score for the settlements will be combined to form a score for a local municipality, and so on, to be able to report on the state of sanitation per settlement, local, district, province, and national levels.

The piloting of the tools for the CS-SHIP occurred on World Toilet Day (19 November 2021) in Enkanini near Stellenbosch in the Western Cape, and in Tshabo 2 near Bisho on 20 November 2021. Even though the photographs needed to be assessed manually, the pilot showed that the two tools were easy to use and successful in gathering the information needed to know what the state of household sanitation in the rural areas is and to report on the national and international imperatives.

CONCLUSIONS

To be able to develop and implement sanitation interventions and appropriate solutions, particularly in this time of COVID-19, it is necessary to be sure that the actual, in real-time state of sanitation in the country is known, that the daily challenges experienced with sanitation (toilets and handwashing) are being captured and reported, and that real-time information on the safety, hygiene, accessibility, equitability and reliability of sanitation services is known, especially in peri-urban and rural areas of a country.

It is clear from the study that Citizen Science is applicable to monitoring sanitation infrastructure in the country. In fact, the inputs from the citizens in what they require a sanitation facility to be and do for them formed the foundation and the basis of designing the Citizen Science sanitation information platform (CS-SHIP).

For the CS-SHIP to be successful and work optimally in obtaining real-time, cost-saving, factual and objective data and information on sanitation facilities in the country, the inputs and participation of all citizens are crucial, meaning that the CS sanitation monitoring platform/system is a citizen-based and citizen scientist-dependent system.

RECOMMENDATIONS

For the CS-SHIP to be successful and work optimally in obtaining real-time, cost-saving, factual and objective data and information on sanitation facilities in the country, it will be necessary to ensure the inputs and participation of all citizens, meaning that the CS-SHIP is a citizen-based and citizen scientist-dependent system. Thus, the role and participation of the citizen need to be explored and central in the further development of the platform. In the CS-SHIP, the role of the citizen was to design and develop the platform, and also to provide the information necessary for the platform/system to stay operational in monitoring the sanitation situation of the country. This focus needs to be maintained in the further development of the platform. Models (incentives, benefits, awards, feedback loops, etc.) for sustainable and consistent participation of the citizens in the CS-SHIP by providing the data and evaluating the platform need to be explored.

Interaction and engagement with national and local government to ensure alignment of the platform and their sanitation planning and reporting needs and requirements.

Further research is necessary to fine-tune the algorithms based on the information provided as the sanitation score is a function of elements that influences the algorithms. The inclusion of the elements of menstrual health needs to be researched and added to the tools of the CS-SHIP.

The next step is to continue to engage with other experts in the water, sanitation and hygiene sectors regarding monitoring sanitation to ensure synergies and alignment of Citizen Science efforts in WASH and menstrual health.

Based on the results of the study, a proposal for further funding for the development of the Smartphone App, the computer vision software, and the algorithms (AI) will be prepared and presented to national and international donors/funders for furthering the application of the outputs of this study.

Once all the elements and tools of the CS-SHIP were developed and tested (such as the computer vision, data storage, algorithms, etc.), the requirements for the roll-out of the CS-SHIP would need to consider and include, inter alia, raising awareness, being inclusive, providing incentives, awards and motivation to maintain citizen participation, and sharing results and findings.

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Sudhir Pillay	WRC
Mark Bannister	DWS
Pikane Mahlane	DWS
Norma Lerobane	DWS
Others	
Penny Jaca	WRC

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ACRONYMS & ABBREVIATIONS

AI	Artificial Intelligence
CS	Citizen Science
CS-SHIP	Citizen Science Sanitation and Hygiene Information Platform
DNN	Deep Neural Network
DWS	Department of Water and Sanitation
ECSA	European Citizen Science Association
EU	European Union
GHS	General Household Survey
GIS	Geographic Information System
GPS	Global Positioning System
H2020	Horizon 2020
IDP	Integrated Development Plan
IoT	Internet of Things
IP	Intellectual Property
IWDM	Integrated Water Demand Management
JMP	Joint Monitoring Programme
MDGs	Millennium Development Goals
MIG	Municipal Infrastructure Grant
OED	Oxford English Dictionary
PAR	Participatory Action Research
RDP	Reconstruction and Development Programme
SAICE	South African Institute for Civil Engineering
SANS	South African National Standards
SDGs	Sustainable Development Goals
SWOT	Strengths, weaknesses, opportunities and threats analysis
UD	Urine Diversion
UK	United Kingdom
UN	United Nations
USA	United States of America
VIP	Ventilated Improved Pit
WASH	Water, sanitation and hygiene
WHO	World Health Organisation
WRC	Water Research Commission
4IR	Fourth Industrial Revolution

GLOSSARY

Adequate sanitation facility	A facility that effectively separates excreta from human contact, and ensures that the excreta do not re-enter the immediate environment or pose any risk to the humans or the environment.
Appropriate sanitation service	A service that effectively protects and preserves public health and the natural environment whilst being acceptable, affordable, manageable and adaptable in responding to the demand; the socio-cultural needs; the users' ability to afford continued operation; and the available organisational/institutional and technical capacities.
Appropriate technology	Is taken to refer to conventional, alternative and intermediate infrastructure/ device, tools and processes that are suited to the specific time and place, and which meet context-specific criteria and key characteristics. This means the sustainable application or operation of a technology (process, tool and/or device) to meet national imperatives within the local institutional, financial, social, cultural, ethical, economic and environmental requirements and constraints experienced by the authority or consumer responsible for the technology.
Basic sanitation	Is the minimum acceptable level of sanitation, as described in the 2016 National Sanitation Policy: a) appropriate health and hygiene awareness and behaviour; b) the **lowest cost, appropriate** system for disposing of human excreta, household wastewater, **greywater**, which **considers resource constraints,** is acceptable and affordable to the users, safe including for children, hygienic and easily accessible and which does not have a **detrimental** impact on the environment; and c) a toilet and **hand washing** facility for each household. **d) ensures clean living environment at a household and neighbourhood levels** **including supervision of/ assistance with defecation practices of small children and people with disabilities and special needs**.
Basic sanitation facility	Is defined by the 2016 National Sanitation Policy as *the infrastructure that* **considers natural (water; land; topography) resource protection**, is safe (including for children), reliable, private, **socially acceptable, skilled and capacity available locally for operation and maintenance** , protected from the weather and ventilated, keeps smells to the minimum, is easy to keep clean, minimises the risk of the spread of sanitation-related diseases by facilitating the appropriate control of disease carrying flies and pests, **facilitates hand washing** and enables safe and appropriate treatment and/or removal of human waste and wastewater in an environmentally sound manner.
Basic sanitation services	As per the 2016 National Sanitation Policy, a basic sanitation service is the provision of a basic sanitation facility which is **environmentally sustainable**, easily accessible to a household **and a consumer**, the sustainable operation and maintenance of the facility, including the safe removal of human waste, **greywater** and wastewater from the premises where this is appropriate and necessary, and the communication and local monitoring of good sanitation, hygiene and related practices.
Citizen Science	Is defined by the European Commission as the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture.
Effluent	Effluent, is defined in the Regulations relating to Compulsory National Standards and Measures to Conserve Water as human excreta, domestic sludge, domestic wastewater, greywater or wastewater resulting from the commercial or industrial use of water.

Free basic sanitation	Is a free basic sanitation service that is affordable ongoing services to at least the basic level of sanitation for indigent households according to the 2016 National Sanitation Policy.
Greywater	Is the untreated wastewater from baths, showers and hand basins. Wastewater from kitchen sinks, dishwashers and washing machines (except if environmentally friendly detergents are used) is excluded from the definition due to its high solids content and the negative impact of softeners and other undesirable chemicals on the environment.
Handwashing	Is the appropriate technique involving the use of water and soap, ash, or other detergent with the required amount of scrubbing of all hand surfaces and finger nails and rinsing with clean water.
Hygiene	Is defined in the 2016 National Sanitation Policy as personal and household practices that serve to prevent infection and keep people and environments clean, and the conditions and practices that help to maintain health and prevent the spread of diseases.
Hygiene education	Relates to all activities that aim to increase an individual's knowledge about issues relating to personal habits and practices that affect one's health, particularly in relation to water and sanitation services. Hygiene education includes personal hygiene, water hygiene, food hygiene, human waste hygiene and environmental hygiene education to ensure appropriate sanitation practices for the protection of human waste.
Hygiene promotion	Is systematic approaches to encourage the widespread adoption of safe hygiene practices in order to reduce diarrhoeal and other water- and sanitation-related diseases by focusing on determinants of behaviour change, which may not necessarily be directly related to knowledge of the health consequences of poor hygiene.
Improved sanitation facility	Is a sanitation facility that meets the basic requirements. All facilities not meeting this requirement, are taken as unimproved. Notwithstanding this, pit toilets without a slab or platform or vent pipe, bucket toilets, chemical toilets (unless used in a temporary or emergency situation), and open defecation in fields, forests, bushes, beaches, bodies of water, or with solid waste are unimproved facilities.
Menstrual hygiene	Is the implements (including sanitation materials, soap and adequate clean water) and practices that will allow girls and women to manage the menstrual bleeding with privacy, comfort and dignity.
Norms and standards	Are the required behaviour that should not be deviated from, whether quantitative or qualitative, or average, or minimum or maximum.
Operation and maintenance	**Operation** refers to the direct access to the sanitation facility by the user (e.g. operating the toilet), to the activities of any operational staff (e.g. operators of motorised suction pumps), and to the rules or by-laws, which may be devised to govern who may access the system, when, and under what conditions. **Maintenance** is about the technical activities, planned or reactive, which are needed to keep the system working and the service sustainable.
Rural sanitation	Is sanitation infrastructure erected in the rural areas, which would typically be on-site sanitation (pit toilets, VIP toilets, UD toilets, composting toilets, pour-flush toilets, low-flush toilets, flush toilets linked to a septic tank).
Safe management of excreta	The containment, extraction, and transport of excreta to a designated disposal or treatment site, or its hygienic reuse to ensure that it (excreta) poses no risk to human health or the natural environment.
Sanitation	Is defined by the 2016 National Sanitation Policy, as the principles and practices relating to the collection, removal or disposal of human excreta and household, **public institution**, **industrial, agricultural and mining** wastewater, **greywater** waste as they impact upon people and the

	environment. Good sanitation includes appropriate health and hygiene education and behaviour, **hand hygiene** and acceptable, affordable and sustainable sanitation services.
Sanitation facility/ infrastructure	Is the structures and technology system(s) that create effective barriers between excreta and human contact from collection, transport, storage, treatment, reuse or disposal.
Sanitation services	Is defined by the 2016 National Sanitation Policy, as the collection, removal**, treatment** and or disposal of human excreta, and domestic **public institution** wastewater, and the collection, treatment and/or disposal of **municipal, agricultural, mining and** industrial wastewater. This includes all the organisational arrangements necessary to ensure the provision of sanitation services including, amongst others, **consideration of natural resources, social acceptance,** appropriate health, hygiene and sanitation-related awareness **and technologies**, the measurement of the quantity and quality of discharges where appropriate, **apply the polluter pays principle**, the associated billing, collection of revenue and consumer care. Water services authorities have a right but not an obligation to accept industrial, **agricultural and mining** wastewater within their area of jurisdiction.
Sustainable sanitation services	Meet the user and environmental requirements, at consistent levels without undue and extended interruption of access. It would typically encompass all five aspects of sustainability, i.e. environmental integrity, social equity, economic efficiency, and appropriateness, underpinned by sufficient and effective institutional support.
User participation	The highest possible meaningful and effective engagement, in appropriate and acceptable ways, of the end consumers of the service.
Wastewater	Any water whose pristine or potable quality has been altered by domestic, industrial or other use or process.

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

The world is facing unprecedented social, environmental, health, and economic challenges, specifically in the time of COVID-19. Tackling and resolving these challenges will require policymakers, the public and private sector, scientists, and citizens to collaborate and work together (Hecker, 2019). Reliable, consistent and disaggregated health, environment and economic data will be essential:

a) to stimulate future political commitments;
b) inform new policy-making and decision-making that will be required due to the global shift that have occurred as a result of the COVID-19 pandemic; and
c) to trigger and inform effective and efficient investments towards.

Now, more than ever, data and information on the sustainability of our actions and activities is necessary. The 2030 Agenda for Sustainable Development, which incorporates the Sustainable Development Goals (SDGs), has elevated the need for scientific monitoring and reporting to track achievements related to the goals, targets and indicators in Agenda 2030. Monitoring, reporting and learning is also critical to reversing the impacts of the global pandemic being experienced by the countries and people of the world. Agenda 2030 reinforced that "quality, accessible, timely and reliable disaggregated data will be needed to help with the measurement of progress and to ensure that no one is left behind" (United Nations General Assembly, 2015).

It is clear, as the globe experiences the first global pandemic in centuries, that the COVID-19 pandemic has and will continue to have significant impacts on the health and economies of countries, plunging more countries into recession and an estimated additional 119 to 124 million people falling into extreme poverty during 2020 (WHO and UNICEF, 2021). Measures taken by governments to contain and mitigate the pandemic have led to widespread disruption in the provision and financing of essential services, including water supply, sanitation and hygiene (WASH). The pandemic has also impacted on where and how countries focus their limited fiscal resources, which could impact on the levels and types of water, sanitation and hygiene (WASH) services provided and thus progress with the SDGs. The COVID-19 pandemic mitigation measures, with a focus on hand hygiene and access to protective materials (i.e. soap), should however, reflect positively on progress with some of the SDG 6.2 indicators. The shifts in fiscal allocation, as well as social distancing and lockdown regulations, are expected to impact on the ability of countries to collect and capture data on SDG6, as well as the other SDG indicators. The 2020 Joint Monitoring Programme (JMP) report on progress with SDG6 indicated that *COVID-19 has posed severe challenges to the collection and production of data at all levels, which will have a long-term impact on national and global monitoring of all key development indicators. At the same time, it has increased demand for new data on emerging issues and for 'real-time' information to evaluate the impact of the outbreak and the effectiveness of responses. In May 2020, the United Nations Statistics Division (UNSD) and the World Bank launched a global survey to assess the impact of COVID-19 on statistical operations at country level. It found that the pandemic has caused widespread disruption to routine data collection and led to delays, interruptions, diversion of funding, and, in some cases, cancellation of planned censuses and household surveys. The final assessment in December 2020 showed that many National Statistical Offices (NSOs) have been forced to close for long periods, 75% reported that face-to-face data collection had been partially or fully suspended, and most were uncertain about when they would resume. Many NSOs reported exploring remote methods of data collection to fill data gaps, but highlighted the need for further capacity building in this area* (WHO and UNICEF, 2021).

The lack of access to ongoing, real-time monitoring and information of the state of sanitation services in South Africa, at a national and local level, has a major impact on the fiscal and decision-making processes at local

and national government levels. To be able to develop and implement sanitation interventions and appropriate solutions, particularly in this time of COVID-19, it is necessary to be sure that the actual, in real-time state of sanitation in the country is known, that the daily challenges experienced with sanitation (toilets and handwashing) are being captured and reported and real-time information on the safety, hygiene, accessibility, equitability and reliability of sanitation services is known, especially in peri-urban and rural areas of a country. The globe, in a post-COVID-19 era, with a focus on a new digital age and the fourth industrial revolution (4IR), has highlighted the need for reinventing the manner in which knowledge is produced, distributed and acted upon (Hecker, 2019). Citizen Science (CS) is one manner in which new knowledge is produced and distributed while building new relationships between science and society. Citizen Science has a role to play in tracking progress towards the WASH SDGs, bridging the current gaps in approaches, methods, tools and platforms to gathering, analysing and reporting high-quality, timely and accessible data. Citizen Science can be utilised as an efficient and effective approach to satisfy data gaps that currently exist in reporting the status quo of WASH services locally, provincially, nationally and internationally. For Citizen Science to be effective, however, it will need to be meaningful to the individuals and communities that are providing information and data on their WASH services. Citizen Science monitoring systems would need to provide useful information to the citizens while reflecting the state of WASH infrastructure at different levels (from the smallest ward or neighbourhood to settlement/ community level, and local, provincial and national levels).

Apart from reflecting the real WASH situation at various scales in the country and providing valuable insight to the citizen scientists on the state of their WASH services, Citizen Science research that directly involve members of the public can also increase the participants' (citizen scientists) awareness and scientific knowledge of WASH monitoring, as well as facilitates changes in their attitudes towards science and in behaviour related to their WASH services.

The United Nations (UN)'s Sustainable Development Goal 6 Synthesis Report 2018 on Water and Sanitation indicated that the use of Citizen Science, now and in the future, "must play an increasing role in addressing data gaps in time and space. It could also provide complementary evidence and broaden the awareness and engagement of civil society and the private sector" (UN, 2018).

The Water Research Commission (WRC) also recognises that Citizen Science tools have the potential to close the perceived gaps between government's role in service delivery and [that] of citizens in responding to and supporting different aspects of service delivery (Graham & Taylor, 2018). Hence, the application of Citizen Science in the WASH sector, is aptly placed to assist South Africa with effectively and efficiently collecting, storing, analysing and reporting data and information on the state of WASH, while at the same time contributing to national and international mandates of stakeholder participation, transparency, accountability, access to basic services and addressing basic human rights.

1.2 PROJECT AIMS

The aim of this study was to determine the application of Citizen Science in the gathering, analysing and reporting of data and information of the state of sanitation in South Africa, utilising a scientifically reliable and inexpensive participatory technique through existing technology.

The project's objectives were the following:

1) Review the theory, practice and case studies of Citizen Science that has been applied in the sanitation sector and other related sectors, i.e. water sector.
2) Identifying the opportunities, risks, and challenges in applying Citizen Science to sanitation in South Africa. This will include a review of the challenges, drivers and barriers for success in using Citizen Science.
3) Scope the requirements, standards, components, indicators and measures necessary for gathering and analysing citizen-based information about sanitation.

4) Examine the possibility of linking with other Citizen Science monitoring that is already in use in the country and other sanitation monitoring and reporting systems.
5) Pilot the tools that will be developed to gather and analyse citizen-based information about sanitation.
6) Based on the outcomes of the above, the specifications for a real-time Citizen Science monitoring system for South Africa could be developed as a follow-on to this project.

The focus of the study is thus on the SH in WASH – namely Citizen Science monitoring and reporting of the state of sanitation and hygiene in South Africa.

1.3 METHODOLOGY OF THE STUDY

The methodology for the project is based on the principles of Citizen Science, as well as Participatory Action Research (PAR). PAR entails collectively diagnosing and defining a "problem", planning a course of action to address the "problem", taking action, evaluating the outcome, and reflecting and learning. Participatory methodologies and Citizen Science recognise that people within communities – the citizens – are best placed to make decisions that affect their lives. Participatory approaches inherently believe in and build on the skills, knowledge, experience and culture of community groupings, in order to engage them in designing and implementing their own development goals.

The study included 6 activities to achieve the aims and objectives:

- **Activity 1:** Literature review of Citizen Science and sanitation.
- **Activity 2:** Identifying the opportunities, risks, and challenges in applying Citizen Science for sanitation in South Africa.
- **Activity 3:** Scoping the requirements, standards, components, indicators and measures necessary for gathering and analysing citizen-based information about sanitation.
- **Activity 4:** Piloting the tools that will be developed to gather and analyse citizen-based information about sanitation.
- **Activity 5:** Workshop with key role players and team members the information that was gathered and how it would shape the future of sanitation information and data gathering.
- **Activity 6:** Report on the outcomes of the project.

1.4 PURPOSE AND STRUCTURE OF THE REPORT

The purpose of this report, Deliverable 5: Final report, is to summarise and report on the theory and practice of Citizen Science; the challenges; the monitoring framework, the specifications; and the results of the pilot of the tools for the Citizen Science sanitation and hygiene information platform (CS-SHIP).

The report has the following structure:

- **Chapter 1** summarises the aim, objectives and methodology of the project and the purpose of the report.
- **Chapter 2** highlights the monitoring challenges for sanitation worldwide and in the country.
- **Chapter 3** discusses the emerging approaches and issues in designing and implementing a Citizen Science research initiatives and includes aspects such as a Citizen Science monitoring programme for sanitation services in South Africa.
- **Chapter 4** sets the framework in which Citizen Science monitoring of sanitation infrastructure operates.
- **Chapter 5** scopes the international, national and civic requirements, standards and components of sanitation monitoring.
- **Chapter 6** provides the specifications for the Citizen Science sanitation and hygiene monitoring system.

- **Chapter 7** summarises the piloting of the tools of the Citizen Science sanitation and hygiene information platform.
- **Chapter 8** indicates some actions and activities necessary for the roll-out of the Citizen Science sanitation and hygiene information platform for rural sanitation facilities in South Africa.
- **Chapter 9** is the conclusions and recommendations related to applying Citizen Science for monitoring rural sanitation facilities/infrastructure in South Africa.

CHAPTER 2: THE SANITATION MONITORING CHALLENGE

2.1 A CHANGING LANDSCAPE – SANITATION AND HAND HYGIENE IN THE COVID-19 PANDEMIC

The year 2020 has seen a massive global shift in the manner in which people go about their business and daily activities. The emergence of the SARS-CoV-2, or coronavirus, and the massive number of COVID-19 cases across the globe, has shifted government's attention to ensuring that barriers to the transmission of the virus are in place. With the main routes of transmission of the coronavirus being respiratory droplets and direct contact with the virus, the health sector has highlighted the need to minimise close contact with an infected individual and to put in place measures to ensure that individuals do not come into contact with respiratory droplets that land on surfaces where the virus could remain viable (WHO and UNCEF, 2020).

Perhaps the greatest shift in focus in the WASH sector during the COVID-19 pandemic is that of hand hygiene. Hand hygiene has become extremely important to prevent the spread of SARS-CoV-2. **Promoting and practicing the best hand hygiene practices** in all settings and ensuring that the necessary infrastructure (equipment and supplies), as well maintenance protocols, are in place to practise these hand hygiene activities are crucial (WHO and UNCEF, 2020).

Handwashing with soap is vital, with research demonstrating that normal soap is effective in inactivating enveloped viruses, such as the coronaviruses (Montville and Schaffner, 2011, Sickbertbennett et al., 2005). Soaps can deactivate/remove the virus from surfaces and hands through a number of mechanisms, as shown in Figure 1:

1) **Deactivation of the virus through disruption of the lipid member** (Figure 1a). The amphiphilic nature of soap makes is both hydrophilic and hydrophobic (Chaudhary et al., 2020). Since the SARS-CoV-2 is enveloped in a lipid layer (lipids themselves are amphiphilic), exposure to amphiphilic chemicals like soap can interrupt this layer, rupturing the lipid membrane and thus deactivating the virus (Chaudhary et al., 2020). However, washing of hands for only 20 seconds would not deactivate all viruses. Two additional mechanisms assist with the process.

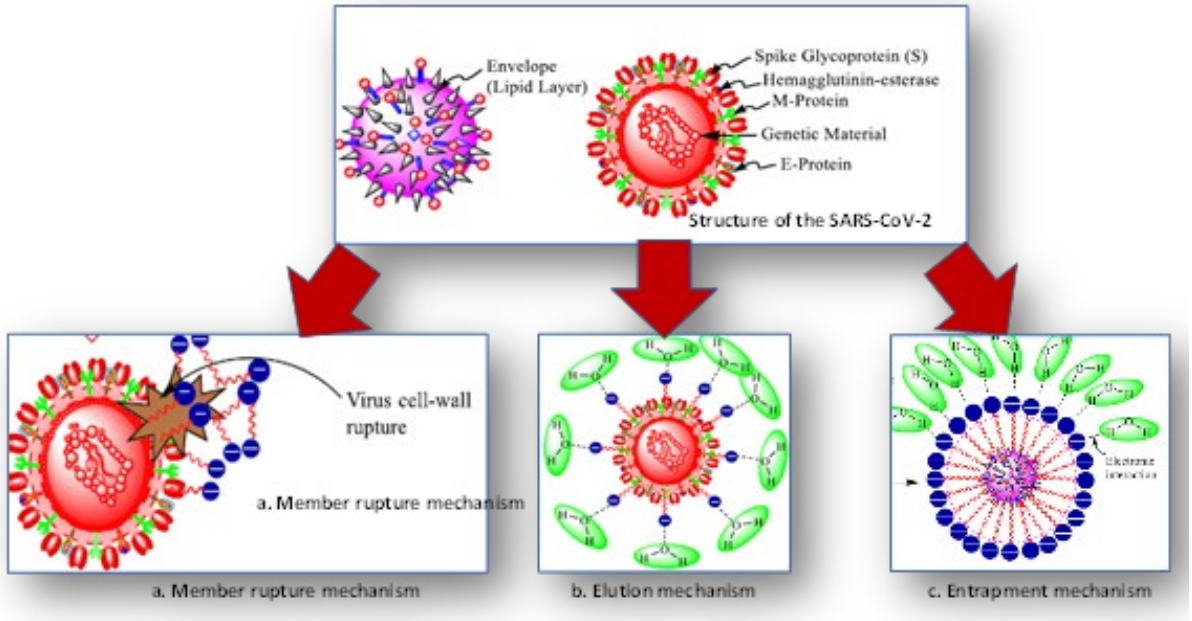


Figure 1: Structure of the SARS-CoV-2 (coronavirus) and the three mechanism of soap deactivating or removing the virus from hands and surfaces (taken from Chaudhary et al. (2020)).

2) **Elution of the virus in soap water** (Figure 1b). In this mechanism, the amphiphilic nature of soap in water can react with the viral particles to form monomers, that can be washed from hands (Chaudhary et al., 2020).
3) **Entrapment in micelles** (Figure 1c). In this mechanism, the amphiphilic nature of soap can form micelles and entrap the virus within the nucleus of the micelle, which in turn can be washed from the hands (Chaudhary et al., 2020).

The use of soap in handwashing must thus become a crucial barrier in the interventions to prevent and minimise exposure to the SARS-CoV-2 virus.

The WHO and UNICEF (2020) indicated in their guidance on infection prevention and control, that while handwashing with soap and water is vital, the quality of water used for handwashing does not necessarily need to be of a potable quality (Verbyla et al., 2019). Potable water quality in the case of South Africa requires water to meet the SANS 241 standards. Research evidence suggests that water with moderate faecal contamination, when used in conjunction with soap and the correct handwashing technique, can effectively remove pathogens from hands (Verbyla et al., 2019). The WHO and UNICEF (2020) guidance does, however, recommend that all efforts should be made to use and source water of the highest quality possible for hand hygiene (WHO and UNCEF, 2020).

The WHO and UNICEF (2020) guidance also indicated that alcohol-based hand rub can be utilised for hand hygiene where soap and water were not available. These hand sanitisers must, however, contain at least 60% alcohol (v/v%) (WHO and UNICEF, 2020). When soap and water, or alcohol-based hand rub, are not available, the use of ash may be considered (WHO and UNICEF, 2020). Drying of hands after washing is important for effective hand hygiene (WHO and UNICEF, 2020).

What is clear from the WHO and UNICEF (2020) and other global guidelines on the prevention and barriers to the spread of the corona virus, is that safely managed water, sanitation, and hygiene (WASH) services are an essential part of preventing and protecting human health during this infectious disease outbreaks (WHO and UNICEF, 2020).

According to the UN-Habitat (2020), COVID-19 is expected to have the greatest impact on the world's most vulnerable people, many of whom live in informal settlements and rural community settings. Provision of safe, hygienic and cost-effective water and sanitation services to these vulnerable communities, to health care facilities, and to schools is critical to enable best practice in handwashing, hygiene, and disinfection as a barrier to the COVID-19 virus and to prevent future pandemics.

According to the World Bank (2020), safely managed WASH services are also critical during the recovery phase of a disease outbreak. WASH services can alleviate the secondary impacts of an outbreak on community livelihoods and wellbeing but can also be impacted by these secondary impacts. These secondary impacts, such as disruptions to supply chains, inability to pay bills, or panic-buying, can have negative impacts on the continuity and quality of water and sanitation services, the ability of affected households to access and pay for WASH services and products (for instance, soap, point of use water treatment or menstrual hygiene products), and the ability of schools, workplaces and other public spaces to maintain effective hygiene protocols. If WASH services and the secondary impacts of the pandemic are not managed effectively, both can increase the risk of further spreading of the virus, as well as increase the spread of water- and sanitation-related diseases World Bank (2020).

2.2 THE GLOBAL SANITATION AND HYGIENE SERVICE PROGRESS AND REPORTING CHALLENGES

It has been 5 years since the globe adopted Agenda 2030, and the Sustainable Development Goals that track progress towards achieving the intentions of the agenda. The Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP), a corroboration between UNICEF and the WHO, is responsible to report country and global progress of the SDG6 '*ensuring availability and sustainable management of water and sanitation for all*' and the supporting targets and indicators.

In 2021, the JMP published a 5-year review (2015-2020) of progress with the SDG6, with the report highlighting that the globe, at the current pace of action and implementation, was not on track to meet either the sanitation or the hygiene SDG 6.2 target of achieving *access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations* (WHO and UNICEF, 2021). Achieving the SDG 6.2 requires universal access to a safely managed sanitation service (i.e. improved facility in the yard with safe management of excreta/wastewater/faecal sludge) and a basic hygiene service (i.e. handwashing station with soap and water). The report indicated, shown in Figure 2, that the global community would need to quadruple their efforts to achieve the sanitation target of universal and equitable access to a safely managed sanitation and universal and equitable access to basic hygiene (WHO and UNICEF, 2021).

Figure 2: Global coverage of sanitation and hygiene services, 2015-2020 (%), and acceleration required to meet targets by 2030 (taken from WHO and UNICEF (2021))

The same JMP report indicated that nearly half the world's population lacked safely managed sanitation services in 2020 and that at current rates of service delivery the globe would only reach 67% coverage by 2030, leaving 2.8 billion people without safely managed services. Similarly, only 71% of the global population had access to a handwashing facility with soap and water, with the JMP report projecting that, at the current rate of progress, this number will only increase to 78% of the population by 2030. The hygiene sector of countries would need to quadruple their sanitation and hygiene efforts to reach the 2030 SDG targets of universal and equitable access to a safely managed sanitation service, including handwashing facility with soap and water in the home.

The JMP was only able to report the above progress and projections due to the significant progress that had been made in collecting and supplying sanitation and hygiene data and information over the past 5 years. The

reports provided by countries, shown in Table 1, led the JMP to indicate that *data availability for SDG indicator 6.2.1a (safely managed sanitation services) has also improved, rising from 84 countries to 120 countries (from 48% to 81% of the population). More countries have gained estimates for safely managed sanitation in rural (45) than in urban (30) areas. By contrast, there has been a relatively small increase in the number of countries with data available for SDG indicator 6.2.1b (basic hygiene services), rising from 70 countries in the 2017 baseline report to 79 countries in this 2021 progress update* (WHO and UNICEF, 2020). The table clearly shows major data gaps, globally and from countries, related to safely managed sanitation from the perspective of whether an on-site sanitation system has been safely emptied and the content treated, with only 7 countries currently having these data available, and only 1 country having this data available for the rural areas. Table 1 also indicated that less than a third of the 234 countries reporting progress on SDG6 could report on access to safely managed sanitation (67 countries) and a basic hygiene facility (79 countries), and the levels of sanitation (58 and 51 countries) and hygiene services (78 and 76 countries) within their urban and rural settlements (WHO and UNICEF, 2021).

Table 1: Percentage of population where data is available for WASH indicators, showing the number of countries with data in 2020 in brackets (taken from WHO and UNICEF (2021))

% of population (# countries, areas and territories) in 2020	DRINKING WATER					SANITATION						HYGIENE
	Basic	**Safely managed**	Accessible on premises	Available when needed	Free from contamination	Open defecation	Basic	**Safely managed**	Safely disposed of in situ	Emptied and treated	Wastewater treated	**Basic**
World (234)	99% (211)	45% (138)	99% (210)	82% (121)	45% (138)	97% (198)	99% (202)	81% (120)	66% (67)	1% (7)	52% (97)	50% (79)
Rural	98% (164)	55% (65)	98% (163)	86% (91)	55% (65)	97% (159)	98% (161)	73% (77)	70% (58)	0% (1)	8% (5)	67% (78)
Urban	93% (175)	56% (87)	93% (173)	75% (108)	56% (87)	94% (172)	94% (172)	75% (98)	62% (51)	0% (1)	48% (28)	37% (76)
Sub-Saharan Africa (51)	99% (47)	57% (21)	99% (47)	92% (32)	57% (21)	99% (47)	99% (47)	63% (21)	60% (21)	0% (0)	7% (6)	93% (33)

Table 1 also indicated that the data gaps related to SDG6 were even greater for sub-Saharan countries, with only 21 (41%) of the 51 sub-Saharan countries reporting progress with SDG6 were able to report on safely managed sanitation. None of these countries were, however, able to report on whether the content of dry sanitation systems was emptied and treated safely. Interestingly, a significant number of countries, 33 (65%) sub-Saharan countries, were able to report on access of their populations to basic hygiene services, showing that 93% of the sub-Saharan population were captured for this indicator (WHO and UNICEF, 2021). The report concluded that *the biggest data gaps were observed for elements of safely managed sanitation services* (WHO and UNICEF, 2021).

2.3 SOUTH AFRICAN PROGRESS AND CHALLENGES WITH SANITATION AND HYGIENE REPORTING

UNICEF Eastern and Southern Africa recently conducted a review of the progress of the countries in the Southern African region with SDG 6 indicators and targets (UNICEF ESARO, 2021). Linking the results of this review and the JMP progress and projects for the globe, shown in the Figure 2 above, progress for South Africa shown in Figure 3 below in 2017 is mixed. Figure 3 demonstrates that South Africa has made much greater progress than the global estimate of 54% of households, with at least 78,5% of households having access to this service in the in 2017 (UNICEF ESARO, 2021, WHO and UNICEF, 2021). This is, however, reaching the Millennium Development Goals (MDG) and does not reflect progress with SDG6.2. The UNICEF ESARO report indicated that, currently, South Africa is unable to report the percentage of the population that has access to a **safely managed** sanitation service, due to data gaps (UNICEF ESARO, 2021). Ending open defecation in the country is linked to access to a basic sanitation service, suggesting that since 99% of

households have some form of sanitation that the country would be able to address this SDG by 2030 (UNICEF ESARO, 2021).

South Africa's progress with achieving universal and equitable access to a hygiene facility is well below the current global estimate of 71% of households, with the country reporting that only 44% of households had access to this basic service. The country will need to make a much bigger effort than the quadruple effort suggested for the globe, to achieve this SDG target (UNICEF ESARO, 2021).

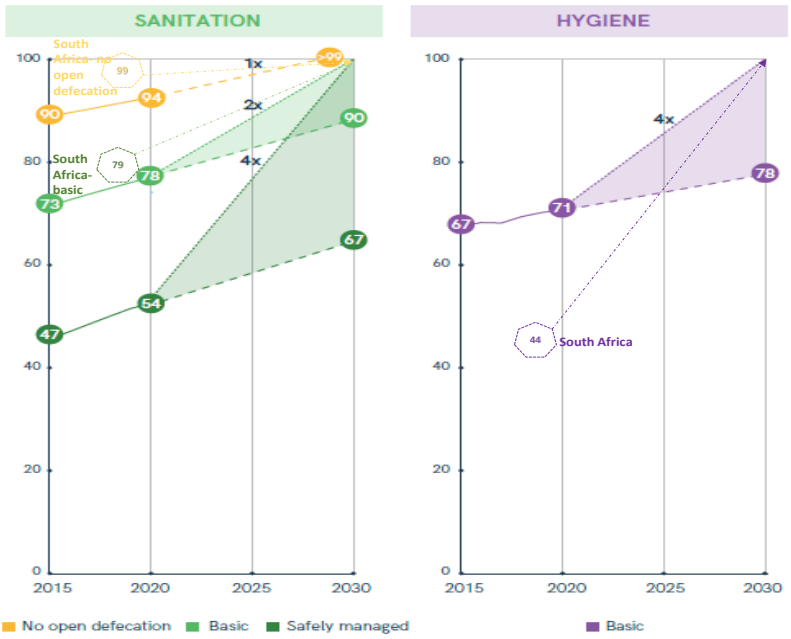


Figure 3: Global coverage of sanitation and hygiene services, 2015-2020 (%), and acceleration required to meet targets by 2030. South Africa's progress with the indicators and targets are shown in the unfilled icons on the graphs (adapted from WHO and UNICEF (2021); UNICEF ESARO (2021))

Due to these safely managed sanitation data challenges and the low progress in achieving access to basic hygiene, the UNICEF ESARO report predicted that South Africa would in fact achieve the SDG6.2 indicators well after the 2030 targets (see Figure 4 below)(UNICEF ESARO, 2021). Figure 4 indicates that, based on current data and 5-year average progress, South Africa, similar to many of the other ESARO countries, was projected to achieve the SDG6.2 targets after the year 2050.

Figure 4: Projected timeframe for South Africa to achieve SDG6.1 targets for universal and equitable access to a safely managed sanitation (left hand map) and access to a basic hygiene facility (right hand map) (UNICEF ESARO, 2021)

As part of the UNICEF ESARO 5-year review of progress on the SDG6, a SDG6 country case study was conducted for South Africa to highlight the unique manner in which the country captures and reports on the indicators for this goal (UNICEF, 2021). The South African case study, that provided a comprehensive review of the water supply, sanitation and hygiene (WASH) reporting systems and process for the SDG6, clearly demonstrated the current gaps in the country's reporting systems for these indicators. Figure 4 shows that the sanitation monitoring and reporting gaps related to in-situ treatment or collection, and safe treatment of the content of on-site, dry sanitation systems, as well as off-site and sewer treatment. South Africa does, through the General Households Survey, collect most of the other relevant data require to report on SDG6. The inability to report on safe and hygienic management and treatment of human sanitation facility contents is the key data that is required for the country to be able to report the levels of access to a safely management sanitation facility (as required by SDG6.2).

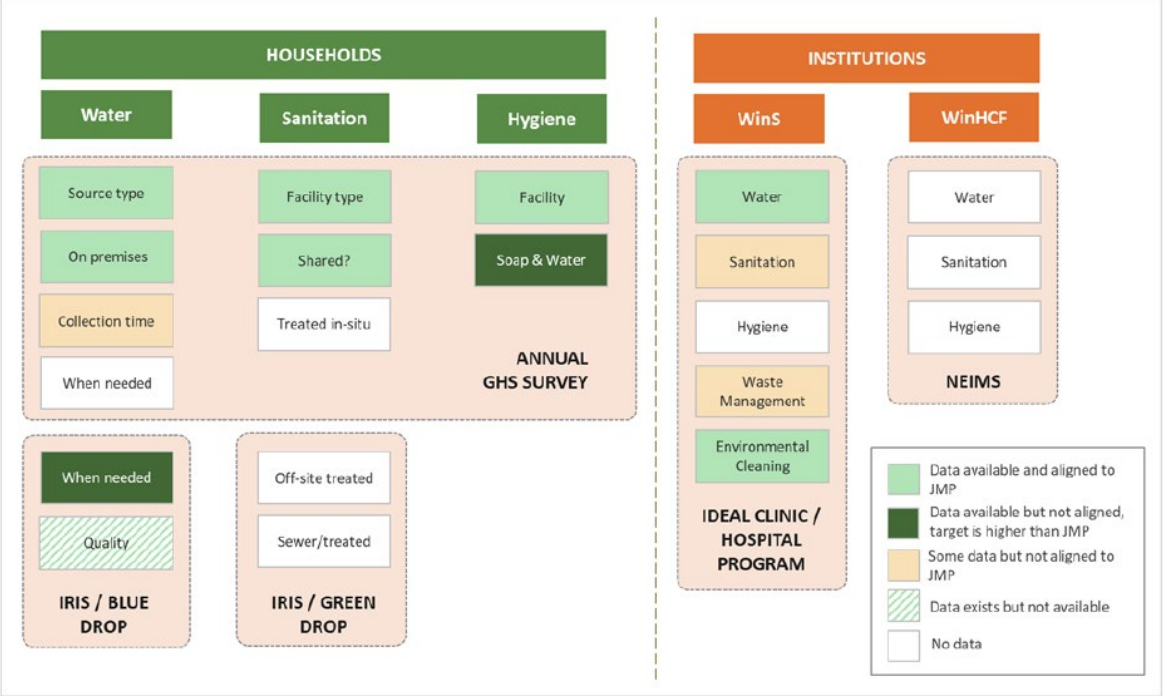


Figure 5: Current routine water supply, sanitation and hygiene monitoring systems in South Africa and gaps in these systems to fully report to SDG6 (taken from UNICEF (2021))

Citizen Science offers an innovative and unique way to address some of the resource and data gaps in South Africa's current SDG6.2 reporting process, specifically for capturing sanitation and hand hygiene data for the rural and on-site, dry sanitation systems in the country. The research assumes that the waterborne sanitation system reporting will be captured through the General Household Survey (GHS), combined with the Green Drop/IRIS wastewater quality reporting.

2.4 CHALLENGES WITH SANITATION AND HYGIENE REPORTING AT A HOUSEHOLD/ LOCAL LEVEL

It is important to recognise that the monitoring scale, method, approach and process for sanitation and hygiene, particularly rural sanitation, is unique. When monitoring water supply and ambient quality of water resource, many of the same methods and tools can be utilised, and the same process of taking a water sample, running analysis and interpreting the result can be utilised. Sanitation and hygiene cannot follow this same process. It is not possible to take a 'sample' for a rural sanitation facility or hand hygiene facility and test, analyse, interpret and report the results of the analysis. Hence, citizen monitoring of sanitation and hygiene needs to utilise very different tools, methods, process and procedures. Some of the important differences in the monitoring of water and sanitation/ hygiene are shown in Table 2 below.

Scale is perhaps the most significant difference when designing a citizen monitoring intervention for sanitation. In the case of Citizen Science water quality monitoring, a citizen can utilise scientifically credible tools and methods to take a water sample from a sample point in the water supply system, run the analysis on the sample, and extrapolate the result of the sample to the entire supply system. Although it would not be scientifically credible to only take a single sample in the water supply system, it is not necessary to take a sample at every tap outlet in the system to infer the quality of the water that the consumers are receiving in an area. The samples from a few points can provide water quality information for a significant population size. Similarly, one can also infer that if households in an area are receiving municipal water supply at a household level, that the majority of households in an area would have access to communal, yard, or in-house water supplies. Sustainability of supply can also be inferred for the larger population, with the assumption being that if the supply of the sampled households is intermittent, the entire population benefiting from the supply system would be similarly affected. Hence, since water supply systems provide water to a network of communal sites or households (yard or in-house), the scale of reporting access to improved water sources/services is at a population scale, i.e. percent of population with access to a basic water supply service – one tap can be linked to a large group of individuals (the entire population using the system).

The scale of monitoring of a sanitation service is, however, at a household level, and reporting is thus most accurate at the level of 'number of households with access to a basic sanitation/hygiene service' – one toilet can be linked to one household (i.e. only the number of people in the households). This is due to a number of unique monitoring challenges in the sanitation sector, including the following:

- Each household in a street/village/local area may have a different type of sanitation system, such as a Ventilated Improved Pit Toilet, Urine Diversion Toilet, or type of flush toilet, etc.
- Each sanitation type has different specifications and requirements to meet 'basic' level of service.
- Each sanitation type collects/stores/treats human waste differently.
- Each sanitation type is used differently by different sectors of the population.
- The social and cultural acceptance of each sanitation type is different.
- Each toilet/sanitation facility needs to be monitored to determine type of service and quality of service for the population in an area.

Monitoring and tracking of the progress of the UN SDGs are conducted according to a global indicator framework. The latest framework for assessing and monitoring the progress on meeting the 17 SDGs is evaluated through reporting on a hierarchy of 169 targets and 232 indicators. Official statistics have typically been based on data that are officially collected by national governments (Fraisl et al., 2020). The funding required to measure all 244 SDG indicators using only traditional data sources can be a barrier for especially developing countries to monitor and assess progress toward the SDGs (IAEG Secretariat, 2014). Effective and efficient monitoring of the SDGs will require better use of new data sources and data techniques (Fraisl et al., 2020).

To date, Citizen Science methodologies and data are not included in SDG data acquisition (Fraisl et al., 2020). Data produced through Citizen Science, which is the involvement of citizens in scientific research and/or knowledge production, can complement and ultimately improve the SDG reporting process (Fritz et al., 2019). Citizen Science, as a concept, has diverse definitions, terms, and interpretations, where no single term or definition is suitable for all contexts (Eitzel et al., 2017).

Citizen Science could make contributions in three types of sustainable development and SDG processes, namely providing input into defining national and sub-national targets and metrics, aiding invaluable inputs into monitoring progress and assisting with implementing actions required to achieve sustainable development and the SDGs.
Stakeholders have no basis for challenging factually incorrect or biased positions without available data. Reliable, consistent and, whenever possible, disaggregated data are essential to stimulate political

commitment, inform policymaking and decision-making, and trigger well-placed investments towards health, environment and economic gains. The 2030 Agenda for Sustainable Development that incorporates the SDGs, states that “Quality, accessible, timely and reliable disaggregated data will be needed to help with the measurement of progress and to ensure that no one is left behind”.

Providing support to citizen-science projects at the local level will ensure contribution to the SDG reporting framework while creating opportunities for social innovation in the sense that citizens can help to both monitor and implement the SDGs (Fritz et al., 2019).

Noting these nuances and challenges in monitoring and reporting rural, on-site, sanitation systems, there is a need to design a system that can address these challenges in partnership with citizens and to encourage the citizens (i.e. households) to participate in monitoring and reporting their access to sanitation services (as outlined in Table 2) and to monitor and report the state of their sanitation service on an ongoing basis. This household monitoring and reporting lends itself to Citizen Science monitoring and reporting of sanitation services in the rural areas, or areas that have access to on-site sanitation systems.

Table 2: Differences in monitoring and reporting of water supply, sanitation and hygiene in South Africa

	Monitoring Water – specifically drinking water supply		Monitoring Sanitation		Monitoring Hygiene
Targets:	**SDG 6.1**	By 2030, achieve universal and equitable access to **safe and affordable drinking water for all** (UNICEF and WHO, 2017)	**SDG6.2**	By 2030, achieve access to adequate and equitable **sanitation and hygiene for all** and **end open defecation**, paying special attention to the needs of women and girls and those in vulnerable situations (WHO and UNICEF, 2017)	
	National	By 2030, **universal, sustainable and reliable water supply** provision (DWS, 2018)	**National**	By 2030, **universal, sustainable sanitation** provision (DWS, 2018)	
Indicators	**SDG 6.1.1**	Proportion of population using **safely managed drinking water** services (UNICEF and WHO, 2017)	**SDG6.2.1**	Proportion of population using **safely managed sanitation** services, including a **hand-washing facility** with soap and water (UNICEF and WHO, 2020)	
	National	Access to a basic water supply	**National**	Access to a basic sanitation facility	
Measure of Indicator	**SDG 6.1.1**	**Safely managed drinking water** services is access to (UNICEF and WHO, 2017): 1. **Improved water source** – basic water supply in South Africa (connect to yard/erf) **+** 2. **Accessible on premises** – yard tap in South Africa **+** 3. **Available when needed** – **+** 4. **Free from faecal and priority chemical contamination** – meets SANS 241 in South Africa	**SDG6.2.1**	**Safely managed sanitation services** is access to (UNICEF and WHO, 2020)**:** 1. **Improved sanitation facility** – basic sanitation facility in South Africa **+** 2. **Not shared with other households** – at household in South Africa **+** 3. **Where excreta are safely disposed of in situ or removed and treated offsite** – emptied pit; septic tank, treated at WWTW, etc.	**Hand-washing facility** with soap and water 1. **Handwashing facility at home –** may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing **+** 2. **Handwashing soap –** bar soap, liquid soap, powder detergent, and soapy water **+** **3. Handwashing water –** linked to basic water supply in South Africa
	National	A basic water supply: 1) A connection within the yard or property (DWA, 2014)	**National**	A basic sanitation facility (DWS, 2016): 1. considers **natural (water; land; topography) resource protection**, 2. **safe** (including for children), 3. **reliable**, 4. **private**, 5. **socially acceptable**, 6. **skilled and capacity available locally** for operation and maintenance, 7. **protected** from the weather 8. **ventilated**, 9. **keeps smells to the minimum**, 10. is **easy to keep clean**, 11. **minimises the risk of the spread of sanitation-related diseases** by facilitating the appropriate control of disease carrying flies and pests, 12. facilitates **hand washing** 13. enables **safe and appropriate treatment and/or removal of human waste and wastewater** in an environmentally sound manner.	

CHAPTER 3: EMERGING APPROACHES AND ISSUES TO CITIZEN PARTICIPATION IN SCIENTIFIC MONITORING AND RESEARCH

3.1 WHAT IS CITIZEN SCIENCE?

Public involvement in scientific discovery and research, commonly referred to as “Citizen Science”, has seen a growing interest and application in the scientific community.

The history of the emergence of term “Citizen Science” in the literature has often been attributed to two distinct sources. Firstly, Alan Irwin used the term in 1995 to refer to a paradigm where research goals were collaboratively determined by professional scientists and the public in the UK; and secondly, Rick Bonney, at approximately the same time, began to use the same term to refer to numerous projects at the Cornell Lab of Ornithology in the United States (Hecker et al., 2018).

Many new definitions of Citizen Science have since emerged. For example, a "Green Paper on Citizen Science" was published in 2013 by the European Commission, with Citizen Science defined as *the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources. Participants provide experimental data and facilities for researchers, raise new questions and co-create a new scientific culture* (Socientize Consortium, 2013). In 2014, the Oxford English Dictionary (OED) also defined Citizen Science as *scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions* (OED, 2014). Citizen Science has also been referred to in the literature as community science, crowd science, crowd-sourced science, civic science, volunteer monitoring, or online Citizen Science (Gura, 2013).

The literature attributed the fields of astronomy and ornithology as leading the participation of citizens in scientific studies (Dickinson et al., 2012). In the astronomy field of research, citizens notably the admiralty, were first recruited to collected data for the 1874 British government funded research of measuring the Earth's distance to the Sun (Dickinson et al., 2012). Amateur astronomers of the Victorian period thus participated in the research. In the case of the CS in the ornithology field of research, amateurs participating in data collection to monitor birds in Europe dates back to 1749 (Dickinson et al., 2012). In the 1900s, the Christmas Bird Count (CBC) project was initiated by American Museum of Natural History, leading to the popularising of ornithological monitoring in the United States of America (USA) up until today. A number of other Citizen Science bird monitoring projects have been initiated over the years, including the U.S. Geological Survey (USGS), the Breeding Bird Survey (BBS), the USGS's North American Bird Phenology Program (focused on first arrivals of migrants), the Cornell Lab of Ornithology's nest record card scheme, and the USA-National Phenology Network tracking of seasonal timing of biological events for a broad range of taxa (Dickinson et al., 2012). Most of these data is now publicly available.

Citizen Science thus engages the public in scientific projects that are often difficult to conduct solely by scientists, due largely to the scientists lacking the resources to gather or analyse data on a large scale (Follett and Strezov, 2015).

The "citizen scientists" that are involved in conducting Citizen Science have been defined in the literature as (Zooniverse, 2014):

(a) *a scientist whose work is characterised by a sense of responsibility to serve the best interests of the wider community (now rare)*; or

(b) *a member of the general public who engages in scientific work, often in collaboration with or under the direction of professional scientists and scientific institutions; an amateur scientist*.

This form of public involvement in scientific research has also been termed Public Participation in Scientific Research (Bonney et al., 2009), participatory science, civic science, and amateur science (Harvey, 2006). Research in Citizen Science balances scientific, educational, societal and policy goals with a common shared goal of collecting and analysing information that is scientifically valuable (Hecker et al., 2018). This combination of balancing sector goals with a common shared goal, according to Hecker et al. (2018), distinguishes Citizen Science from areas such as experiential learning or environmental education for sustainability.

Research by de Araujo et al. (2017) indicated that Citizen Science could be a powerful tool for connecting members of the public with research and for obtaining large amounts of data. Conducting Citizen Science project in developing countries was, however, far less common than in the developed countries. Figure 6 shows that Citizen Science publications were largely emanating from Northern American countries, Australia and European countries. The next level of Citizen Science publications was emanating from the BRICS countries, namely Brazil, Russia, India, China and South Africa. Very few Citizen Science publications were emanating from the other African and developing countries. De Araujo et al. (2017) attributed this Citizen Science publication disparity to fewer Citizen Science projects in the developing world, due to (a) a lack of volunteer participation in developing countries, and (b) few national consortia that include numerous local coordinators in these countries (Figure 6).

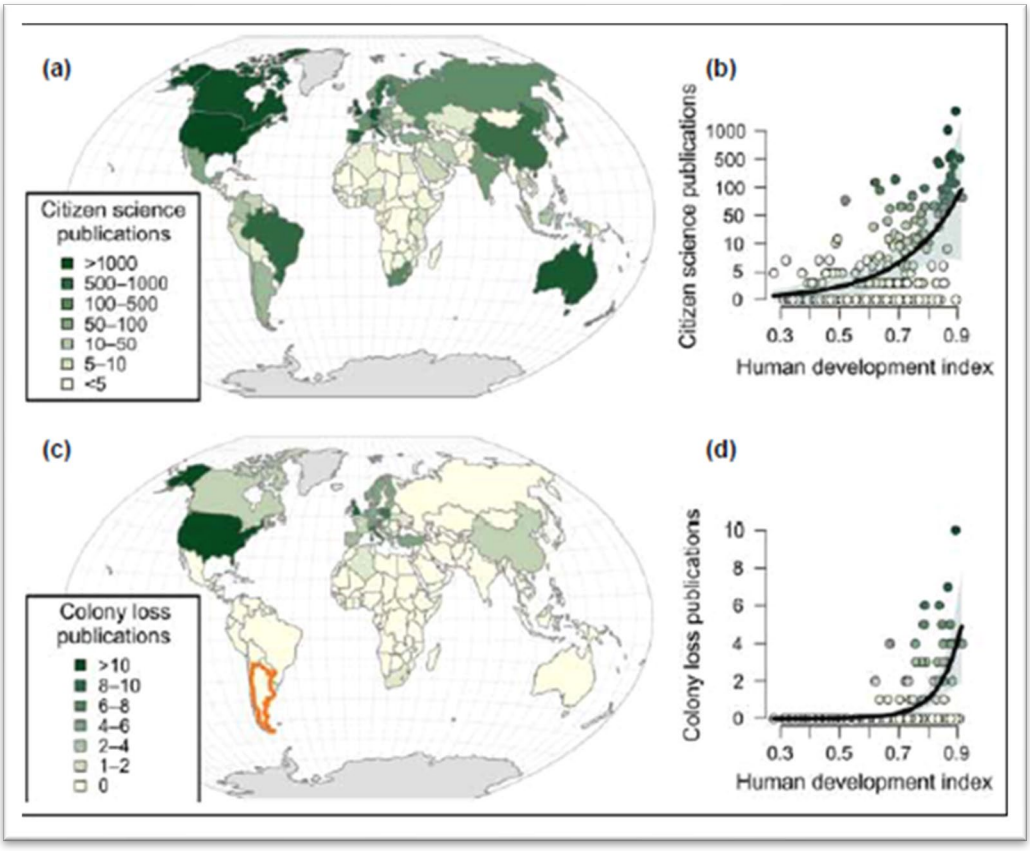


Figure 6: Map of where citizen-science studies are conducted. (a) The global distribution of citizen-science studies published over the past 30 years (1987-2017); 7774 studies were identified following Follett and Strezov (2015), based on Web of Knowledge searches. (b) The number of citizen-science publications per country was found to be positively associated with its human development index (HDI; HDR 2018). (c) The global distribution of honeybee colony loss publications produced through citizen-science programs. Data were collected through an exhaustive synthesis of 39 papers (complete list in WebPanel 1). The Argentinean study case is shown in orange. (d) The number of colony loss publications per country was also positively influenced by its HDI and was correlated with the number of citizen-science publications. (Taken from Requier et al. (2020))

To improve the uptake of Citizen Science in developing countries, de Araujo et al. (2017) suggest the following:

- The use of web-based questionnaires and face-to-face interviews could increase coverage and representativeness.
- Large-scale consortium and a combination of several recruitment strategies could improve participation.
- Establishment of Citizen Science programmes in developing countries was necessary.

3.2 PRINCIPLES OF CITIZEN SCIENCE

The global increased participation of scientists and citizens in Citizen Science clearly demonstrates the societal desire to participate more actively in knowledge production, knowledge assessment and decision-making (Hecker, 2019). However, ensuring the credibility of Citizen Science outputs in the scientific community requires not only institutionalising Citizen Science, but also ensuring professionalisation of Citizen Science (Hecker, 2019). The first steps in this institutionalising and professionalising was taken by the European Citizen Science Association's best practice working group in 2015, with the publication of the ten principles of Citizen Science (shown in Table 3) (ECSA, 2015). These 10 principles frame and should be applied in any Citizen Science research in the sanitation sector in the world.

Table 3: Ten principles of Citizen Science (taken from European Citizen Science Association (2015))

PRINCIPLES OF A CITIZEN SCIENCE ENDEAVOUR	
The citizens should:	
1	Contribute, collaborate or lead to generate new knowledge or understanding
2	Be able to participate in multiple stages of the scientific research process, i.e. research question design, method selection and design, data gathering and analysis, etc.
3	Be acknowledged in results and publication
The CS project leaders should:	
4	Take into consideration legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentially and environment impacts
All participating parties should:	
5	Benefit from the research activities
6	Receive feedback from the research project/study
The Citizen Science study/programme should:	
7	Have the purpose of achieving a scientific outcome
8	Consider research approaches like any other research study, but utilises citizen participation
9	Make project data and meta-data publicly available
10	Be evaluated for scientific output, data quality, participant experience and societal/policy impact

3.3 EMERGING ISSUES IN CITIZEN SCIENCE

Citizen Science has evolved over the past four to five decades, becoming even more popular with researchers and communities in the last 5-10 years. Citizen Science outputs have been utilised to inform local policies, enhance formal and informal education initiatives, conserve natural resources, and support environmental sustainability (Keyles, 2018).

This section of the report categorises the emerging Citizen Science issues and considerations under the 10 principles of Citizen Science.

3.3.1 Principle 1 and 2: Active participation, contribution, collaborate or leading by citizens

Citizens need to be active participate as contributors, collaborators or leaders in any Citizen Science efforts. There are however always challenges in ensure that this balance between citizen active participation, scientific

needs and interventions sustainability. Various tools and interventions may be needed to maintain this balance and ensure the long-term participation of the citizen scientists, including the following:

a) Utilising innovative approaches: As the field of Citizen Science evolves, innovative approaches are increasing to recruiting and retaining Citizen Science. These approaches include raising awareness about Citizen Science opportunities through large media organisations; developing and designing smartphone apps that allow underrepresented groups to participate in Citizen Science projects; and using virtual peers (i.e. 'bots') to influence the levels of engagement from individual participants to minimise risks of data bias, which can occur if some contributor's complete tasks too many or too few times (Leach et al., 2020).
b) Designing user-friendly and engaging platform interfaces: Technical approaches have included user-friendly and engaging platform interfaces. Gamification (Burnett et al., 2016), or turning Citizen Science projects into a game-like experience, is important in the field of Citizen Science. A degree of competition, which is a part of many games, has acted as a motivator and helped sustain participant engagement (Bowser et al., 2013).
c) Recognising participation is influence by a range of factors: It is likely that participation in Citizen Science project will be lower for people living within socio-economically deprived communities because of the challenges they may face relating to their basic physiological needs (Hobbs et al., 2012). Factors such as lack of awareness of volunteering opportunities, financial costs, not enough time to get involved, ill health and lack of confidence may also play an important role for people from low socio-economic groups (Wolcott et al., 2008; Martinez & McMullin 2004; Mitchell et al., 2017).
d) Maintaining interest: Citizen Science presents challenges related to motivating, involving and keeping citizens engaged within the projects. Schröter et al. (2017) found in the literature that failure in communication with the participants, lack of clear goals or ambiguous instructions can lead to a decrease in participation. The recruitment, retention and engagement of participants in Citizen Science projects involves not only the number of citizen scientists that need to be engaged, but also their representativeness in terms of the population diversity.
e) Harnessing citizens skills-sets and interests: Roy et al. (2012) stated that Citizen Science projects should be tailored to match the interests and skill sets of participants and recommend that understanding the motivations and expectations of potential participants is crucial to developing successful Citizen Science projects. Once participant provided information and data, etc., they have expectations of either receiving compensation for their efforts or have the situation they provided data about be improved/changed. The fact of their participation in a Citizen Science project might mean that their expectations will be addressed or fulfilled.
f) Using the right framework and communication strategy: Citizen Science offers an effective way to connect citizens and policy, bringing societal and economic as well as scientific and political benefits. Even though Citizen Science has the potential to bring societal benefits, inclusivity is not automatic. The right framework and communication strategy are needed to ensure citizens are heard and feel they are part of the solutions that concern them. Tweddle et al. (2012) recommended that, in return for the participants' input and to encourage further participation, the project leaders could:
    - host feedback or closing events, incorporating a social activity, to thank the participants for their input and present results to them;
    - give free access to all non-sensitive records;
    - run a competition to encourage repeat participation; and/or
    - simply say thank you.
g) Manage expectations: Public institutions wanting to engage in Citizen Science also have to consider the resources required to manage expectations from actively engaged citizen scientists and participants. Empowering individuals and communities with information requires constant feedback and dialogue (Nascimento et al., 2018), as well as visible change or mitigation following participation. Bottom-up contributions should be supported, and top-down policy processes engaged to connect the two perspectives so that policymakers are ready to receive data and findings from participants and take action (Nascimento et al., 2018).

3.3.2 Principle 3: Acknowledging citizens in Citizen Science

Citizen Science need to be acknowledged in project communications, result reporting and publications. In the processes of recognising and acknowledging the valuable contributions of these participations, the following should be noted:

a) Preventing exploitation of citizen participants: A major issue of Citizen Science is participants' exploitation, particularly when participants are volunteers. It is, therefore, crucial in Citizen Science projects that involves human participants that researchers provide opportunities for participants to ask questions if they do not understand a specific instruction and allow them to leave the project if they do not consent to any of the project's tasks or terms (Chandler & Shapiro, 2016).
b) Recognising and dealing with conflicts of interest between parties: An editorial in the journal *Nature* raised concerns that citizen participants might advance their political objectives, such as when opponents of fracking might help track possible pollution because they want to gather evidence of harmful effects (Vacha & Jiang, 2015). Nascimento et al. (2018) related that a debate was sparked in the Citizen Science community on social media, mailing lists and blogs about bias as a result of asymmetrical power relations in science and policy; claims of falsification or data fraud outside of Citizen Science; and the integration of personal motivations, value judgements and social norms in epistemological understandings of objectivity.
c) Applying rewards and recognition: Social interventions in Citizen Science have included rewards and recognition for contributors and how best to apply these, providing feedback and updates to participants, allowing them to interact with one another socially online to create a sense of community, and giving participants a choice in terms of the types of tasks they complete.

3.3.3 Principle 4: Legal and ethical Citizen Science

Citizen involvement in scientific studies raises novel ethical issues, as citizens have traditionally occupied the role of researcher or subject, but not at the same time. The confluence of these two different roles in the same person poses challenges. Citizen Science projects and citizen-led research are raising concerns over the ethics of collaboration and partnership between researchers and research participants. In March 2019 the online journal *Citizen Science: Theory and Practice* launched a collection of articles on the theme of Ethical Issues in Citizen Science (Razmussen & Cooper, 2019). The journal indicated that "Citizen Science can challenge existing ethical norms because it falls outside of customary methods of ensuring that research is conducted ethically. What ethical issues arise when engaging the public in research?" (Razmussen & Cooper, 2019). The ethical challenges that most often occur are those inherent to the use of volunteers to conduct research, as well as the absence of a governing body to decide if the research is good or bad. To address and acknowledge these challenges the following needs to be considered in Citizen Science actions:

a) Protecting Intellectual Property in Citizen Science: It is crucial for intellectual property to be protected legally in order to restrict the usage of what is rightfully that of the inventor or creator (South Africa, 2013). In the Citizen Science context, patents and copyrights are the most important aspects, although other rights, such as trade secret protection, may also be relevant (Scassa & Chung, 2015). In most Citizen Science projects, this is done automatically when the user accepts the terms of use with a checkbox in the registration form.
b) Applying Intellectual Property (IP) Rights to Stimulate Citizen Science Innovation: The other main purpose of IP law is to encourage the creation of intellectual goods. By giving people and businesses property rights to what they create, the desire to innovate is stimulated through economic incentives. IP rights and IP considerations should never hamper or stop innovative ideas for increasing public engagement with scientific research. Because Citizen Science information is voluntary, it is important that the information be shared first with those who provided it, as well as with other researchers, once it is aggregated (Becker et al., 2013).

3.3.4 Principles 5 and 6: Benefits and incentives of participating in Citizen Science.

In general, environmental literature categorises motivations for participants as intrinsic (or inherently valuable or satisfying) or extrinsic (or leading to some other benefit, such as future career prospects). Citizen Science literature provides motivators, such as:

- egoism, where the motivation is personal growth or gain;
- altruism, where others benefit; collectivism, where a particular group benefit;
- principalism, where individual principles are upheld;
- competition or reputation to encourage (continued) participation (Geoghegan et al., 2016);
- for personal development (to learn something new, want to enhance my own development, want to help my future career);
- personal (to meet people/for fun, to get exercise and get fresh air, prevent boredom, lose weight, financial incentive);
- to share knowledge/raise awareness (to encourage children's or other's interest); and/or
- did not have a choice (required for a degree course, job or part of government agricultural support schemes).

In ensuring that the benefits of Citizen Science are shared and to incentivise participating in Citizen Science, the following should be considered:

a) Harnessing the benefits of Citizen Science: Citizen Science is a broad concept and can be deployed in various ways, with equally varying benefits, to entire societies and communities. The results of research gained through Citizen Science projects have been used to inform local policies, enhance formal and informal education initiatives, conserve natural resources, and support environmental sustainability (Keyles, 2018). Citizen Science also adds value in terms of public engagement and collaboration.
b) Harnessing citizens willingness to participate: Most Citizen Science projects, because it is based on volunteers, rely on the willingness of the public to participate, and on the interest of the participants in the subject. Many managers of these projects battled with how to motivate participation. The literature shows evidence that motivations vary between types of projects and these need to be explore and utilised in Citizen Science efforts.
c) Providing appropriate benefits: It is important that benefits are provided as appropriate, such as formal recognition for contributions, education related to the study conducted, in some cases financial compensation, acknowledgement in an article, or authorship credit (Lichten et al., 2018).

3.3.5 Principle 7 and 8: Citizen Science for achieving a scientific outcome

It is proposed that encouraging participation in Citizen Science projects will benefit scientific outcomes by delivering them to a wider population and thus growing science capital. Standardised metrics for scientific outcomes of Citizen Science exist, but in grassroots initiatives it may require additional metrics to provide evidence of their scientific impact. The following must be considered:

a) Ensuring good governance in Citizen Science: Citizen Science is increasingly focusing on ways to enable the participation of seldom-heard or hard-to-reach populations (geographically remote populations, people who are illiterate, people who are not technology-competent), such as through smartphones requiring minimal signal capacity and through demographically and culturally sensitive design of the Citizen Science interface. The governance of Citizen Science projects is evolving and includes both technical and social safeguards for data privacy, security and informed consent, as well as efforts to clarify data ownership practices (Leach et al., 2020).
b) Ensuring methodological rigour and research integrity in Citizen Science: Professional researchers are bound to methodological rigour and research integrity and are held accountable for the quality of their work, while citizen scientists might not be accountable to such formal mechanisms and pressures (Guerrini et al., 2018; Resnik et al., 2015). But a trade-off between scientific rigor and citizen monitoring efforts is

unavoidable and it is therefore important to develop strategies that promote integrity in research collaborations among professional and non-professional scientists through:

- standards for data quality, integration and interoperability; the development of good-practice guidance by organisations, such as the European Citizen Science Association, the Citizen Science Association in the USA, and the Cooperation in Science & Technology (COST) Action Citizen Science group;
- review of contributions by Citizen Science peers or by researchers;
- validation of Citizen Science data with a secondary source; and
- the use virtual peers or 'bots' to regulate risks of bias.

3.3.6 Principle 9: Availability and quality of project data and meta-data from Citizen Science

With the boom in Citizen Science, there is a growing need for adequate infrastructure to support Citizen Science activities. It is obvious from the growing data and meta-data challenges that Citizen Science infrastructure is increasingly in demand. Ethical and legal sharing and management of the data and meta-data from these efforts is also necessary. The following need to be considered related to CS project data and meta-data:

a) Ensuring data accuracy of Citizen Science: Despite the growth in the number of Citizen Science projects, scientists remain concerned about the accuracy of Citizen Science data (Aceves-Bueno et al., 2017). Some studies have found volunteer data to be more inconstant than professionally collected data (Harvey et al., 2002; Belt & Krausman, 2012, Specht & Lewandowski, 2018), while other studies revealed that data from volunteers are comparable to those of professionals or scientists (Hoyer et al., 2012; Oldekop et al., 2011). Citizen Science has however been shown to be able to improve research quality by complementing traditional research methods and by providing additional data or approaches from a different methodological or analytical angle. Researchers should closely supervise citizen scientists to enable qualitative accuracy checks or employ other quality assurance methods.
b) Making data-collection protocols, instruments and analysis robust: A perception could be that citizen scientist cannot be put into training programmes, be asked to follow quality assurance procedures, or be expected to use standardised equipment, are impeding the productive use of Citizen Science. Questions are also raised about the lack of coordination and top-down forms of production that may affect the quality of the information that emerges from Citizen Science.
c) Collecting, storing and providing data at scale: Whichever way data are collected, storing and provisioning data at scale can quickly become unmanageable without highly specialised data management solutions.
d) Using smartphones for data gathering: Drollette (2012) argues that the importance of smartphones as scientific instruments cannot be underestimated as their GPS provides accurate time and good location; phone pictures provide location and timestamps; and when they communicate with other sensors (e.g. air pollution) or a microphones (e.g. for noise levels), the observation has a time stamp from the instrument used.
e) Data ownership and conflicts in Citizen Science: Ownership of data generated by citizen scientists is a hot topic, with creative commons licensing and the setting up of not-for-profit organisations to manage any resulting discoveries being seen as promising approaches. Conflicts of interest in data gathering may arise from citizen scientists' affiliations to private, public, or political organisations, or from their individual perceptions of the harm or benefit of the research. This creates scope for citizen scientists to influence which research questions are being addressed and what data is published (Leach et al., 2020).
f) Ensuring data security: As a result of the growing interest in using personal health data in Citizen Science projects, there has been an evolution in the governance approaches for using such data, including through both technical and social interventions. These interventions span software that enables the secure storage of data collected through apps and secure access to such data, and platforms that allow for decisions related to the use of patient data to be controlled by either the patients themselves or by a trusted intermediary (Leach et al., 2020).
g) Managing sensitivity of data: Access to data can be costly and can signify a valuable source of income to maintain the necessary infrastructure and opening the data without provision of alternative funding can

undermine the basic data collection support. Data can also be sensitive in its content, as in the case of endangered species (Bowser & Shanley, 2013), especially in cases where information was collected by a local group and there may be issues of collaborative decision making regarding which data should be released, to whom and under which conditions. In large-scale projects, agreements with participants are more standardised, but the data aggregators and analysts need to be aware of sensitive issues such as privacy.

h) Applying social interventions to Citizen Science: Social interventions are also receiving increasing attention, including data trusts (platforms that allow for decisions related to the use of patient data to be controlled by a trusted intermediary), data cooperatives (where decision-making authority resides with the patients themselves), and permission management systems that limit access to data to specified individuals (COST, 2019).

3.3.7 Other emerging issues

3.3.7.1 Artificial Intelligence and Citizen Science

Advances in artificial intelligence (AI) and machine learning present opportunities for speed and efficiency gains in how Citizen Science data are analysed. As the technical capacity for AI increases, so will the need to reflect on its benefits and risks on a project-by project basis. The challenge is how to balance the often-competing objectives of Citizen Science research, such as conducting research in the most efficient manner with the best tools available (thus utilising AI, machine learning and other big data tools), while striving for conducting research using more open and inclusive science methods (Leach et al., 2020). The following should be considered related to AI and Citizen Science:

a) Applying ethical AI in Citizen Science: As the use of AI grows and humans increasingly rely on machines to complete tasks, it is important to understand how AI is used and what the ethical considerations may result from it. Various decision-making organisations (such as the European Commission's Joint Research Council and the UK Research and Innovation) have studied the issues related to big data in Citizen Science and the role that AI and machine learning can play in overcoming them. AI are often required to make meaning of large datasets, and Citizen Science has a significant role to play in ensuring that data are collected, analysed, and interpreted in meaningful ways that benefit everyone. Machine learning can be used to assist with the interpretation of complex data collected through new methods, such as data from smartphone sensors, and can identify patterns within such data (Ceccaroni et al., 2019).
b) Scaling up of AI use: It has been shown that unnecessary use of artificial intelligence (AI) can be detrimental to the goals of Citizen Science. However, if used carefully, AI can be an important tool for accelerating Citizen Science to ultimately massive scale scientific research (Ceccaroni et al., 2019).

3.3.7.2 Citizen Science for policy making

In general, the literature regards Citizen Science only as science tool; with little attention paid to the benefits and challenges of Citizen Science as a tool for policy development. The follow should however be considered by policy makers:

a) Applying Citizen Science in policy development and implementation: Citizen Science is a way of empowering communities in driving forward policies (Rowland, 2012). Some studies reported that Citizen Science projects allow citizens to be more active in society, protect their environment and drive a participatory form of democracy (Mueller et al., 2012). Citizen Science has and can in future make a significant contribution in policymaking – as an example for conducting inclusive research on socially relevant issues and for informing policy decision-making. Policymakers worldwide are presenting a growing interest and commitment to building capacity for and of Citizen Science in the research and innovation system (Leach et al., 2020). An example is the move towards Citizen Science in the European Union (EU), which has been part of the strategy to increase citizen engagement in science and

policymaking, such as the Science with and for Society (SWAFS) programme within Horizon 2020 (H2020). H2020 has been instrumental in growing Citizen Science within Europe through clear and formal patronage by European Commission decision makers. H2020 has also provided a framework around which Citizen Science associations and researchers can combine and merge their work (Leach et al., 2020).

b) Using Citizen Science for interactions with local governments: Citizen Science projects also provide opportunities for closer interactions with local governments (Irwin, 2018). Hacklay (2015) stated that the local and city levels may be more open to community-led Citizen Science activities, while larger scale and longer temporal scales need standardisation that may limit the tasks of individual participants.

3.3.7.3 Citizen Science for citizen concerns

Local communities have used Citizen Science to research and address their concerns and challenges especially around social and environmental issues, such as pollution and health inequalities, to facilitate political change. This has happened through community members or researchers taking a collaborative approach in which citizen scientists help shape the research questions and interpret the data in order to ensure that the resulting research was relevant to local community members. The citizen scientists subsequently used the results of their research to transform local policies or practices (Leach et al., 2020).

3.3.7.4 Scaling up Citizen Science

Increasing Citizen Science scope, scale and impact: As the field of Citizen Science evolves, opportunities are mounting to increase its scope, scale and impact. New platforms and portals are emerging that make Citizen Science more accessible to, and feasible for, researchers. These new tools can tap into and connect with existing Citizen Science and crowdsourcing infrastructure, which renders the development of new technological interfaces or trying to identify potential participants unnecessary (Leach et al., 2020).

Increasing Citizen Science capacity: Interventions to build and scale up Citizen Science capacity in the research system are also emerging. These include innovative resources and services to help researchers without deep programming knowledge to develop Citizen Science platforms and mobile applications, for example through training, stakeholder networking events and hands-on support in developing technological solutions (Leach et al., 2020). Initiatives include innovative resources and services to help researchers without in-depth knowledge to develop Citizen Science platforms and mobile applications (Leach et al., 2020). These initiatives include companies providing platforms on which project apps for Citizen Science projects can be created, such as SPOTTERON (2019), which has supported the CrowdWater Citizen Science project seeking to source hydrological observations to help predict floods and areas of low water flow (Seibert et al., 2019). This indicates opportunities for greater citizen scientist involvement across the research process (e.g. in research design, data collection, analysis, dissemination, etc.).

3.4 SUMMARY OF THE EMERGING RESEARCH ISSUES IN CITIZEN SCIENCE

The table below summarises the emerging issues in the Citizen Science arena and the considerations under each of these issues. These issues and considerations need to be recognised and noted in the design and implementation of a Citizen Science research initiative, including initiatives such as a Citizen Science monitoring programme for sanitation services in South Africa.

These issues and considerations were utilised in a later section of the report to guide the development of the specifications for the Citizen Science sanitation and hygiene information platform (CS-SHIP).

Emerging CS Issue		Considerations
1	Actively contribute, collaborate or lead to generate new knowledge or understanding	• Utilising innovative approaches • Designing user-friendly and engaging platform interfaces • Recognising participation is influence by a range of factors • Maintaining citizen interest • Harnessing citizens skills-sets and interests
2	Acknowledging citizens in Citizen Science	• Preventing exploitation of citizen participants • Applying rewards and recognition
3	Legal and ethical Citizen Science	• Ensuring ethical Citizen Science • Protecting intellectual property (IP) in Citizen Science • Applying IP rights to stimulate Citizen Science innovation
4	Benefits and incentives of participating in Citizen Science	• Motivation for participation • Harnessing the benefits of Citizen Science • Harnessing citizens willingness to participate • Providing appropriate benefits
5	Citizen Science for achieving a scientific outcome	• Ensuring good governance in Citizen Science • Ensuring methodological rigour and research integrity in Citizen Science • Applying social interventions to Citizen Science
6	Data from Citizen Science	• Ensuring data accuracy of Citizen Science • Making data-collection protocols, instruments and analysis robust • Collecting, storing and providing data at scale • Using smartphones for data gathering • Data ownership and conflicts in Citizen Science • Ensuring data security • Managing sensitivity of data
7	Artificial Intelligence and Citizen Science	• Balancing citizen needs with artificial intelligence (AI): • Applying ethical AI in Citizen Science • Scaling up of AI use
8	Citizen Science for policy making.	• Applying Citizen Science in policy development and implementation • Using Citizen Science for interactions with local governments
9	Citizen Science for citizen concerns	• Using Citizen Science to research and address citizen concerns
10	Scaling up Citizen Science	• Increasing Citizen Science scope, scale and impact • Increasing Citizen Science capacity

CHAPTER 4: FRAMEWORK FOR THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM

The principals of Citizen Science were applied to develop a framework for Citizen Science monitoring and reporting of the sanitation and hygiene SDGs, international parameters, South African legislation and policy parameters, as well as being able to monitor and report the sanitation publics sanitation and hygiene imperatives.

A monitoring framework, also known as an evaluation matrix, has no standardised definition. For many organisations, a monitoring framework is a table that describes the indicators that are used to measure whether the programme was a success. The framework describes how the whole monitoring system for the program works, including things like who was responsible for it, what forms and tools would be used, how the data would flow through the organisation, and who would make decisions using the data.

Generally, a monitoring framework is a hierarchical model which structures and links programme goals, strategic objectives and indicators in a logical manner. Monitoring frameworks are usually based on a hierarchal structuring of a goal/s, strategic objectives and targets, demonstrating the relationships between these (Figure 7). Hierarchy theory suggested that higher levels of organisation in the framework (a water goal) would incorporate and constrain the behaviour of lower levels of the framework (water indicators) (Allen & Starr, 1982; O'Neill et al., 1986; Noss, 1992). The importance of higher-order imperatives did not, however, suggest that monitoring and assessment be limited to higher levels (e.g. national assessment of the water sector) (Noss, 1992).

The hierarchy needs to be linked not only vertically (i.e. goal to indicator) but also horizontally. Linking horizontally would prevent overlap of water future intentions (objectives); while linking vertically ensure that the lower levels of the hierarchy were relevant and directly related to the level above.

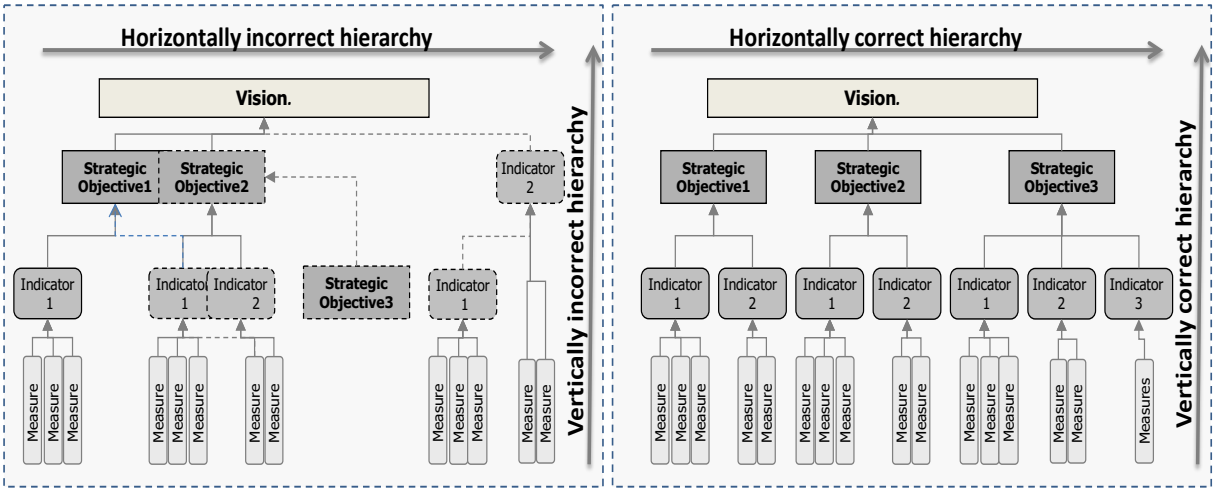


Figure 7: Incorrect Water Futures Monitoring Framework hierarchy (left diagramme) showing overlaps in objectives and indicators and incorrect relationship between indicators and objectives. Correct Water Futures Monitoring Framework hierarchy (right diagramme) showing no overlap at the objective level and between indicators and the correct relationships between objective, indicators and measures (adapted from Lammerts von Bueren and Blom, 1996)

The hierarchy framework for sanitation monitoring suggested monitoring at multiple levels and at multiple spatial and temporal scales would be required. The use of a hierarchical framework in designing the sanitation monitoring framework had a number of advantages, including the following:

1. The framework facilitated the capture and reporting of the "big picture" of sanitation in South Africa.
2. The framework facilitated recognition that the effects of environmental stresses can be expressed in different ways at different levels in the hierarchy, namely the effects at one level in the hierarchy could be expected to resonate through the other levels of the framework, i.e. linking cause-effects.
3. Structuring sanitation monitoring systems in this conceptual framework facilitated the selection of indicators that represented many aspects that warrant attention in monitoring of sanitation in South Africa.
4. The hierarchical framework helped to develop sound monitoring and evaluation plans and implementation of monitoring and evaluation activities.
5. The framework articulated policy goals and measurable short, medium and long-term objectives, in a systematic and structured manner.
6. The hierarchy structure of the framework defined relationships between inputs, activities, outputs, outcomes and impacts, and thus demonstrated how activities would lead to desired outcomes and impacts, especially when resources were not available to conduct rigorous impact evaluations. They often display relationships graphically.

In designing a Citizen Science monitoring framework for South Africa it is necessary to understand the top-down strategic objectives and intents that would form the higher levels of the hierarchical framework. The bottom-up citizen determined monitoring requirements for sanitation in the country would then be categorised to speak to each of the upper-level national sanitation strategic objectives/policy intents. The Citizen Science monitoring framework thus applied the bottom-up citizen driven monitoring priorities with the top-down international and national sanitation objectives and intents (Figure 8).

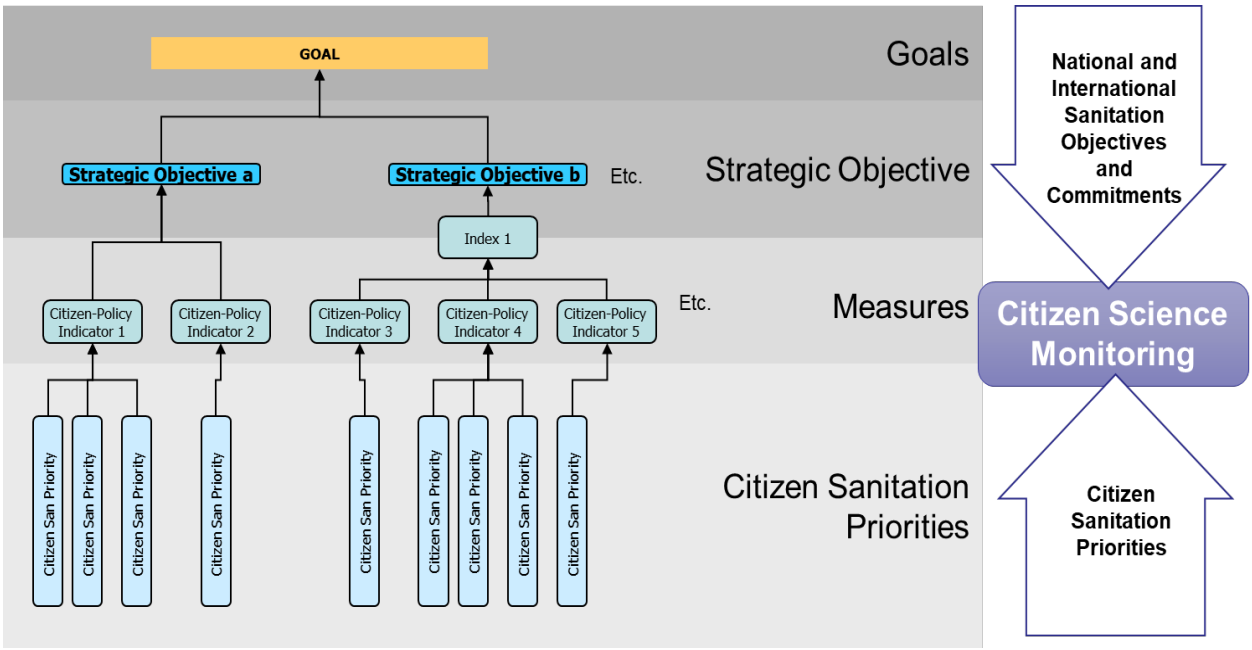


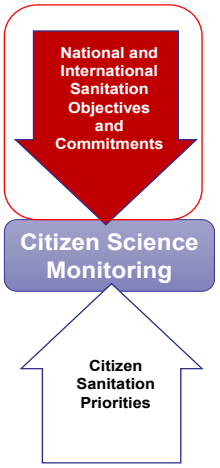
Figure 8: Sanitation monitoring hierarchy showing the linkages between bottom-up citizen sanitation priorities and top-down national and international sanitation monitoring objectives and commitments. Where the two meet is the site of a Citizen Science monitoring systems.

CHAPTER 5: SCOPING OF REQUIREMENTS, STANDARDS, COMPONENTS, INDICATORS AND MEASURES NECESSARY FOR CITIZEN SCIENCE MONITORING AND REPORTING OF SANITATION

This chapter presents the application of the top-down-bottom-up Citizen Science monitoring framework for sanitation in determining the monitoring and reporting requirements:

1. at a national and international level, and
2. by the individual households.

5.1 NATIONAL AND INTERNATIONAL SANITATION MONITORING AND REPORTING REQUIREMENTS



As outlined in the framework for Citizen Science monitoring in Section 6 of this report, it is necessary to understand national and international sanitation objectives and commitments to ensure that citizen sanitation priorities that are monitored by a Citizen Science monitoring system that contribute to South Africa's national reporting and monitoring. This section of the report provides an overview of South Africa's national and international sanitation objectives and commitments that need to guide and inform the Citizen Science monitoring framework and systems, i.e. this section of the report focusses on the content of the red arrow shown in the Citizen Science monitoring framework on the right of this page.

5.1.1 A rights-based approach to monitoring

According to the Webster & Selebalo (2018), the key indicators for realising the human right to sanitation are access, adequacy and quality. The handbook by the United Nations (De Albuquerque, 2014) on the human rights principles for water and sanitation advocates the standards of the human right to water and sanitation as the following:

- Availability – everyone is entitled to sufficient and continuous water for personal and domestic use, and a sufficient number of sanitation facilities.
- Affordability – services must be affordable to all – they must not compromise the ability to pay for other necessities guaranteed by human rights, e.g. food or housing.
- Quality – water has to be safe and present no threat to health. Sanitation must be hygienically and technically safe. Access to water for cleansing and hand washing is essential.
- Acceptability – sanitation facilities must be culturally acceptable, often meaning gender-specific and ensuring privacy and dignity.
- Accessibility – water and sanitation facilities must be accessible to everyone within – or in the immediate vicinity of – households, health and educational institutions, public institutions and places, and workplaces. Physical security must not be threatened.

5.1.2 South Africa's International Sanitation Commitments – the Sustainable Development Goals

Since 2015, the globe has focussed developmental efforts based on monitoring of the SDGs. In adopting the 2030 Agenda for Sustainable Development (2030 Agenda), countries, including South Africa, resolved to free

humanity from poverty, secure a healthy planet for future generations, and build peaceful, inclusive societies as a foundation for ensuring lives of dignity for all (2). The 2030 Agenda set out the 17 SDGs and 169 targets to track progress of nations in achieving these development imperatives (2). Progress in achieving the SDGs is measured by a number of global indicators.

Noteworthy in the SDGs was the formal adoption of a WASH SDG, namely SDG6 that related to ***ensuring availability and sustainable management of water and sanitation for all***. This SDG represented a monumental achievement for the water and sanitation community, where WASH was only a target in the Millennium Development Goals (MDGs) (UN-Water, 2015).

5.1.2.1 The SDG Sanitation Target 6.2

The sanitation target of Goal 6 of the SDGs is SDG 6.2 of, by 2030, achieving ***access*** *to* ***adequate*** *and* ***equitable sanitation*** *and* ***hygiene*** *for all and* ***end open defecation****, paying special attention to the needs of* ***women and girls*** *and those in* ***vulnerable situations***, pays special attention to addressing the sanitation and handwashing needs of women, girls and vulnerable groups.

SDG 6.2 aims not only on achieving access to sanitation, but aspires to achieve adequate access, equitable access, access for all (universal access) and ending open defecation for the entire population of a country by 2030. The criteria to achieving SDG targets for sanitation and hygiene can be explained as follows:

Table 4: Normative interpretation of SDG 6.2

By 2030	Normative interpretation
Achieve **access**	Implies facilities close to home that can be easily reached and used when needed
To **adequate**	Implies a system that hygienically separates excreta from human contact as well as safe reuse/treatment of excreta in situ, or safe transport and treatment off-site
And **equitable**	Implies progressive reduction and elimination of inequalities among population subgroups
Sanitation	The provision of facilities and services for safe management and disposal of human urine and faeces
And **hygiene**	See Framework Guide 3 (WRC Report K2558/4)
For all	Suitable for use by men, women, girls and boys of all ages, including people with disabilities
And **end open defecation**	Excreta of adults and children are deposited (directly or after being covered by a layer of earth) in the bush, a field, a beach or any open area, discharged directly into a drainage channel, river, sea or any other body, or are wrapped in temporary material and discarded
Paying special attention to the **needs of women and girls**	Implies reducing the burden of water collection and enabling women and girls to manage sanitation and hygiene needs with dignity. Special attention should be given to the needs of women and girls in high-use settings such as schools and workplaces, and high-risk setting such as health-care facilities and detention centres
And those in **vulnerable situations**	Implies paying attention to specific drinking water, sanitation and hygiene (WASH) needs found in special cases including in refugee camps, detention centres, mass gatherings and pilgrimages

5.1.2.2 The SDG Hand Hygiene Target 6.2

The **hygiene** component of the SDG 6.2 target is defined by the UN-Water (2015) as *the condition and practices that help maintain health and prevent spread of disease including handwashing, menstrual hygiene management and food hygiene*. The National Sanitation Policy for South Africa provides the following definition for hygiene: *personal and household practices that serve to prevent infection and keep people and environments clean. The conditions and practices that help to maintain health and prevent the spread of diseases* – thus following the UN-Water's definition of hygiene.

The components that make up the '**hand-washing facility with soap and water**' of SDG 6.2 are meeting the four criteria of:

a) a handwashing facility available when needed (i.e. may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing);
b) on premises (i.e. at a minimum, situated in the yard in the South African context);
c) with soap (i.e. bar soap, liquid soap, powder detergent, and soapy water but does not include ash, soil, sand or other handwashing agents); and
d) with water (i.e. at a minimum, a tap situated in the yard in the South African context).

According to the WHO and UNICEF (2017), a handwashing facility could be fixed or be mobile, but should consist of:

- a sink with tap water on the premises;
- devices that contain, transport, or regulate the flow of water on the premises;
- buckets with taps on the premises;
- tippy-taps on the premises; or
- portable basins on the premises.

Tracking progress towards the SDG 6.2 of achieving access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations, requires high-quality, timely and accessible data, often in areas where very little data exists today.

Data acquisition and monitoring also requires political commitment to transparency that includes efforts such as Citizen Science for data-monitoring systems at all levels to complement existing data-collection efforts.

The achieving of the SDGs also requires public engagement and participation in the development sector of a country. Citizens need to hold government accountable and to ensure that intended societal transformations are achieved with the SDGs. Citizen Science could make important contributions to addressing this need.

5.1.3 South Africa's National Sanitation Commitments – sanitation and hygiene legislation and policy

The South African legislation and policy regarding sanitation is summarised below.

5.1.3.1 Sanitation in the South Africa Policy

A basic sanitation facility is as defined by the 2016 National Sanitation Policy (DWS, 2916) as follows:
"*The infrastructure necessary to provide an appropriate sanitation facility which considers natural (water; land; topography) resource constraints, is safe including for children, reliable, private, socially acceptable, maintainable locally, protected from the weather and ventilated, keeps smells to the minimum, is easy to keep clean, minimises the risk of the spread of sanitation-related diseases by facilitating the appropriate control of disease carrying flies and pests, facilitates hand washing and enables safe and appropriate treatment and/or removal of human waste and wastewater in an environmentally sound manner*".

The National Sanitation Policy definition of a basic sanitation facility is (amongst others) one which is *private, safe and protected from the weather,* thus offering privacy (a toilet is deemed to offer privacy to the user when it has four in-tact walls and a door), is technically safe and protected from the weather (the walls and roof are in-tact and protect the user and the toilet from the weather), is well ventilated and has sufficient light during daylight hours. It should be big enough (0,9 m x 1.15 m) to be used by most people. A toilet for people with

disabilities should measure at least 1,2 m x 1,4 m and equipped with handrails that is placed 1 m above the floor and a ramp at a comfortable angle for access.

Sanitation facilities must:

- provide technical safety and protection from the weather;
- provide privacy;
- be appropriate;
- provide adequate light and ventilation;
- minimise the risk of the spread of sanitation-related diseases;
- be easy to operate and maintain;
- have ownership;
    - be reliable – the maximum length of time that a household, school or clinic can safely be without a sanitation facility, without drastically increasing exposure to sanitation-related disease risks, is 3 days; and
- promote good sanitation and hygiene practices.

An appropriate and adequate sanitation facility in South Africa is thus defined as a facility that effectively separates excreta from human contact, and ensures that the excreta do not re-enter the immediate environment or pose any risk to the humans or the environment. A sanitation facility has to comply with, at least, the following requirements to be appropriate to the context:

(1) *Safe containment:* A sanitation facility that forms a safe barrier between the user and the excreta.

(2) *Water and anal cleansing material:* Water must be available for toilets with water flush and/or hygienic seal mechanisms. Users should be consulted on the most culturally appropriate cleansing materials and their safe disposal.

(3) *Menstruation consideration:* Women and girls of menstruating age must have access to suitable materials for the absorption and disposal of menstrual blood. Toilets must include provision for appropriate disposal of menstrual material or private washing facilities.

(4) *Containment of children's faeces:* Particular attention must be paid to the disposal of children's faeces, as they are commonly more dangerous than those of adults (excreta-related infection among children is frequently higher and children may not have developed antibodies to infections). Parents and caregivers must be provided with information about safe disposal of infants' faeces, laundering practices and the use of nappies (diapers), potties or scoops for effectively managing safe disposal.

(5) *Accessible for all*: Special toilets need to be constructed for children, older people and persons with disabilities, e.g. toilets with seats or handrails or provision of bed pans, potties or commodes.

(6) *Operation and maintenance:* Operations and maintenance are the activities related to the performance of routine, preventative, predictive, scheduled, and unscheduled actions aimed at preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety. The owner must adhere to the relevant by-laws of their local municipality regarding on-site sanitation. The owner is fully responsible for all capital, operation, maintenance and refurbishment actions and costs pertaining to on-site sanitation, unless it is provided as a free basic sanitation service, in which case the local authority is responsible for these actions and costs.

(7) *Wastewater management and effluent disposal*: Sewage, sewage effluent and wastewater shall be disposed of without causing a public health nuisance and/or hazard, following the *Guidelines for the Utilisation and Disposal of Wastewater Sludge Volumes 1 to 6* (Herselmann & Snyman, 2006). These guidelines encourage the beneficial use of sludge while setting strict requirements for all disposal options. It can be used in agriculture or aquaculture, but not discharged indiscriminately into lanes, drainage

ditches, onto open urban spaces and into inland waters, estuaries, or the sea, causing serious health impacts and water pollution.

An essential aspect of any sanitation improvement initiative is the provision of simple information to households to strengthen their understanding of the linkages between good sanitation, safe drinking water and comprehensive hygiene. To reduce the prevalence of sanitation-related diseases, these paths have to be blocked.

Experience in South Africa and elsewhere showed that sanitation programmes that focused exclusively on toilet provision only tended to have limited and short-lived benefits. User education is essential for any sanitation installation, regardless of whether it is urban or rural, on-site or off-site, wet or dry. Sanitation services must promote awareness of the linkages between health, hygiene and sanitation, and provide users with information on how to keep their toilet functioning well. Unless users understand the basic requirements for operating and maintaining a hygienic toilet it is likely to malfunction and – particularly for on-site toilets – provide a powerful disincentive to being used (SALGA, 2008).

Comprehensive user education and awareness raising should address, at least, the following:

- Safe handling of drinking water
- Safe disposal of wastewater
- Safe disposal of human faeces and urine
- Maintaining a hygienic toilet
- Personal hygiene
- Food hygiene
- Safe disposal of solid waste.

5.1.3.2 Norms and standards for sanitation services

The proposed norms and standards for domestic water supply and sanitation (DWS, 2017) were based on the principle of human rights to basic water and sanitation and aimed to achieve the SDGs by 2030. The norms and standards were prescribed in terms of a number of factors, such as the different users, and the different geographical, socio-economic and physical attributes of areas, with the aim to scale up Integrated Water Demand and Conservation Management (IWDM).

The norms and standards particularly draw on the principles of universal access, human dignity, user participation, service standards, redress and value for money. The norms and standards were based on the 2016 National Sanitation Policy (DWS, 2016) and all the other legislation that it derived from including, but not limited to, the lessons that the sector has learned to date. The 2016 National Sanitation Policy was grounded on the following principles:

1. The right to access to basic sanitation.
2. Prioritising hygiene and end-user education in sanitation service provision.
3. Prioritising basic sanitation services to vulnerable people and unserved households.
4. People-centred and demand-driven sanitation service provision.
5. Polluter pays principle.
6. User pays principle.
7. Sanitation has economic value.
8. Integrated development.
9. Equitable regional allocation of development resources.
10. Recognising the value of sanitation by-products.
11. Prioritising operation and maintenance.
12. Integrated waste management.

5.1.4 Summary of International and National Sanitation Monitoring Requirements

Based on the international commitment and national policy review conducted for this section of the report, Figure 9 demonstrates the policy intents that will need to be monitored to be able to report progress with these. The policy intents also have a number of components that need to be monitoring and reported for each intent. Designing a sanitation monitoring programme that measures and reports these intents and components, should address international and national sanitation reporting obligations, i.e. to design a top-down sanitation monitoring system. Citizens would not be expected to contribute to or participate in the research behind such a system.

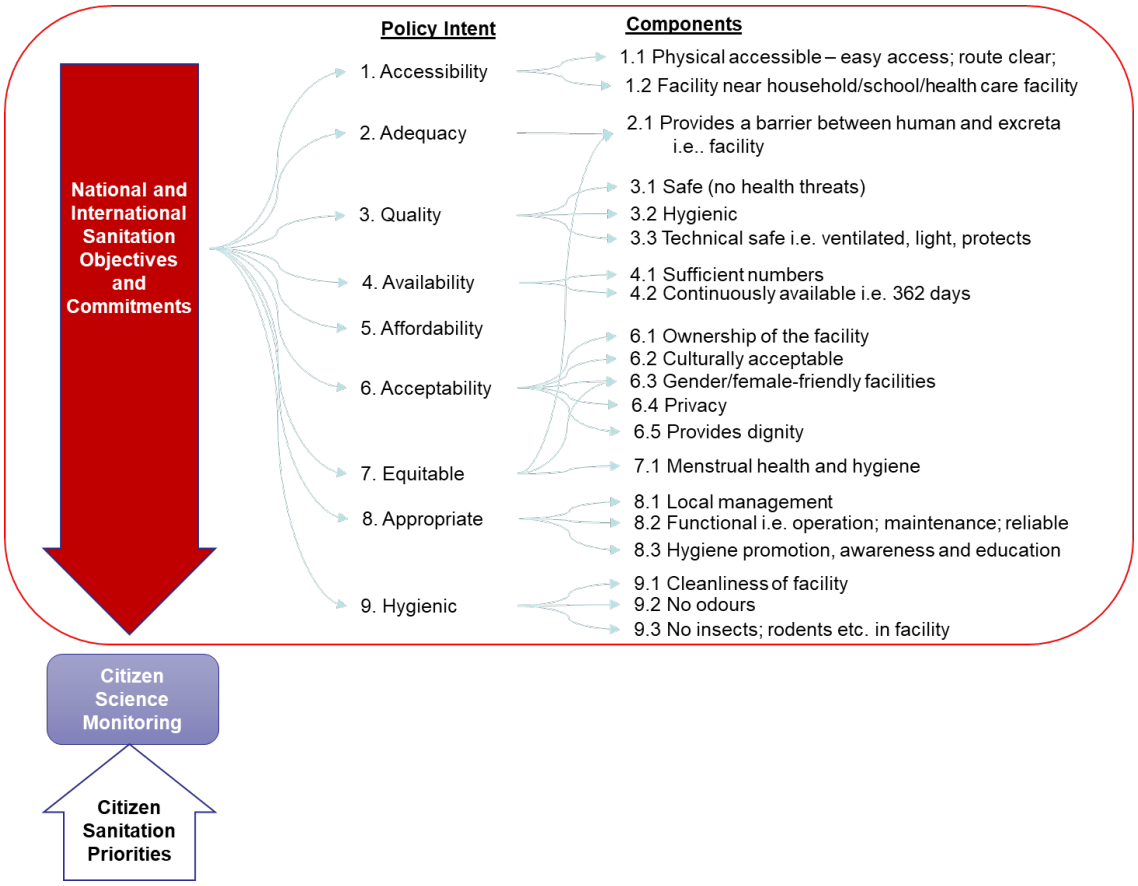
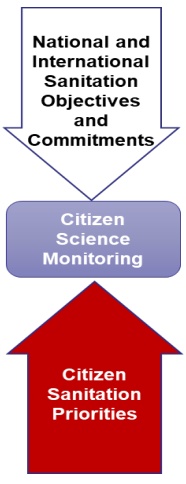


Figure 9: International commitments and South African policy intents that need to be monitoring to report progress in achieving universal access to sanitation and hand hygiene.

5.2 CITIZEN-DRIVEN MONITORING



Participation of citizens in this research or monitoring progresses will be dependent on their interest in the subject (i.e. sanitation), the perceived benefits of participating and the ability of the monitoring system to encourage their inputs, participation and continued support. Hence, to ensure that citizens' needs inform the Citizen Science sanitation and hygiene information platform, a survey of citizens perceptions, interest and priorities for sanitation was conducted. These perceptions, interest and priorities are utilised in the later section of the report to inform the specifications of the Citizen Science information platform. This section focusses on capturing the citizens "intent" for their sanitation and thus a bottom-up approach to designing the Citizen Science sanitation and hygiene systems. The focus is thus on capturing the bottom arrow inputs of the diagram shown on the right of this page.

To garner citizen perception and insight in Citizen Science monitoring of sanitation, a short, 10-questions citizen survey was developed and completed. Apart from capturing invaluable

citizens' insight into monitoring of sanitation through participation in Citizen Science, the survey also had the purpose of providing some insight into the effectiveness of using electronic surveys to capture citizens' insight in the South Africa context.

This section of the report provides the method and results from the survey.

5.2.1 Method of the survey

To ensure that citizens' input and insight could be captured for this research study, the citizen survey was designed based on the following principles:

- The language of the survey should to be simple and citizen friendly.
- The number of questions in the survey should to be limited to a maximum of 10 so that the survey could be captured in 5-7 minutes.
- The survey should to be able to be distributed through various platforms.
- The surveys and results of the survey should to be electronic as the long-term vision of this research study is that Citizen Science monitoring of sanitation would be conducted through an electronic platform.

A short questionnaire was developed to facilitate information gathering of the views and opinions of the public on the role of Citizen Science in the monitoring of the sanitation sector, as well as on sanitation facilities. The questions were designed to be applicable in formal and informal settings. They were equally appropriate for officials and for community members.

The survey made use of both closed and open-ended questions. Respondents were able to provide unique answers to a number of questions. The questions were the following:

- Do you think people/the public can assist in gathering information on sanitation or toilets?
- Would you feel comfortable providing information on your sanitation or toilet? If no, why not?
- When you use a toilet for the first time, what are the 5 (five) most important things that you check/consider when using sanitation facilities or toilet? Please list them from most important (1) to less important (5).
- Since COVID-19, which of the above things have changed or became more important for you?
- What would motivate you to provide information on your sanitation or toilet?
- What would be the easiest way for you to provide information on sanitation or toilet?
- What would prevent you from providing information on your sanitation or toilet?
- What would you expect to happen once you have given information on your sanitation or toilet?

To gather the information, a number of tools were considered. The best tool for this purpose proved to be the SoGoSurvey. The SoGoSurvey is a feature-rich modern online survey tool. It is a cloud-based SaaS application and platform designed to create, distribute, and analyse multilingual surveys, forms, polls, quizzes and assessments.

The survey was distributed through two electronic media platforms to a list of over 150 stakeholders in various sectors and organisation of the country. The platforms were the following:

- A WhatsApp message containing an electronic link to the survey.
- Emails containing and electronic link to the survey.

The responses received added up to 32 in total after a period of 3 weeks. These responses were immediately captured by the electronic survey tool and uploaded to the SoGoSurvey site. Each response was captured as a single row entry in the SoGoSurvey data set. The SoGoSurvey database was downloaded by the research team in an Excel format and analysed in this format to generate the graphs and graphics for the results of the survey. Any statistical analysis that was conducted on the survey results were also conducted in Excel.

5.2.2 Findings from survey

The results of the survey, due to the size of the sample and perhaps the targeting of stakeholders in the email distribution, should not be viewed as representative of the entire South Africa citizenry, but rather as results that could be gathered from the citizenry in future, or platforms that could be utilised in future to garner participation of Citizen Science in monitoring of sanitation. The outputs of the survey do, however, provide some insight into what was important to the citizens in terms of sanitation use and their perceptions in the country. These were utilised to inform the Citizen Science monitoring framework in Section 5 of this report.

The findings from the survey were as follows:

A total of 32 individuals responded to the survey. One (1) respondent declined to participate in the survey (Figure 10).

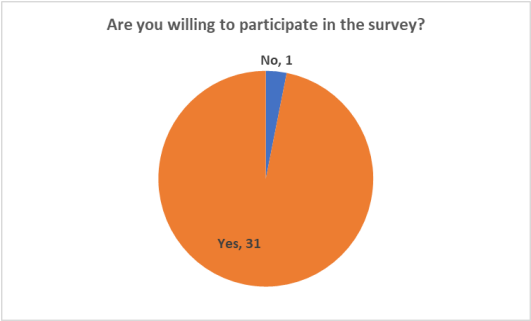
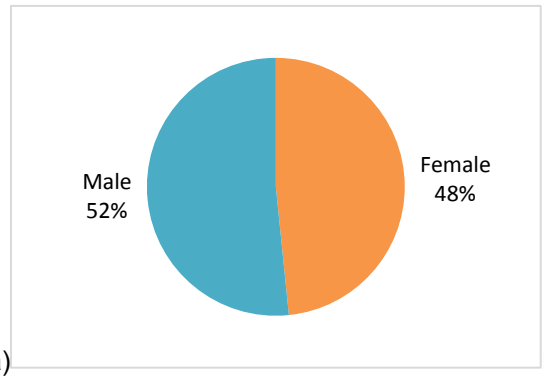


Figure 10: Number of respondents willing to participate in the survey.

5.2.2.1 Citizen Respondents Demographic Profile

Figure 11 below shows the demographic profile of the survey respondents. More males (52%) responded to the survey, as compared to females (48%). The age profile of the respondents, shown in Figure 11b, demonstrates that the majority (59%) fell into the South African age category of "youth", which is the age group between 19-35 years. At least a quarter of the respondents were between 36-60 years and the remaining 16% fell in the age category of "pensioners".

a)



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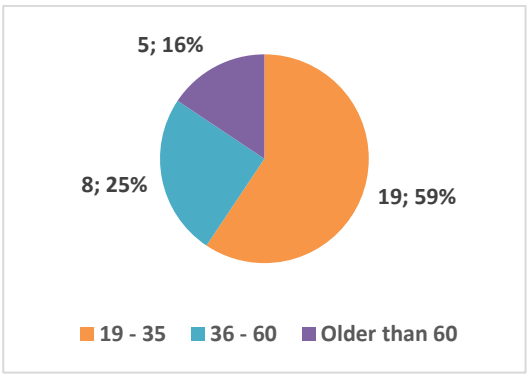


Figure 11: Demographic profile of survey respondents by (a) gender and (b) age

A Two-Sample Assuming Equal Variances t-test showed no statistical different between gender and age in the respondent dataset (two tailed t>0.05). Hence, males and females were represented by all the age categories in the survey.

5.2.2.2 Citizen Respondents Sanitation Types

This question in the survey captured the type of sanitation that respondents most often use in a normal day. It was important to capture these broad categories of sanitation to provide some insight into the type of sanitation

systems that would be informing the other questions related to sanitation in the survey. Figure 12 shows that the majority (n=26 or 81%) of the survey respondents had access to a waterborne sanitation system on a daily basis. Only 4 respondents had access to a pit/Ventilated Improved Pit toilet, with a further one (1) each having access to a Urine Diversion Toilet and a bucket toilet. Waterborne sanitation access was thus the dominant sanitation type informing the survey perceptions and insights.

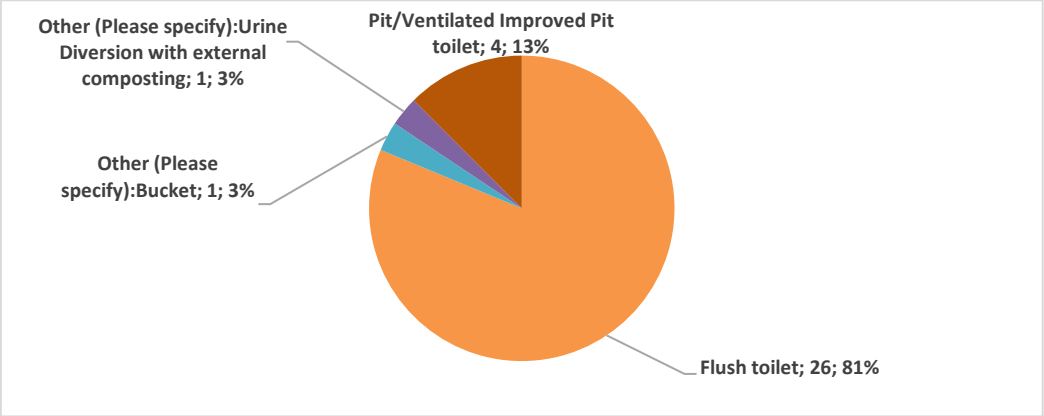


Figure 12: Number of respondents per sanitation type

A Two-Sample Assuming Equal Variances t-test showed no statistical different between gender vs toilet type and age vs toilet type (two tailed t>0.05). This could, however, be due to the large number of respondents having access to a flush toilet, with very few of the respondents having access to the other sanitation types.

5.2.2.3 Citizen Respondents Perception of Participation in Monitoring of Sanitation

A question was put to respondents as to whether they felt that people/the public can assist in gathering information on sanitation or toilets. The purpose of this question was to determine whether respondents felt that citizens could contribute to monitoring of sanitation in the country. Figure 13 shows that the large major (91%) of respondents felt that the public could assist with gathering information on sanitation or toilets in the country. This was a pleasing positive result, demonstrating that citizen participation in sanitation monitoring could be well received by the country's citizenry if such a citizen monitoring system is design and implemented in a participatory, efficient and sustainable manner.

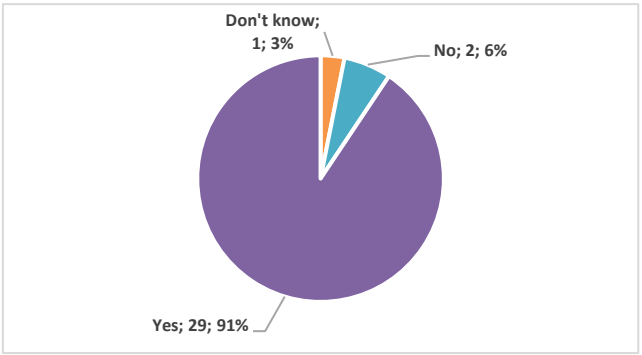


Figure 13*:* Number of responders per response to the question: do you think people/the public can assist in gathering information on sanitation or toilets?

One of the key concerns in the research arena is the perception that citizenry would not be willing to provide information and insight on the own sanitation as sanitation is a "private" or "sensitive" subject. Hence, the survey put a question to the respondents on whether they would feel comfortable providing information on their sanitation or toilet. Figure 14 shows that they respondents responded positively to the question, indicating that almost all respondents would be comfortable providing information on their sanitation services. Certainly, from this sample, respondents have indicated comfort with providing information on their sanitation/toilet.

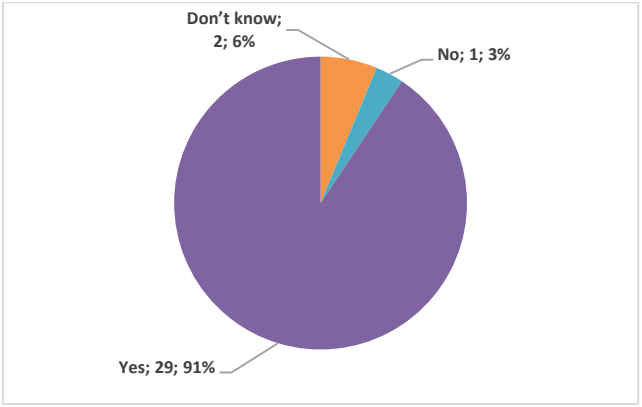


Figure 14: Number and percent of respondent per answer type for the question: would you feel comfortable providing information on your sanitation or toilet?

The one negative response to the question provided the reason for not being comfortable with providing information on their sanitation/toilet as "It is my private business". The Citizen Science sanitation monitoring system design and implement will need to recognise that there may be a reluctance by citizenry to providing information on their sanitation/toilet and will need to ensure that this does not result in exclusion of large groups, or groups with specific sanitation type and challenges, in the sanitation monitoring system in future. Tools, incentives and systems will need to be explored to address this challenge to monitoring of sanitation by citizens.

Noting the positive responses from citizen regarding participation in monitoring of sanitation, the survey sought to determine what would motivate or prevent citizens from participating in these endeavours. Figure 15 shows the responses from the citizens surveyed to the question 'what would motivate you to provide information on your sanitation or toilet?' The figure showed that most respondents cited that citizen would participate to see an improvement in sanitation (n=8), follow by payments for participating (n=4), and to help people (n=3). At least 3 respondents indicated that nothing would motivate them to participate.

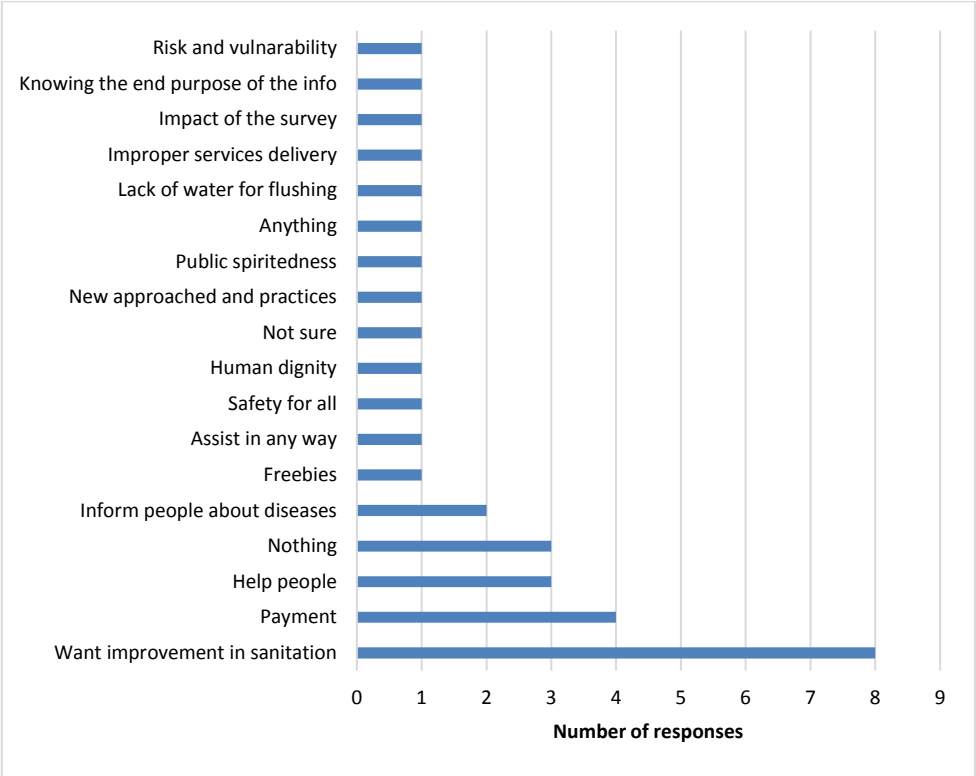


Figure 15: Number of respondents per response to the question 'what would motivate you to provide information on your sanitation or toilet?'

The citizen respondents were also asked what would prevent them from providing information on their sanitation/toilet, with Figure 16 showing that the largest group of respondents (n=12) indicated that nothing would prevent them for participating in endeavours to gather information on their sanitation/toilet and hygiene facility. A smaller number indicated that preventing their participation would be lack of time (n=3), a long survey (n=2), and the survey not being confidential (n=2). A number of respondents replied that citizen respondents would not participate in endeavours to capture information on their toilets/sanitation. This needs to be considered in designing a Citizen Science monitoring programme for sanitation in South Africa.

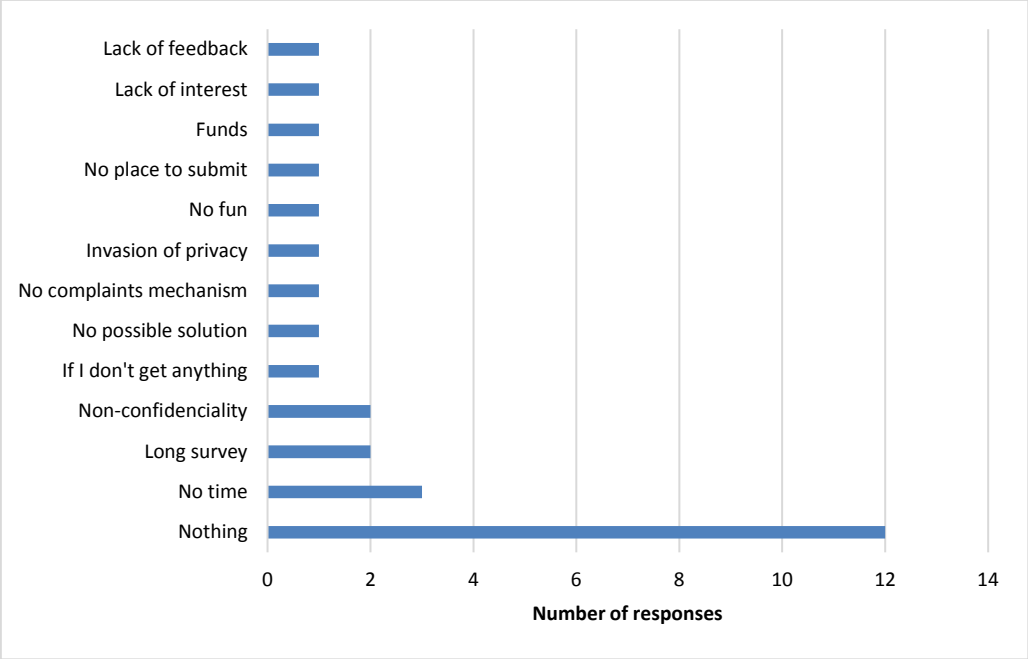


Figure 16: Number of respondents per response to the question 'what would motivate you to provide information on your sanitation or toilet?'

5.2.2.4 Citizen Respondents' Toilet Priorities

To capture respondents' priorities for a toilet when visiting a toilet for the first time, they were asked to prioritise, from 1 to 5, the 5 (five) most important things that they check/consider when using the facility/toilet. Table 5 demonstrates that the citizens' highest priority issues when using a facility or toilet were the following:

- Cleanliness of the toilet, i.e. seat; cubical; toilet.
- Function of the toilet, i.e. water to flush; does it have a seat; can the toilet flush; is the toilet working.
- Availability of sanitary material, i.e. toilet paper; newspaper; wiping supplies.
- Availability of water.
- Handwashing.

Cleanliness was shown to be the most important toilet issue to the respondents.

The second-level priorities for respondents related to availability of sanitary material, i.e. toilet paper, newspaper for cleaning, wiping supplies, etc., which also highlight the importance of numbers 3 and 4 above. Priority 2 also added the importance of the proper functioning of the toilet, i.e. water to flush, does it have a seat, can the toilet flush, is the toilet working, etc.

The third-level priorities were again highlighted as availability of sanitary materials and functioning of the toilet, but saw the addition of toilet floor durability, cleanliness and wetness.

The fourth-level most cited priority for a toilet was the availability of toilet cleaning materials, i.e. brush, bleach, etc., followed by privacy provided by the toilet, i.e. door on the toilet; door must close.

Finally, the fifth-level most cited priority for the toilet was in fact one of the priorities sited in the other 4 priority areas, although safety of the toilet and availability of handwashing facilities was cited by at least 3 respondents.

Table 5: Number of responses per category of priorities when visiting a toilet for the first time.

Category of Priority	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5
Cleanliness of the toilet, i.e. seat; cubical; toilet	20	2	2	2	
Availability of **sanitary material**, i.e. toilet paper; newspaper; wiping supplies	2	8	8	3	3
Privacy, i.e. door on the toilet; door must close	1		1	5	3
Availability of **water**	1	4	1	1	
Availability of **handwashing** facility	1		1		3
Safety of the toilet, i.e. lock the toilet while inside. of the toilet	1	1	1		3
Function of the toilet, i.e. water to flush; does it have a seat; can the toilet flush; is the toilet working	3	6	5		2
Aesthetic, i.e. no smell; no noise		4	2		
Durable, clean, dry floor			3		
Availability of toilet **cleaning materials**, i.e. brush; bleach				6	

To determine the highest priority for a toilet, based on the number of respondents mentioning the priority, the categories of priorities were weighted and summed. For example, each response for cleanliness was given a score of 5 in priority 1, a score of 4 as priority 2, etc. The weighted prioritisation is shown in Figure 17, which demonstrates that cleanliness of the facility is a priority for citizens, followed by availability of cleansing materials, and the functionality of the facility. Aesthetic, privacy and availability of water were also key priorities for citizen respondents.

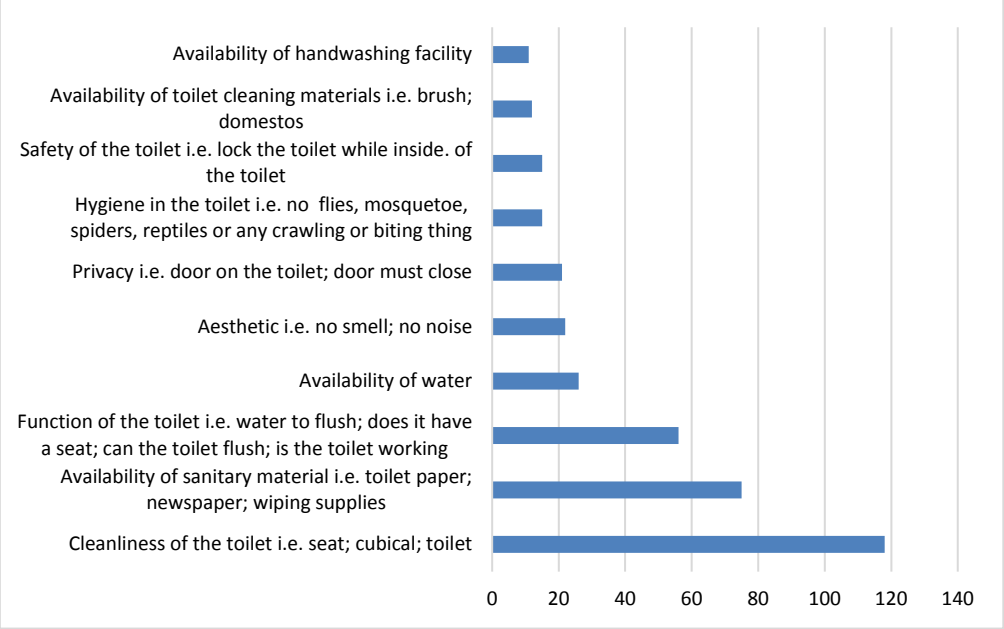


Figure 17: Weighted priorities of citizen respondent's indication of important consideration when use a toilet facility.

5.2.2.5 Citizen Respondents Priority Change due to COVID-19.

To garner citizen respondents' perception of changes in toilet priorities that may have occurred as a result of the COVID-19 pandemic, the respondents were asked: "Since COVID-19, which of the above list of things have changed or became more important for you and why?" Figure 18 demonstrates that citizen respondents

highlighted that the most important sanitation priority change due to COVID-19 related to the cleanliness of the toilet and to handwashing. A number of respondents did, however, indicate that there was no change in their priorities for a sanitation facility as a result of the COVID-19 outbreak. Handwashing and handwashing with soap do emerge as a new key priority in this case.

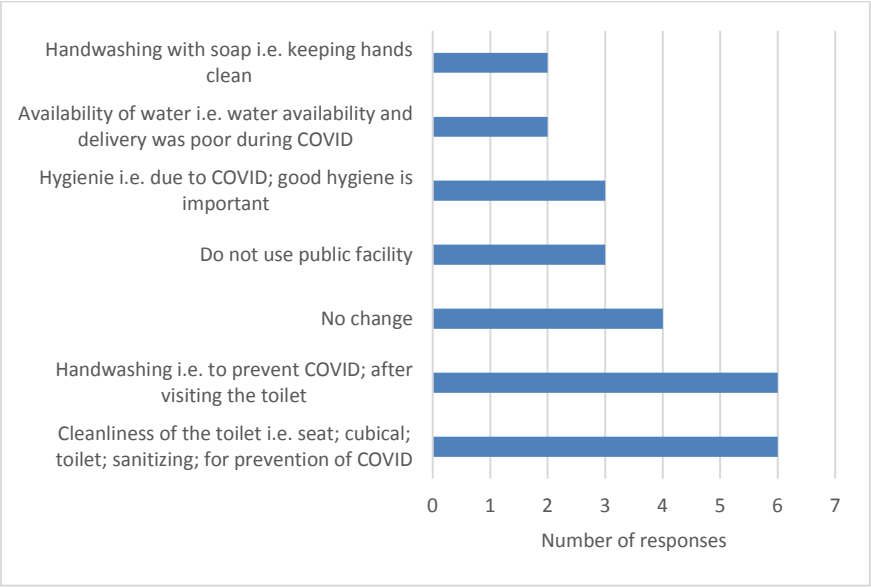


Figure 18: Changes in citizen respondents' priorities for sanitation/toilet use after COVID-19.

5.2.2.6 Citizen Respondents' Suggestions of Collection of Information

Finally, citizen respondents were asked what the best manner would be for them to provide information on their sanitation/toilet. Figure 19 shows that the majority of citizen respondents indicated some form of electronic communication, namely a cell phone app (n=7); an electronic survey (n=6); email (n=5), and/or the media/social media (n=4). These results could, however, be due to the current survey being conducted through electronic tools.

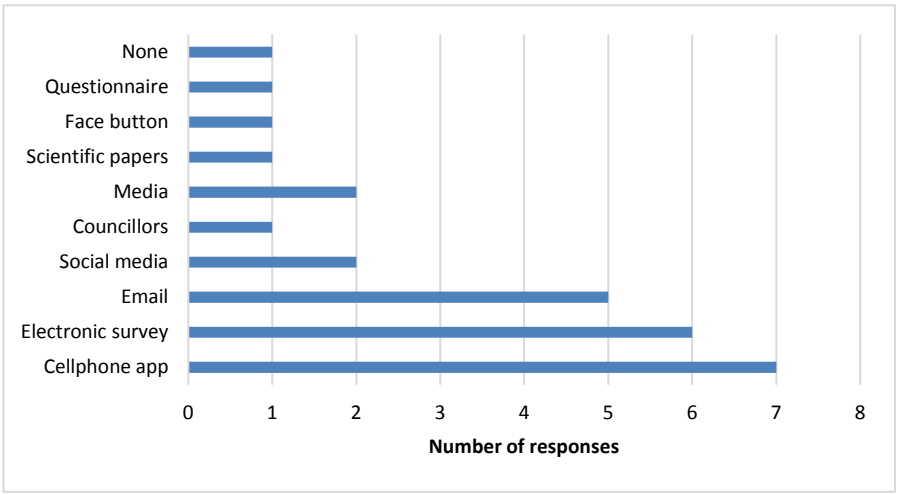


Figure 19: Changes in citizen respondents' priorities for sanitation/toilet use after COVID-19.

5.2.3 Summary of key findings from the survey

The following are key consideration, from the survey of citizen respondents that will inform the research going forward:

4. It is possible to gather sanitation information from citizens from an electronic platform.

5. Almost all citizen respondents were willing to participate in the survey – indicating a generally positive attitude to those that started the survey.

6. Citizen respondents could clearly inform the design of the monitoring systems through providing invaluable information on the following:

    a. What they consider important in their use of a sanitation facility. If these key priorities are utilised to design Citizen Science monitoring programmes for sanitation, one would expect greater participation in the study.

    b. What would motivate participation of citizens in such a Citizen Science monitoring programme. Again, designing a Citizen Science monitoring programme to consider these motivations should increase participation in the monitoring.

    c. What prevents participation of citizens in such a Citizen Science monitoring programme. Again, designing a Citizen Science monitoring programme to remove or minimise the barriers to participation should increase participation in the monitoring.

    d. The correct communication/ Citizen Science monitoring programme tools. Designing a Citizen Science monitoring programme utilising the simplest, easiest and preferred communication tools should increase participation in the monitoring.

Based on citizens priorities emerging from this section of the report, Figure 20 demonstrates the citizens sanitation priorities that need to be including in Citizen Science monitoring of sanitation to be able to report progress with these. Designing a sanitation monitoring programme that measures and reports on these citizen priorities should encourage and facilitate citizens participation in monitoring of sanitation in the country.

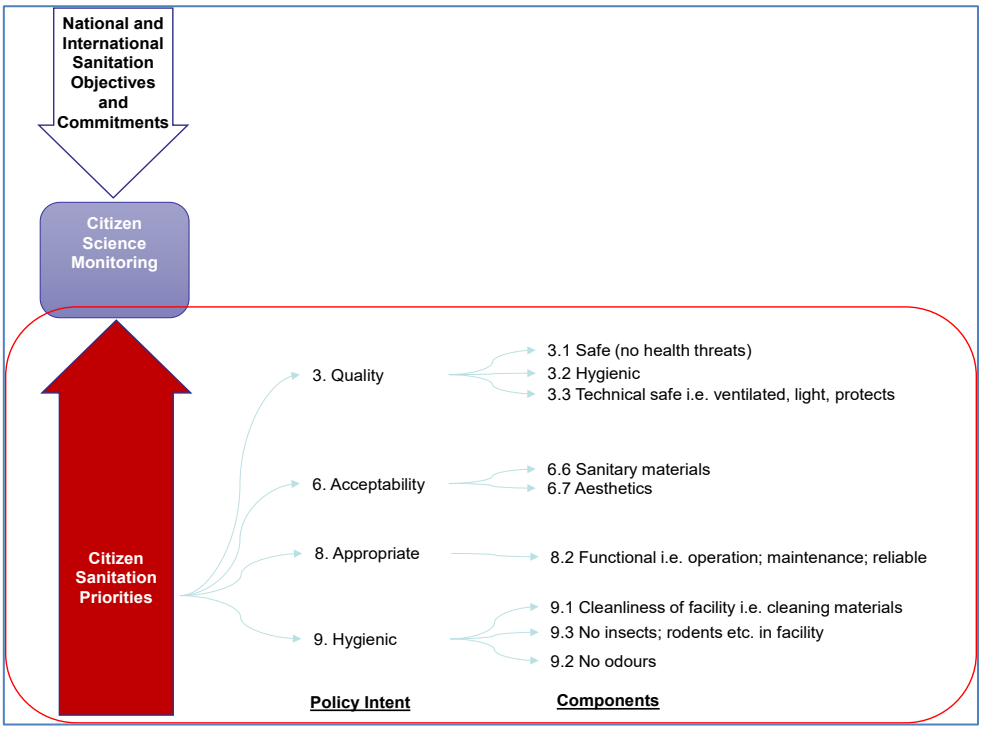


Figure 20: Citizens' priorities for the sanitation/toilet and hygiene facility that need to be monitored to report progress in achieving universal access to sanitation and hand hygiene.

CHAPTER 6: THE SPECIFICATIONS FOR THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM TO ASSESS RURAL SANITATION IN SOUTH AFRICA

6.1 WHAT DATA OR INFORMATION NEEDS TO BE COLLECTED BY THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM?

The specifications of a Citizen Science sanitation and hygiene information platform (CS-SHIP) in South Africa merged the top-down international sanitation and hygiene commitment (i.e. SDGs) and the South African sanitation and hygiene policy intents with the sanitation priorities of the citizens.

The assumption was made that a CS-SHIP that recognise both the top-down national and international sanitation and hygiene monitoring and reporting requirements, and the bottom-up citizens' sanitation and hygiene monitoring and reporting priorities, the CS-SHIP would have application at many levels in the country and thus enjoy wide acceptability and use.

Figure 21 demonstrates where these top-down commitments/intents meet the bottom-up citizen priorities, forming the specifications for the CS-SHIP.

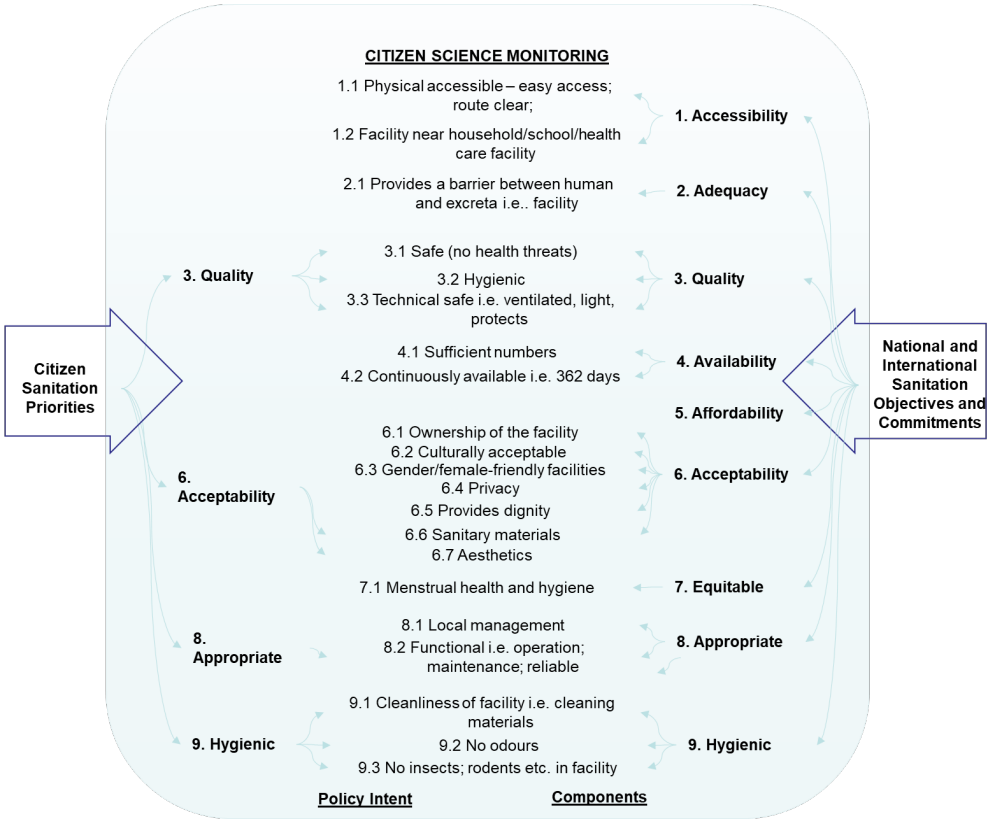


Figure 21: Citizens and national/international priorities for the sanitation that need to be monitored to report progress in achieving universal access to sanitation and hand hygiene

The assumption was made that a CS-SHIP that recognises all levels of monitoring requirements, i.e. national/international intents and citizens priorities, would encourage the participation of citizens in the monitoring and reporting process while ensuring that the monitoring system contributes to South Africa's national and international reporting commitments.

Table 6 below shows the links between intents, components and measurements required for each. The measurement requirements would capture the sanitation information and data to be able to report each of the intents and components of the CS-SHIP. The system would be designed so that Citizen Science could provide the relevant information and data on the sanitation and hygiene facility, and that this information and data would contribute to the national/international sanitation monitoring and reporting system. The CS-SHIP would also be able to monitor and report to citizens priorities for their sanitation/toilet and hygiene facility, thus providing them with the information and insight into their system and thus, report on the state of the system. Citizens would also need to receive feedback from the system on the state of their system and potential corrective actions, if the status of the sanitation/toilet and hygiene facility is shown to be inadequate. A reporting feedback loop will be required for the CS-SHIP.

Table 6: Citizen and international/policy priorities to measure the state of sanitation in South Africa and the measurement requirements to capture the information and data to report on these.

Priorities	Components	Measurement Requirements
Citizens and Policy/International Priorities		
3. Quality	3.1 Safe (no health threats)	• Four intact walls. • A door that can close properly. • A floor that does not flood during rain. • An intact and securely attached roof with a slope away from the door.
	3.2 Hygienic	• Appropriate facility, sink or wash basin within 1 metre of the toilet for washing hands after using the toilet. • Availability of soap and water for hand washing.
	3.3 Technical safety, i.e. ventilated, light, protects	• Sufficient air flow through the toilet to leave it odour free. • A gap above the door, below the door, or a gap between the roof and the walls. • An air vent built into the wall, or a window which can be opened. • Adequate light inside the toilet at all times.
6. Acceptable	6.6 Sanitary materials	• Availability of wiping materials • Availability of menstrual materials
	6.7 Aesthetics	Keeps smells to a minimum • An air vent built into the wall, or a window which can be opened to allow air flow. • A toilet seat and lid that can close.
8. Appropriate	8.1 Local management	Easy to use and maintain. • Facilities (sanitation and hygiene) is maintained by households or local contractor. • Simple and easy to understand, use and maintain by all users. • Instructions for use are available and easy to understand. • Maintenance materials are widely available and easy to use. • Spare parts are widely available and easy to acquire.
	8.2 Functional, i.e. operation; maintenance; reliable	Toilet and hygiene facility is working. • No problems with the facilities, i.e. leak, etc. • Facilities (toilet and hygiene) available 362 days of the year

Priorities	Components	Measurement Requirements
9. Hygienic	9.1 Cleanliness of facility, i.e. cleaning materials	• Smooth floor and walls. • Smooth pedestal and lid. • Cleaning materials are affordable to users. • Cleaning materials are available, i.e. brush, bleach, etc.
	9.2 No odours	See 6.7 above
	9.3 No insects; rodents, etc. in facility	• No mosquitoes in the facilities (toilet, handwashing station). • No flies in the toilet facility. • No spiders/spiderwebs in the facility. • No rodents in the toilet facility.
Policy/International Priorities		
1. Accessible	1.1 Physical accessible – easy access; route clear;	• Marginalised groups (women, children, disabled) were considered, such as a kiddie seat, railings/space for disabled, locks for doors, etc. • At least 0,9 m by 1,15 m in dimension on the inside of the toilet building. • The toilet seat should not be higher than 400mm from the floor.
	1.2 Facility near household/school/health care facility	• At most 20 m from the house/school/health care facility
2. Adequate	2.1 Provides a barrier between human and excreta, i.e. facility	• Toilet facility is on-site/in the households. • Toilet facility is function, i.e. no leaks, etc. • Safe and appropriate treatment and/or removal of human waste. • Groundwater protection. • Water source protection and conservation – rainwater harvesting. • Energy efficient – solar or other than ESKOM. • Recycle and re-use.
		Enables safe and appropriate treatment and/or removal of human waste. • A receptacle for sewage that is accessible for emptying. • Separates the pit/tank contents from the user of the toilet, preventing direct contact with contents.
4. Available	4.1 Sufficient numbers	• 1 facility per 30 family users • Toilet not shared with non-family households
	4.2 Continuously available	• Toilet and hygiene facility is working. • No problems with the facilities, i.e. leak, etc. • Facilities (toilet and hygiene) available 362 days of the year.
5. Affordable	5.1 Affordability of the technology to users	• Capital costs are affordable to users. • Maintenance materials and costs are affordable to users. • Spare parts are affordable to users. • Skills are transferred at user level. • Jobs are created at user level.
6. Acceptable	6.1 Ownership of the facility (sanitation and hygiene)	• Citizens demonstrate ownership of the toilet, i.e. recognise that maintenance is their responsibility. • Toilet is decorated or personalised.
	6.2 Culturally acceptable	• Citizens indicate that the facility (sanitation and hygiene) adheres to their cultural norms.
	6.3 Gender/female-friendly facilities	• Toilet facility if female-friendly, i.e. water available, female toilets, doors with locks, well lit, signed, soap, privacy, safe, etc.

Priorities	Components	Measurement Requirements
	6.4 Privacy	• Four vertical, upright intact walls. • A door, that closes, with mechanism that will keep the door closed when the toilet is in use and that can be locked.
	6.5 Provides dignity	• See above
8. Appropriate	8.3 Accompanied by appropriate health and hygiene education material to place 'barriers' in transmission pathways of sanitation-related diseases.	• Health and hygiene training form part of the technology. • Posters/pamphlets re use of the technology are available. • Posters/pamphlets re the maintenance of the technology are available.

Figure 21 and Table 6 above provide the key aspects that need to be considered to collect data and information to be able to report the state of sanitation in South Africa. Effectively they provide the specifications for the data and information requirements of a Citizen Science monitoring programme. Apart from these key data and information specifications, Table 7 below provides additional issues and considerations that need to be noted when designing a Citizen Science monitoring programme for sanitation in South Africa.

6.2 WHO SHOULD BE COLLECTING SANITATION AND HYGIENE DATA AND INFORMATION FOR THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM?

Figure 22 below shows the flow of data and information between the various stakeholders in the CS-SHIP. The figure clearly shows four crucial stakeholders required to operationalise the sanitation and hygiene CS-SHIP, namely the following:

1) **Button 1: the participating citizens** – These key stakeholders are the pivotal human component of the sanitation and hygiene CS-SHIP, as these individuals will be the key source of data that is provided to the platform/systems. Citizens are expected to utilise standards tools, outlined in the next section of the report, to capture and report crucial information on their sanitation and hygiene facilities to a centralised platform for data cleaning, processing and analysis.
2) **Button 2: the scientist but ultimately the artificial intelligence (AI) system** – This group of stakeholders have a range of roles to play, including data storage, cleaning, analysis and reporting. Data quality assurance will also be the responsibility of this stakeholder group.
3) **Button 3: local government** – This group of stakeholders have a role to play in utilising the CS-SHIP to generate credible, up-to-date and scientifically valid data on sanitation and hygiene in their rural and peri-urban areas. This data can be utilised in the municipal planning and policy documents.
4) **Button 4: national government** – This group of stakeholders have a role to play in utilising the CS-SHIP to generate credible, up-to-date and scientifically valid data on sanitation and hygiene in the country. This data can be utilised in the national planning and policy documents and can be used to report in the international SDG targets.

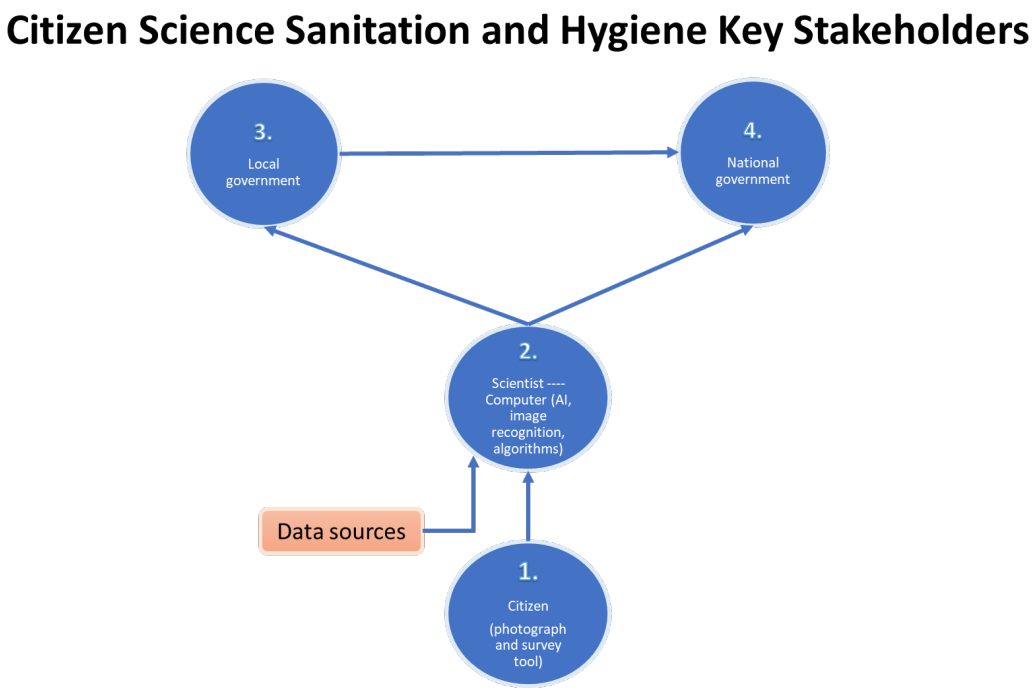


Figure 22: Key stakeholders involved in the CS sanitation and hygiene monitoring platform for South Africa

6.2.1 Stakeholder Group 1: The Citizen – Data Collection and Analysis Tool

This section of the report outlines the tools that citizens, Group 1 of stakeholders shown in Figure 22 above, can utilise to provide data and information to the CS-SHIP. In order to collect data to report on the above requirements and imperatives for sanitation in South Africa, a tool has been designed specific to South African conditions and cultures. The citizens, in monitoring and submitting information on their sanitation and hygiene systems, are envisaged to utilise two tools:

- Short electronic questionnaire
- Photography.

The Internet of Things (IoT), improved access to internet, and smartphone/cell phone technology have infinitely expanded the opportunities for Citizen Science as each household, no matter how remote, has at least one cell phone. The tool focuses on utilising existing hardware, i.e. computers, laptops, tablets and smartphones, that most people already have and use. Thus, there is thus no need to incur expenditure in terms of hardware to gather the data.

The two tools can also be used by an individual representing his/her community/settlement in the deep rural areas by taking photos of toilets and administering the questionnaire to those who may be not have a smartphone or may not be able to read/write.

6.2.1.1 Questionnaire to assess the status quo of sanitation

The reality of gathering new households level data from citizens under COVID-19 pandemic conditions is that information and data gathering using fieldworkers and face-to-face surveys have become rare and have increased risks for the parties involved in the survey. As a result, the survey arena is changing daily, with digital and electronic surveys increasing and becoming easier and more common.

To assess the state of a sanitation and hygiene facility, a photo/image can be used as the principal information gathering tool, but the image/photo of the sanitation facility would not necessarily provide sufficient information for the AI/computer vision software to score the sanitation facility/toilet appropriately. The image would also not necessarily be able to score/report the key elements that citizens have highlighted as important for their sanitation and hygiene facilities. A short and easy to complete questionnaire on a digital platform can assist with obtaining this additional information on the sanitation facility to substantiate the points for scoring, as well as to provide a means of data verification.

Conversely, the questionnaire could be the principal information gathering tool with the photo/image as verification of the information in the cases where the participants cannot upload photos.

A number of digital platforms already exist to conduct questionnaires, for example Outgrow, Google Forms, Quaraloo, Zoho Survey, Survey Gizmo, Survey Planet, etc. The most popular digital platforms are SoGoSurvey, Google Forms, KoboToolbox, and MonkeySurvey.

- SoGoSurvey is an end-to-end survey design, distribution, and analysis platform and is a feature-rich modern online survey tool that is a cloud-based SaaS application and platform designed to create, distribute, and analyse multilingual surveys, forms, polls, quizzes and assessments. SoGoSurvey offers many formats through which project results can be exported to review as raw data offline, such as Excel, SPSS, and CSV, amongst others. This service offers a free account with many features and a paid account with enhanced features.
- Google Forms is a free survey tool that is part of G Suite – Google's complete office suite. The other main services included in the cloud-based suite are Sheets (Excel), Docs (Word), and Slides (PowerPoint). Google Forms is the only free online survey tool that provides many features.
- KoBoToolbox, developed by the Harvard Humanitarian Initiative, is an open-source suite of tools for data collection and analysis in humanitarian emergencies and other challenging environments. It can collect data online and offline and allows for the upload of photos. KoBoToolbox is funded entirely through grants and donations from partners.
- MonkeySurvey is an online service that allows users to create web browser-based surveys. This service offers both a free account and a paid account that includes enhanced features.

SoGoSurvey was used to gather information from the citizens earlier in the study, providing insight on the citizens opinion and perceptions of the most important issues related to their sanitation facility. SoGoSurvey worked well and the data reports were clear and concise. However, SoGoSurvey does not allow for the upload of a photo, hence this tool could not be applied in future to the CS-SHIP. KoboToolbox, on the other hand, does provide the ability for uploading photos and completing a questionnaire on the same platform, but the photo/image cannot be analysed by the KoboToolbox. In addition, KoboToolbox allows for capturing of GPS coordinates for the site where the citizen is capturing the data on their sanitation and hygiene facility.

To determine the specification for the survey that will be necessarily for the CS-SHIP, a short and concise questionnaire was developed on KoboToolbox for laptops, tablets and smartphones. The questions included in the survey were designed to be applicable in formal and informal settings and to focus on the needs of the citizens.

6.2.1.2 Citizens' photography for image recognition

Photo/image monitoring is simple, inexpensive and rapid. While it cannot portray the whole story of the households' acceptance, use and perception of their sanitation and hygiene facility, it can portray the state of the sanitation facility. Photographic images of households' sanitation and hygiene facilities can be used for the following purposes:

- To describe or document current conditions (baseline monitoring).
- To describe or document abnormal or catastrophic events.
- To detect and document change (trend/progress monitoring).
- To confirm assessments.
- To investigate perceived problems.
- To document the application or implementation of management/maintenance practices (implementation monitoring).
- To document the effectiveness of management/maintenance practices (effectiveness monitoring).

When using photos/images for Citizen Science monitoring, the following need to be considered and addressed:

- Intellectual property rights: Photos belong to the people who upload them. Some people may choose to revoke the Creative Commons license to retain complete legal control over copies of their photos, while others may choose different versions of the Creative Commons license. Some users may choose to waive their copyright entirely by making no warranties about the work, and disclaiming liability for all uses of the work, to the fullest extent permitted by applicable law. It's important to understand these options when deciding whether or not you can use each photo.
- Geoprivacy: When creating and uploading a photo, there is a geoprivacy field that by default is set to 'open'. By changing this to 'obscured' or 'private', public access to this information can be restricted.
- Large data: Image recognition software relies on machine learning technology, which requires massive data sets to "learn" to deliver accurate results. Such large data sets require robust data storage. Small and medium-sized companies may not have sufficient resources to store the required data.

In using the CS-SHIP, citizens can upload images of their sanitation and hygiene facilities to assess their condition through image recognition/computer vision. The technological evolution in the quality of cameras on smartphones makes uploading photos/images an easy task. Section 4.2.1 explain how the images would be analysed by the system to determine the state of the sanitation and hygiene facility in a household, as well as to carry out landscape assessment of sanitation facilities at a local level.

The CS-SHIP would be designed to capture 4 or 5 images of a household's sanitation and hygiene facility, such as the images shown in Figure 23 below. These images are expected to provide sufficient information for the AI to analysis the images and generate a score and report for each household's sanitation and hygiene facility.

Front view with door closed	Back view	Side view	Inside view	Handwashing facility

Figure 23: Photographic submission required from citizens as their contribution to the CS-SHIP

These image submission requirements are expected to be included in the application (App) that will be developed for the CS-SHIP. The App will include both the image specification and the questionnaire that will be needed to be completed by the citizens.

6.2.2 Stakeholder Group 2: Scientist and AI – Hosting, analysing and applying the data

The second component or stakeholder group in the CS-SHIP is that of the scientist, but in future the artificial intelligence (AI). It is envisaged that the images and the information from the survey that are provided by the citizens, discussed in the section above, will be captured, stored, cleaned and analysed initially by the scientists overseeing the CS-SHIP, but over time through electronic systems and the AI. The tool developed for the group of stakeholders focuses on utilising existing hardware, i.e. computers, laptops, tablets and smartphones, thus, there is no need to incur expenditure in terms of hardware to gather the data.

The component specification for this group of stakeholders include:

- Photo/image recognition (software)
- Data storage
- Algorithms and neural network to respond to queries
- Reporting, including feedback loops.

6.2.2.1 Hosting/storing the data submitted by the citizen scientists

Data storage is the collection and retention of digital information – the bits and bytes behind applications, network protocols, documents, media, address books, user preferences, and more.

The most popular data storage companies to date are pCloud, Zoolz, BigMIND, Polarbackup, PureStorage, Microsoft Azure, AWS, Dell EMC, IBM, NetApp, Oracle, and Seagate Technology.

The selection of the data host for storage of the sanitation data will be linked to the development of the App and the computer vision software specific for sanitation.

6.2.2.2 Analysing the citizen surveys/questionnaires

The citizens' needs in the survey were collated with the national and international imperatives and targets for sanitation (see Table 7).

Table 7: Citizen priorities measures included in the Citizen Science survey envisaged to be completed by the participating citizens in the CS-SHIP.

Priorities	Components	Measurement Requirements	Score for Correct Answer	Score for Element	Score for Priority
3. Quality	3.1 Safe (no health threats)	· Do you have access to a toilet?	2	Score/8	Score/18
		· What type of toilet is it?	2		
		· Where is the toilet located?	2		
		· Do you share the toilet with other households?	2		
	3.2 Hygienic	· Is there a handwashing facility near the toilet?	2	Score/6	
		· Does the handwashing facility have water?	2		

Priorities	Components	Measurement Requirements	Score for Correct Answer	Score for Element	Score for Priority
		· Does the handwashing facility have soap?	2		
	3.3 Technical safety, i.e. ventilated, light, protects	· Is there a light in the toilet during the night?	2	Score/4	
		· Can you lock the toilet door from the inside?	2		
6. Acceptable	6.6 Sanitary materials	· What cleansing material is in the toilet?/Toilet paper	2	Score /8	Score/10
		· What cleansing material is in the toilet?/Soap	2		
		· What cleansing material is in the toilet?/Bin for rubbish	2		
		· What cleansing material is in the toilet?/Nothing	2		
	6.7 Aesthetics	· Is it clean inside the toilet seat?	2	Score /2	
8. Appropriate	8.2 Functional, i.e. operation; maintenance; reliable	· How long have you been using the toilet?	2	Score /6	Score/6
		· Who uses the toilet?/Everyone	2		
		· Can the toilet be used every day?	2		
9. Hygienic	9.1 Cleanliness of facility, i.e. cleaning materials	· Is it easy to keep the toilet clean?	2	Score /4	Score/6
		· Are there cleaning materials (like bleach, Jik, soap, toilet brush, etc.) for the toilet?	2		
	9.2 Odour	· Does the toilet smell	2	Score /2	

6.2.2.3 Photo and image recognition for assessment of the status quo of sanitation

Image recognition is a sub-category of computer vision technology and a process that helps to identify the object or attribute in digital images or video. In image recognition, the computer visualises the images as an array of numbers and analyses the patterns in the digital image, video graphics, or distinguishes the critical features of images. Image recognition tasks can be categorised into the following parts:

- Classification: It identifies the “class,” i.e. the category to which the image belongs.
- Tagging: It is a classification task with a higher degree of precision. It helps to identify several objects within an image.
- Localisation: It helps in placing the image in the given class and creates a bounding box around the object to show its location in the image.
- Detection: It helps to categorise the multiple objects in the image and create a bounding box around it to locate each of them.
- Semantic segmentation: It helps to locate an element on an image to the nearest pixel. In some cases, it is necessary to be extremely precise in the results, such as the development of autonomous cars.
- Instance segmentation: It helps in differentiating multiple objects belonging to the same class.

With this kind of software, images are the input, and a computer vision algorithm provides an output, such as a label or bounding box. Image recognition software can be used by data scientists to train image recognition models to recognise images. The system can be trained to map out the patterns and relations between different images using this information. After training the system, intermittent weights to neural networks could be updated to increase the accuracy of the systems and get more precise results for recognising the image.

Although many image recognition software are multipurpose and allow for the recognition of various types of images and objects, some have particular focuses. These focuses include logo detection, facial recognition, object detection, and content detection. Some of these products are only able to handle image files, while some can handle videos as well. The majority of these tools process the images in the cloud, some provide the ability for image processing on the edge or on device. To qualify as an Image Recognition tool, a product must:

- provide a deep learning algorithm specifically for image recognition;
- provide a deep learning algorithm specifically for image recognition;
- connect with image data pools to learn a specific solution or function;
- consume the image data as an input and provide an outputted solution; and
- provide image recognition capabilities to other applications, processes, or services.

Figure 24 below displays the roadmap of image recognition:

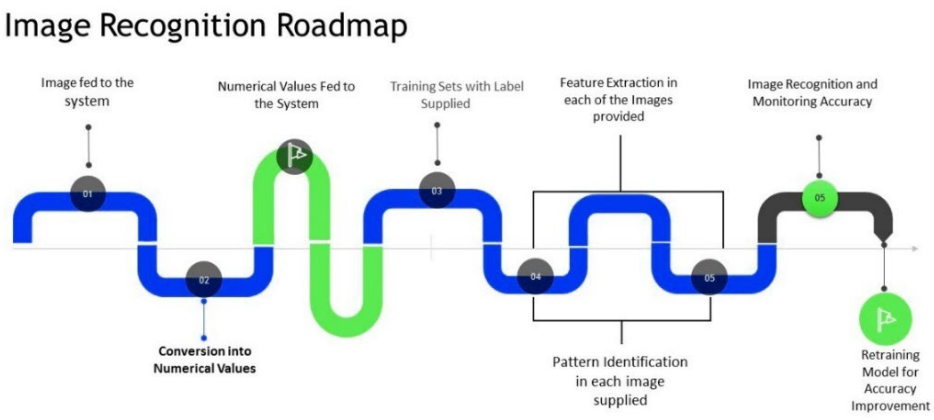


Figure 24: The roadmap of image recognition (Taken from What is the Working of Image Recognition and How is it Used? (marutitech.com))

Some examples of image recognition/computer vision are reflected in Table 8 below:

Table 8: Examples of computer vision

Computer vision	Applications
Facial recognition: Most facial recognition technology relies on 2D rather than 3D images because it can more conveniently match a 2D image with public photos or those in a database. The software reads the geometry of your face. Key factors include the distance between your eyes, the depth of your eye sockets, the distance from forehead to chin, the shape of your cheekbones, and the contour of the lips, ears, and chin. The aim is to identify the facial	Health care providers Healthcare providers are testing the use of facial recognition to access patient records, streamline patient registration, detect emotion and pain in patients, and even help to identify specific genetic diseases. AiCure has developed an app that uses facial recognition to ensure that people take their medication as prescribed. As biometric technology becomes less expensive, adoption within the healthcare sector is expected to increase.

Computer vision	Applications
landmarks that are key to distinguishing your face. The face capture process transforms analogue information (a face) into a set of digital information (data) based on the person's facial features. A face's analysis is essentially turned into a mathematical formula. The numerical code is called a faceprint. The faceprint is then compared against a database of other known faces.	Workplaces Facial recognition can be used for workers to sign in and out of their workplaces, so that employers can track attendance.
	Law enforcement Facial recognition is used by police services to assist with fighting crime and delivering justice.
Image recognition Image recognition is a technology that enables the identification of objects, people, entities, and several other variables in images that were shared through apps, social networks, and websites. The rise of smartphones equipped with high-resolution cameras generates many digital images and videos that could be used to assess the state of sanitation in the country.	Car companies Modern vehicles include numerous driver-assistance systems that can avoid car accidents and prevent loss of control to drive safely. Image recognition helps autonomous vehicles analyse the activities on the road and take necessary actions. Algorithms allow the car to recognise the real-time environment, road signs, and other objects on the road. Car companies are also experimenting with facial recognition to replace car keys.
	Logistic companies Mini robots with image recognition can assist logistic industries identify and transfer objects from one place to another to maintain the database of the product movement history and prevent it from being stolen.
	Visual Look Up This App from Apple recognises many kinds of plants and animals, famous landmarks, books, album covers, and famous works of art. It shows details about the camera and exposure the photo was taken with, and a map of where it was taken if the photo contains location data. If Visual Look Up recognises something in the photo, a small icon will show on it: a pawprint for an animal, a leaf for a plant or flower, a book for a book, or a painting for artwork. For landmarks, a small icon with a pop-up card shows the Visual Look Up results, such as Siri Knowledge results (about pet breeds, plants, landmarks, or artwork), a list of similar images on the web, or Apple Maps directions to landmarks.
Remote sensing through images Remote sensing can detect and monitor the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (aerial photographs from satellite or aircraft).	Wetlands Remote sensing is a cost-effective way for delineating wetlands over a large area at different points of time and can provide useful information on wetland characteristic. Visual interpretations of wetlands from maps, aerial photography, and hard copy of satellite images have been used extensively. Currently, digital image processing is used. The most distinctive feature is the energy absorption at Near-IR wavelengths and beyond. Characteristics like water quality, turbidity and chlorophyll contents can also be determined using optical remote sensing techniques but are more complicated to assess.
	Coastal monitoring LANDSAT imagery to map coastal water turbidity, estimate the concentration of suspended sediments through LANDSAT-MSS data.

A number of software already exist that facilitate image recognition, such as:

- NVIDIA Deep Learning GPU Training System (DIGITS) – deep learning for data science and research to quickly design deep neural network (DNN) for image classification and object detection tasks using real-time network behaviour visualisation.

- Microsoft Computer Vision API – Microsoft Computer Vision API is a cloud-based API tool that provides developers with access to advanced algorithms for processing images and returning information, by uploading an image or specifying an image URL, it analyse visual content in different ways based on inputs and user choices.
- Syte – product discovery platform, powered by visual AI, for eCommerce include camera search, augmented site search, personalisation engines, and smart in-store tools. Leading brands and retailers' partner with Syte to provide on-demand, hyper-personalized experiences that drive conversion, and increase average order value.
- Rekognition – Amazon Rekognition makes it easy to add image and video analysis to your applications. It can identify the objects, people, text, scenes, and activities, or any inappropriate content from an image or video.
- Azure Custom Vision Service – Azure Custom Vision Service is a tool for building custom image classifiers, and for improving them over time. This service enables users to identify objects and things in images.
- IBM Watson Visual Recognition – this tool that allow users to automatically identify subjects and objects contained within the image and organise and classify these images into logical categories.

Any of the above software may be applied for sanitation, however, the machine learning specific to sanitation and including the scoring and feedback/output will need to be built from scratch. In using this assessment tool, photos/images could be uploaded to assess the condition of a sanitation facility through image recognition/computer vision. The technological evolution in the quality of cameras on smartphones makes uploading photos/images an easy task.

Different levels of assessment can be applied using images and photos:

- **Level 1**, 'landscape assessment' relies on rough settlement-scale information, typically gathered through aerial photographs and stored in, or converted to, a geographic information system (GIS) format (Meenu et al., 2011).

  Level 1 assessment of sanitation in the CS-SHIP, would mean that a sanitation facility/toilet is present and functional on the stand. The number of sanitation structures are identified, marked and counted (see Figure 25 for a scientist generated example of identification of sanitation facilities using google earth images). Figure 25 clearly demonstrates that almost each stand had a building on-site that could be identified by a sanitation scientist as a sanitation (on-site, outside) facility.

Figure 25: Example of landscape assessment (red triangle indicates a set of 4 toilets in the corner of 4 yards).

- **Level 2** is 'rapid assessment' at the specific site scale, using relatively simple, rapid protocols. Level 2 assessment protocols are to be validated by and calibrated to Level 3 assessments.

  For sanitation, this would mean that the absolute necessary elements of a sanitation facility/toilet are present and functional, i.e. those elements shown in Figure 26 below including a pit slab, floor, walls, roof, door, pedestal, ventilation, vent pipe, handwashing facility. The photographic image submitted by citizen scientists in Figure 25 above, via the electronic app (i.e. KoboToolbox, etc.), can be utilised by the scientist, and later by the photo imaging software, to carry out the Level 2 assessment.

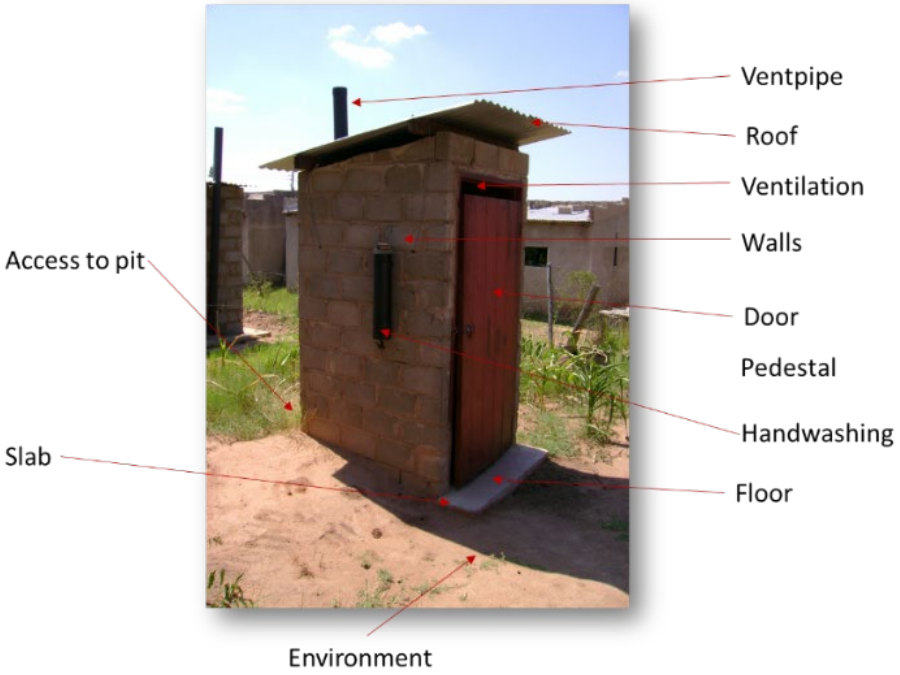


Figure 26: Example of rapid assessment photograph that can be analysed by the sanitation scientist/photo image recognition software

- **Level 3** is 'intensive assessment' and uses intensive research-derived, multi-metric indices. They are meant to give detailed information regarding how well a sanitation facility is functioning.

For sanitation, the photographic image submitted by the citizen scientists in Figure 26 above, via the electronic app (i.e. KoboToolbox, etc.), can be utilised by the scientist, and later by the photo imaging software, to carry out the Level 3 assessment. The level 3 photographic imagery assessment of the sanitation and hygiene facilities would include more detailed image software analysis of elements, shown in Figure 27, such as present of crucial elements and functional elements, for example, clear and easy access to the toilet, toilet seat and lid, flyscreen on the vent pipe, locking mechanism on the door, ventilation window that can open/ventilation gaps that allow airflow, handwash facility with water and soap, wet spots to detect possible leaks, solid waste in the environment, pollution of the environment, etc.

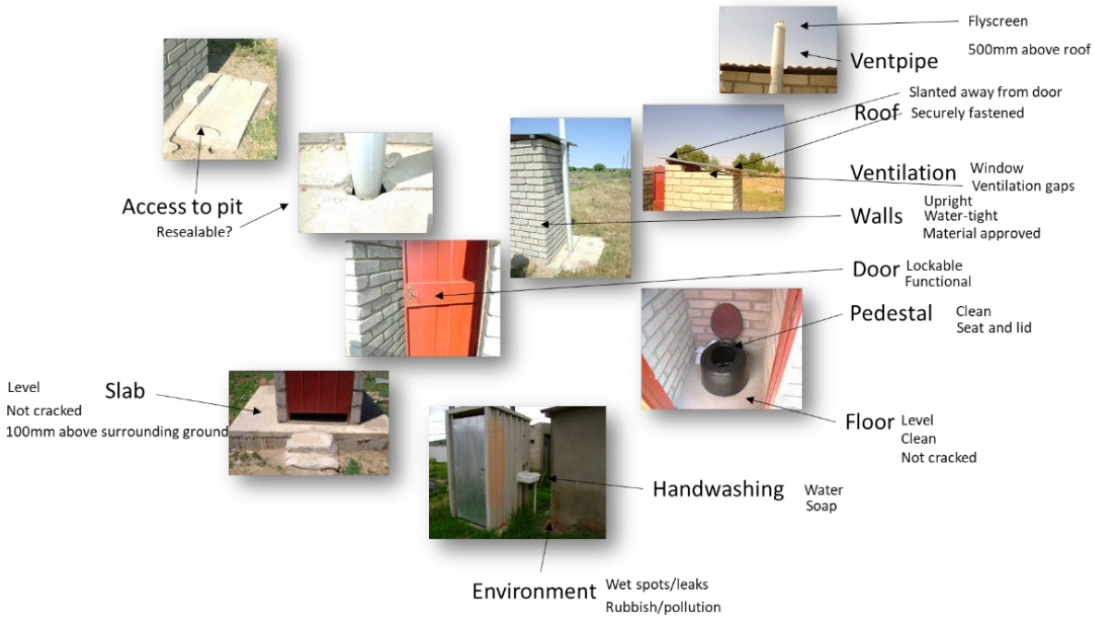


Figure 27: Example of intensive assessment that can be analysed by the sanitation scientist/photo image recognition software

6.2.2.4 Establishing the minimum elements required to provide a scientifically credible Level 2 and Level 3 image assessments

One of the key questions of the scientists in this study was what were the most crucial elements of a sanitation and hygiene facility that need to be assessed to provide a scientifically credible score for the state of a sanitation and hygiene facility at a household and community level. South Africa has conducted a number of expensive assessments of sanitation over the years, using a checklist to determine the presence or absence of elements that are required to meet SDG requirements and to comply with policy and national norms and standards for a basic sanitation and hygiene facility. Some of these checklists utilised assessment of over 40 elements to determine a score for the facility and for facilities with a community.

Using a 2007/08 and 2008/08 dataset collected from 1,958 households VIP sanitation facilities across the country, which were installed as part of Municipal Infrastructure Grant (MIG)-funded and Reconstruction and Development Programme (RDP)-funding programmes, a stepwise regression analysis was conducted using SPSS software to determine the key elements for a VIP toilet to the score that was calculated for each of the facilities (in the 2008/9 dataset) and the programme (community) (in the 2007/08 dataset). Despite the scores being at different levels for the two years of the assessment, a stepwise regression was also conducted on the entire dataset to determine whether the key assessment elements would be vastly different for this dataset. The result of the regression provides the suite of elements that had the greatest impact on the score for the facility, with these elements assumed to be vital to include in any image/scientific assessment (using photo

images) of the state of a sanitation facility. The regression analysis also provided an algorithm that could be utilised in future to estimate the score for the state of a household's sanitation facility by the AI in the CS-SHIP.

The Stepwise Regression Analysis of the 2007/08 VIP Dataset for Programmes

This dataset comprised 311 household VIP toilets that were provided to households via a (MIG)-funded programme in a rural area. The assessment followed checklist review of the facilities, based on policy and norms and standards requirements for a VIP toilet in the country, and a score was generated for the programme based on the individual score for each of the VIP toilets. For example, a MIG project was provided with a score of 100, with the percentage score reflecting the compliance of the sanitation facilities provided by the project to the national policy requirements for a sanitation facility, and norms and standards for these structures.

The results of stepwise regression analysis of the presence/absence of the elements of the VIP toilets, against the final score of the programme, are shown in Appendix A. The regression demonstrated that the most significant elements to the programme score were those in Table 9 below. The results of the statistical analysis were extremely interesting, indicating that the score of a programme (or effectively a community/settlement) for VIP toilets to national imperatives was largely depended on the presence/absence of water in a handwashing facility; the correct length of the vent pipe with an intact flyscreen; good ventilation in the facility; undamaged, sealed pits; a clean facility; and a safe and undamaged pedestal.

Table 9: The key VIP elements that had a significant relationship with the score estimated for a MIG-funded programmes compliance to basic sanitation policy and norms and standards.

No.	VIP Element	Unstandardised Coefficients (B)	Sig.
	(Constant)	87.030	0.000
A	Handwashing facility has water	3.703	0.000
B	Vent pipe extends above roof	3.160	0.000
C	Has openings for daylight and air	13.764	0.000
D	Well ventilated toilet	-13.613	0.000
E	Concrete slab damaged	-1.741	0.004
F	Toilet is clean inside	-2.313	0.001
G	Pedestal has seat and lid	3.393	0.000
H	Damaged pedestal	-2.990	0.004
I	Fly screen damaged	-0.932	0.012

Based on the statistical results above, if these elements are captured in the photographic image analysis of the CS-SHIP, the algorithm below could be utilised to compile a score for each of the VIP toilets being analysed by the AI/scientist:

Pred Programme Score = $87.030+(3.703xA)+(3.160xB)+(13.764xC)+(-13.613xD)+(-1.741xE)+(-2.313xF)+(3.393xG)+(-2.990xH)+(-0.932xI)$

Simply put, analysing the presence/absence of the 9 elements for a VIP toilet shown in Table 17, and applying the above formula could generate (AI generated) an accurate score for the community's/programme's sanitation and hygiene facilities in 73,6% of the time (R^2 =0.736).

The Review of the 2008/09 VIP Dataset for Facilities

This dataset comprised 1,347 household VIP toilets that were provided to households via MIG-funded and RDP-funded programmes. The assessment followed the same 40-question checklist as the 2007/08 assessment, to review the facilities against the requirements by policy, and norms and standards for VIP toilets in the country. For this dataset, a score was generated for each of the VIP toilets for their compliance to the national policy requirements for a sanitation facility and norms and standards for these structures.

The results of stepwise regression analysis of presence/absence of the elements of the VIP toilets against the final score of the VIP toilet are shown in Appendix B. The regression demonstrated that the most significant elements to the score for a VIP toilet were those in Table 10 below.

Table 10: Key VIP elements that had a significant relationship with the compliance score of the facility to basic sanitation policy and norms and standards.

No.	VIP Element	Unstandardised Coefficients (B)	Sig.
	Constant	0.108	0.012
A	Has door or screen wall	0.066	0.000
B	Toilet is clean inside	0.060	0.000
C	Door latch (inside)	0.038	0.000
D	Well ventilated toilet	0.069	0.000
E	Handwashing facility within 1 m of toilet	0.057	0.000
F	Toilet floor unequal to or higher than surroundings	0.032	0.000
G	Concrete slab damaged	0.061	0.000
H	Toilet has concrete slab	-0.031	0.012
I	Has durable walls	0.028	0.001
J	Has damaged door	0.027	0.000
K	Damaged pedestal	0.041	0.000
L	Handwashing facility has soap	-0.065	0.000
M	Holes in roof	0.020	0.004
N	Has vent pipe	-0.025	0.000
O	Fly screen damaged	0.012	0.002
P	Pedestal has seat and lid	0.012	0.013
Q	Has a roof	-0.112	0.000
R	Has securely attached roof	0.053	0.000
S	River/stream/well/borehole within 10m of toilet	0.028	0.011
T	Smooth, easily cleaned floor	0.013	0.047

The results of the statistical analysis were extremely interesting, indicating that the score of a VIP toilet was based on the 20 elements for a VIP toilet relating to:

External VIP elements:

1. Doors – the presence of an undamaged (intact) door that can latch from the inside of the toilet
2. Walls – the presence of durable walls
3. Roof – the presence of an undamaged roof (i.e. leakproof) that is securely attached to the structure
4. Slab – the presence of slab that is elevated above ground and that is sealed (no damage)
5. Vent pipe – presence of a vent pipe with an intact flyscreen
6. Handwashing – a facility within 1 metre of the toilet that has soap available
7. Environmental – the facility is not within 10metre of a water resource, i.e. river, stream, borehole.

Table 11: Key VIP elements that had a significant relationship with the compliance score of the facility to basic sanitation policy and norms and standards.

No.	VIP Element	Unstandardised Coefficients (B)	Sig.
	Constant	0.108	0.012
A	Has door or screen wall	0.066	0.000
B	Toilet is clean inside	0.060	0.000
C	Door latch (inside)	0.038	0.000
D	Well ventilated toilet	0.069	0.000
E	Handwashing facility within 1 m of toilet,	0.057	0.000
F	Toilet floor unequal to or higher than surroundings	0.032	0.000
G	Concrete slab damaged	0.061	0.000
H	Toilet has concrete slab	-0.031	0.012
I	Has durable walls	0.028	0.001
J	Has damaged door	0.027	0.000
K	Damaged pedestal	0.041	0.000
L	Handwashing facility has soap	-0.065	0.000
M	Holes in roof	0.020	0.004
N	Has vent pipe	-0.025	0.000
O	Fly screen damaged	0.012	0.002
P	Pedestal has seat and lid	0.012	0.013
Q	Has a roof	-0.112	0.000
R	Has securely attached roof	0.053	0.000
S	River/stream/well/borehole within 10m of toilet	0.028	0.011
T	Smooth, easily cleaned floor	0.013	0.047

Internal elements:

8. Floor – a floor that is smooth and easy to clean
9. Pedestal – an undamaged pedestal with a seat and lid
10. Ventilation – good ventilation in the toilet
11. Cleanliness – the facility being clean inside

Based on the statistical results above, if these elements are captured in the photographic image analysis of the CS-SHIP, the algorithm below could be utilised to compile a score for each of the VIP toilets being analysed by the AI/scientist:

Pred Programme Score = $0.108 + (0.066xA) + (0.060xB) + (0.038xC) + (0.069xD) + (0.057xE) + (0.032xF) + (0.061xG) + (-0.031xH) + (0.0282xI) + (0.027xJ) + (0.041xK) + (-0.065xL) + (0.020xM) + (-0.025xN) + (0.012xO) + (0.012xP) + (-0.112xQ) + (0.053xR) + (0.028xS) + (0.013xT)$

Simply put, analysing the presence/absence of the 20 VIP elements shown in Table 11 and applying the above formula could generate (AI generated) an accurate score for the VIP toilets in 53% of the time (R^2 =0.539). This is in fact a low level of accuracy and further investigation would be required to improve the accuracy of predicting a score by the AI.

6.2.2.5 Implementing Image Recognition

To implement image recognition, an application (App) still needs to be developed in future for citizens to upload the photo/image, which is linked with the computer vision software that uses a set of sanitation indicators for image recognition and assessment. The neural network/artificial intelligence of the computer vision needs to be taught to search for, recognise and score, inter alia, the elements shown in Figure 28 as an example.

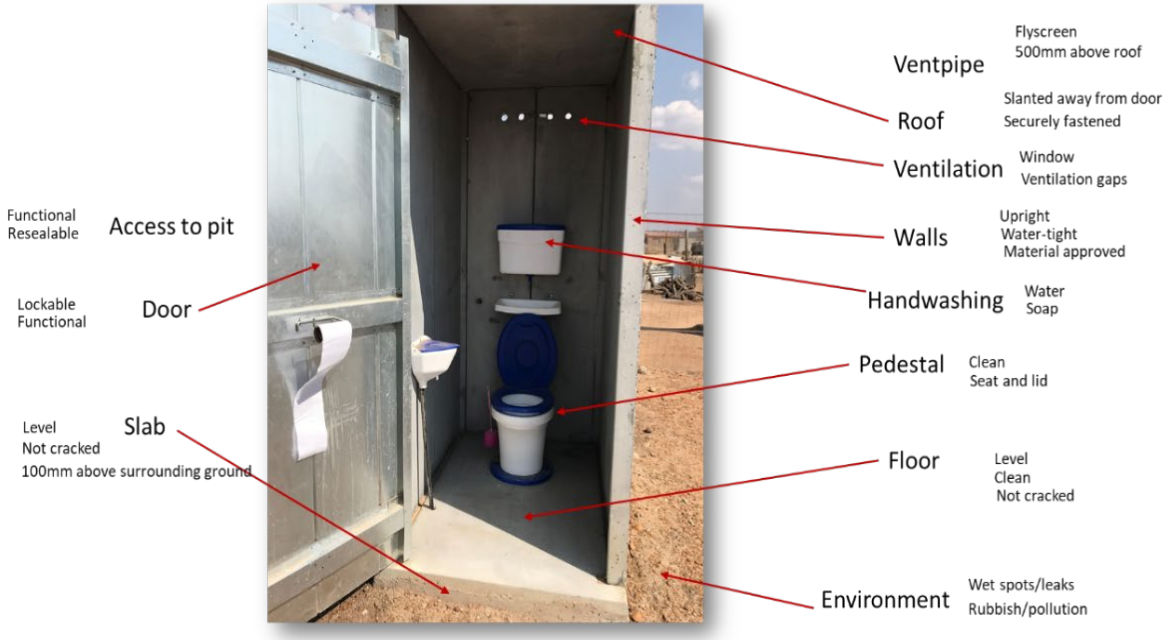


Figure 28: Some elements of sanitation to be recognised by computer vision

For the purposes of this study, a basic checklist was compiled to be used manually by the project team to score the basic elements of VIP toilets on the photographs. The checklist was designed on KoboCollect to streamline the analysis on Excel.

The full range of elements for all kinds of toilets (dry and waterborne) will be finalised during the design and development of the computer vision/image recognition software. The elements will be calculated to comply with policy requirements, the building code, and the applicable water and sanitation norms and standards.

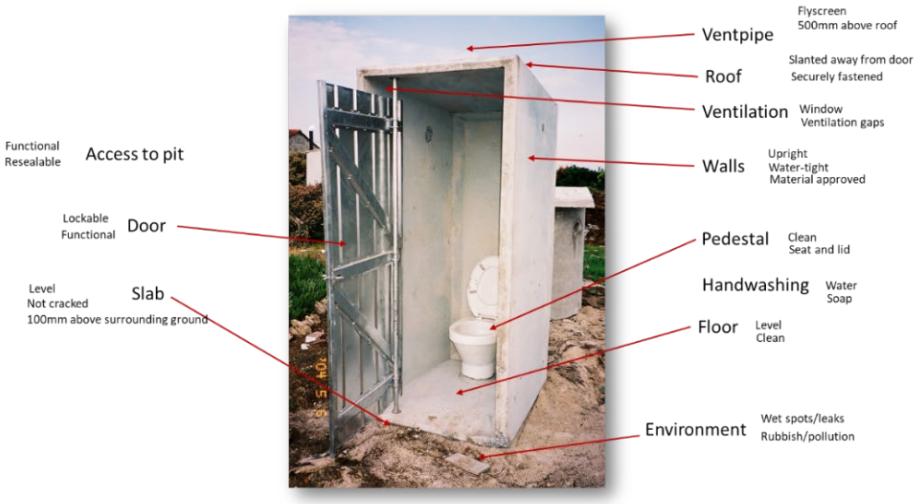
Once the information and photos/images have been collected, applying the tool/assessment method will result in a sanitation facility receiving a score or a rating, which can be categorised and colour coded as follows:

A: Excellent and well maintained	Score of 100%
B: Good condition and maintained	Score of 80-99%
C: Satisfactory	Score of 50-79%
D: At risk of failure	Score of 30-49%
E: Dangerous/unfit for purpose/not complying	Score below 30%

The score and the rating can be reflected as a letter of the alphabet, which aligns with the ratings of the South African Institute for Civil Engineering (SAICE) Infrastructure Report Card.

The two images below are provided as a very rough demonstration of the scoring and colour coding. The elements of a sanitation facility are more complex than depicted in the images below and will be refined during the development of the AI/computer vision software that will be applying the image recognition.

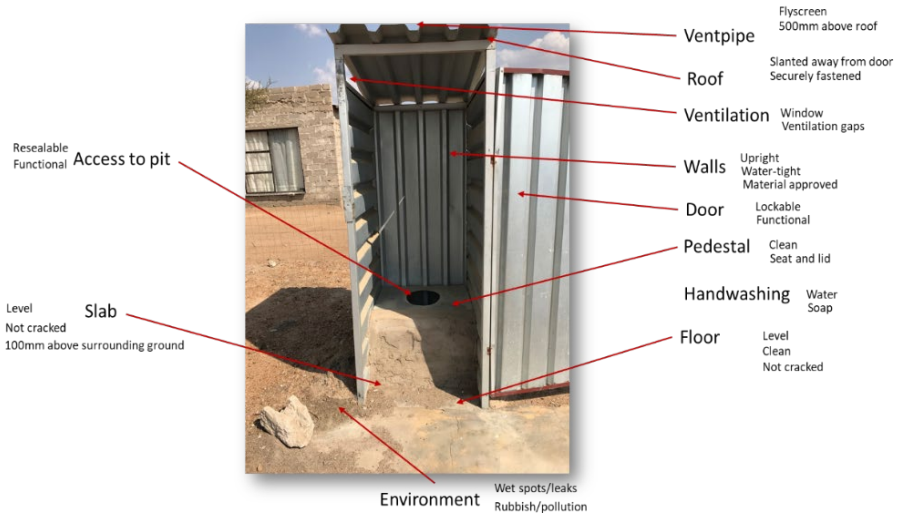
Example 1 – an acceptable and adequate sanitation facility:



Element	Sub-element	Not observed	Score	Aggregated score
Pit access	Access possible	√	No score	-
	Resealable	√	No score	
Slab	Level		1	3/3
	Not cracked		1	
	100 mm above surrounding ground level		1	
Floor	Dry and clean		1	2/3
	Level		1	
	Smooth		1	
Pedestal	Clean		1	2/2
	Seat and lid		1	
Hand washing facility	Water		0	0/3
	Soap		0	
	Drying material		0	
Walls	Upright		1	3/3
	Water-tight – not leaking		1	
	Approved building material		1	
Door	Hung right		1	3/3
	Can close		1	
	Can be locked		1	
Ventilation	Window that can open		0	2/3
	Openings in the walls		1	
	Gaps above and below door		1	
Roof	Securely fastened to the building		1	3/3
	Slant away from the door		1	
	Not leaking		1	
Vent pipe	100 mm pipe		0	0/3
	Flyscreen		0	
	500mm above highest point of roof		0	
Environment	No rubbish/solid waste		1	3/3
	No pollution		1	
	No wet spots		1	
Access	Clear access route		1	2/3
	Easy access for disabled		0	
	Appropriate size of structure		1	
Immediate disqualification	Not complying to policy, norms, standards	Comply	No score	
Total score				**23/32**

This sanitation facility scores **23** out of 32 (72%), which places the facility in the 'Satisfactory' category, which means that some actions are required by the household/owner of the facility to improve the score of the facility to become acceptable and adequate (excellent and well maintained).

Example 2 – an unacceptable and inadequate sanitation facility:



Element	Sub-element	Not observed	Score	Aggregated score
Pit access	Access possible		1	½
	Resealable		0	
Slab	Level		1	1/3
	Not cracked		0	
	100 mm above surrounding ground level		0	
Floor	Dry		1	¼
	Clean		0	
	Level		0	
	Smooth		0	
Pedestal	Clean		1	½
	Seat and lid		0	
Hand washing facility	Water		0	0/3
	Soap		0	
	Drying material		0	
Walls	Upright		1	0/3
	Water-tight – not leaking		1	
	Approved building material		0	
Door	Hung right		1	2/2
	Can close		1	
	Can be locked	√	-	
Ventilation	Window that can open		0	2/3
	Openings in the walls		1	
	Gaps above and below door		1	
Roof	Securely fastened to the building		1	3/3
	Slant away from the door		1	
	Not leaking		1	
Vent pipe	100 mm pipe		0	0/3
	Flyscreen		0	
	500mm above highest point of roof		0	
Environment	No rubbish/solid waste		1	3/3
	No pollution		1	
	No wet spots		1	
Access	Clear access route		1	1/3
	Easy access for disabled		0	
	Appropriate size of structure		0	
Immediate disqualification	Not complying with policy			0
Total score				**0/34**

Even though this sanitation facility scored **15** out of 34 (44%), which could have placed the facility in the '**At risk of failure**' category with prompt actions required by the household/owner of the facility to improve the

score of the facility to become acceptable and adequate, the facility scored **0** (‘**Dangerous/unfit for purpose/not compliant**’ category) due to the use of corrugated iron as building material for the structure, which is unacceptable according to the National Sanitation Policy, and the Water and Sanitation Norms and Standards of the Department of Water and Sanitation.

6.2.2.6 Feedback loops

The score of the toilet can be used for corrective actions on household, settlement, local government, and national government levels. It focuses on the learning element where the feedback to the participants contains the score for the sanitation facility, as well as the corrective actions that can be taken.

The scoring and feedback are case specific, each toilet’s score per element will determine the feedback to the user through automatic triggers that will be developed as part of the computer vision software. To report to local and national governments, the scoring will be aggregated from individual toilets to form a score per settlement. The score for the settlements will be combined to form a score for a local municipality, and so on, to be able to report on the state of sanitation per settlement, local, district, province, and national levels, as shown in Figure 29.

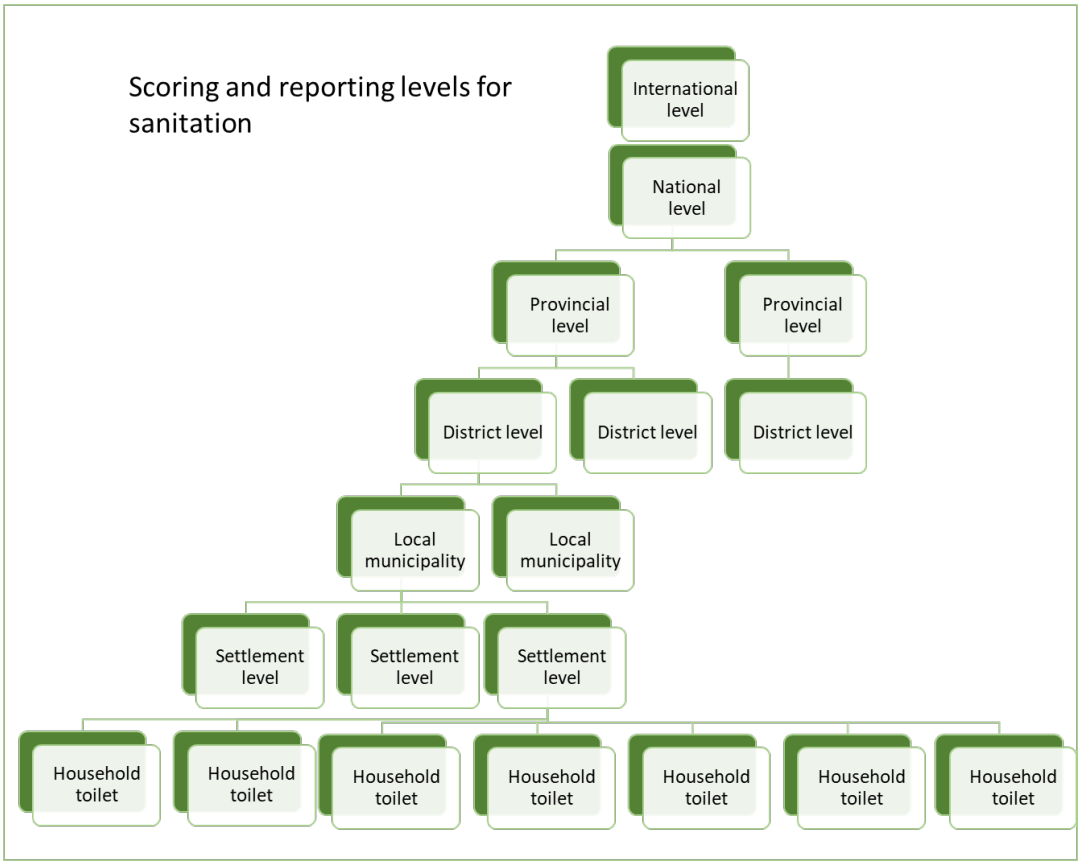


Figure 29: Reporting levels of the scores from each toilet – bottom-up.

Examples of the corrective actions per scoring level are provided below but will be finalised upon the development of the Smartphone App and the computer vision software.

On household/settlement level

Score	Description	Corrective actions		
		Building	Hygiene	Safety
A	Infrastructure is in excellent condition and well maintained.	Maintain status quo	Maintain status quo	Maintain status quo
B	Infrastructure is in good condition and properly maintained.	Maintain structure	Maintain handwash facility and cleanliness	Keep path clear and door lockable
C	Infrastructure is in an acceptable condition but will need interventions to avoid serious deficiencies.	Repair leaks, door, etc.	Repair handwash facility Add soap and water	Clear access path, repair lock on door
D	Infrastructure is not adequate and is poorly maintained. Prompt corrective action is needed.	Repair failing structure immediately	Repair/add handwashing facility and add soap and water	Clear access path Add lock on door
E	Infrastructure has failed or is on the verge of failure, exposing the public to health and safety hazards. Immediate action is required.	Demolish and rebuild properly	Add handwash facility with soap and water	Add a clear access path Add door that can lock and a lock

On local/district/provincial government level

Score	Description	Corrective actions
A	Infrastructure is in excellent condition and well maintained, with capacity to endure pressure from unusual events	Maintain status quo
B	Infrastructure is in good condition and properly maintained.	Inspect and monitor the sanitation facilities.
C	Infrastructure is in an acceptable condition but will need interventions to avoid serious deficiencies.	Inspect sanitation facilities and draw up a snag list. Raise users' awareness about hygiene and maintenance. Raise users' awareness about maintenance and hygiene.
D	Infrastructure is not adequate and is poorly maintained. Prompt corrective action is needed.	Inspect situation and conduct a needs analysis. Ensure proper maintenance and repairs through raising awareness and training users.
E	Infrastructure has failed or is on the verge of failure, exposing the public to health and safety hazards. Immediate action is required.	Conduct a needs analysis and rectify the situation immediately. Allocate budget for sanitation services delivery.

On national government level

Score	Description	Corrective actions
A	Infrastructure is in excellent condition and well maintained, with capacity to endure pressure from unusual events	Maintain status quo
B	Infrastructure is in good condition and properly maintained.	Ensure proper maintenance through inspections and raising users' awareness.
C	Infrastructure is in an acceptable condition but will need interventions to avoid serious deficiencies.	Allocate budget for repairs and maintenance.
D	Infrastructure is not adequate and is poorly maintained. Prompt corrective action is needed.	Plan and allocate budget for maintenance and user training.
E	Infrastructure has failed or is on the verge of failure, exposing the public to health and safety hazards. Immediate action is required.	Plan and allocate budget for sanitation services delivery.

6.3 WHY SHOULD THE STAKEHOLDERS PARTICIPATE IN THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM?

Figure 30 below shows the value of the CS-SHIP. The platform is designed to provide data, information and report to the various stakeholder. Figure 30 demonstrates the reports that could be generated for, and by, stakeholders through an operationalised CS-SHIP, namely the following:

1) **State of Your Toilet** report for citizens – This report closes the loop between the citizen and the system. It is vital that these reports provide feedback to the citizens on the status of their sanitation and hygiene, with a focus specifically on the key elements that these citizens have shown to be of importance to them, i.e. the citizen will receive a report with a score for A^2HQ – how appropriate, acceptable, hygienic and quality was their sanitation and hygiene facility (see Section 4.2.2.1 below for the specifications) for this report. The report will be computer-generated, based on the scoring of a simple questionnaire that is electronically completed and submitted by the citizen.
2) **The AI system** – The ultimate intent of the CS-SHIP it to utilise artificial intelligence (AI) to capture, store, analyse and report the sanitation and hygiene information that are provided by the citizens. A number of tools will be developed and finalised, such as the computer vision software for recognising and scoring sanitation elements, the data base and the algorithms for analysing the data.
3) **Municipal State of Rural Sanitation and Hygiene Report** – This group of stakeholders can request a 'state of' report for rural sanitation and hygiene in their jurisdiction. Data from the CS-SHIP can also be utilised to inform municipal Water and Sanitation Development Plans, IDPs and other local planning and strategic plans and actions.
4) **National State of Rural Sanitation and Hygiene Report** – This group of stakeholders can request a 'state of' report for rural sanitation and hygiene from the CS-SHIP. Data from the CS-SHIP can also be utilised to inform national strategic planning (i.e. Sanitation and Hygiene Master Plans) and for international reporting, i.e. SDGs.

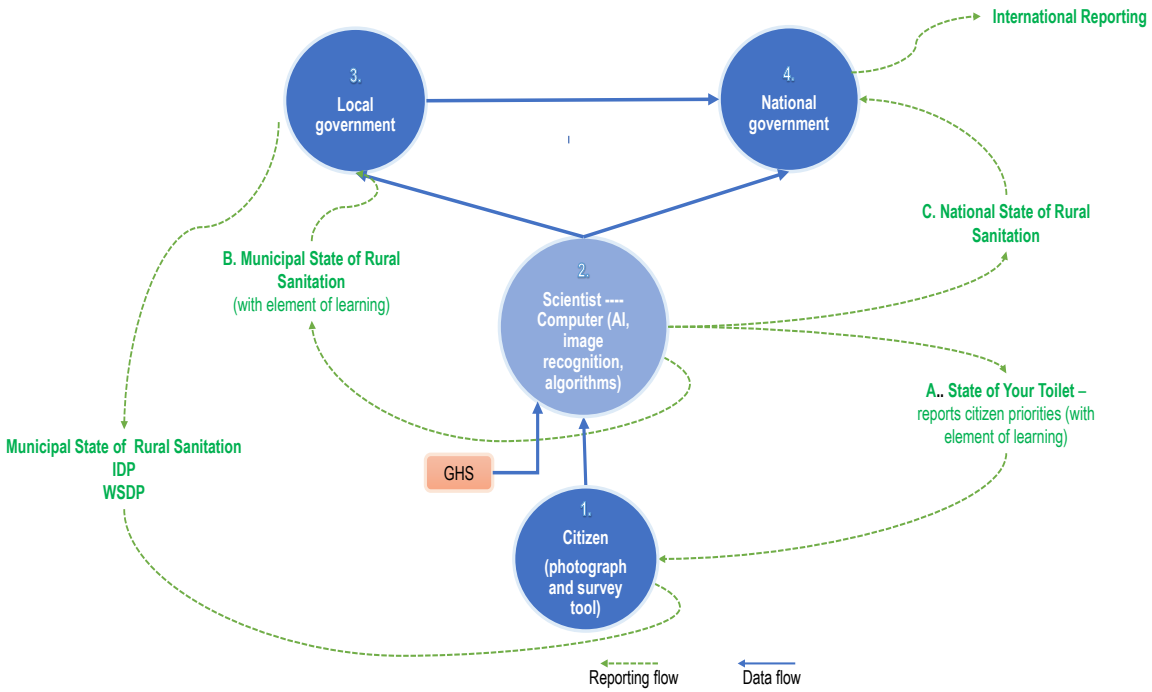


Figure 30: Reporting flow from the CS sanitation and hygiene monitoring platform/system for South Africa

6.4 STAKEHOLDER GROUP 3 AND 4: USERS OF THE CITIZEN SCIENCE MONITORING PLATFORM/SYSTEM

These stakeholder groups are envisaged to be users of the CS-SHIP. The specifications for the reports and data that will be available to these users will be accessible on the platform/ system that will be developed and this first input data and information is available.

6.5 SUMMARY OF INFORMATION AND DATA COLLECTED BY THE SURVEY AND PHOTOGRAPHIC IMAGES IN THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM

The tables below demonstrate which crucial sanitation and hygiene data can be provided by the tools that will be utilised in the CS-SHIP.

C1. Is your toilet safe?

	From Ques	From photo
Easy access	√	√
Clear route	√	√
Inside the house or within 10 m of the house	√	√
Safe barrier to human excreta		√
Protects from the weather		√
Door can lock		√
Ramp for disabled		√

C2. Is your toilet easy to clean?

	From Ques	From photo
Smooth floor		√
Smooth walls		√
Smooth pedestal		√
Smooth seat and lid		√
Cleaning materials available	√	√
Cleaned at least once a week	√	√

C3. Is your flush toilet functional?

	From Ques	From photo
Can be used every day	√	
Water is available	√	√
Toilet not leaking		√
Pipes not leaking	√	√
Sewer pipes not leaking	√	√
Septic tank not leaking	√	√
Access for septic tank emptying		√
Toilet pedestal with seat and lid		√
Upright walls		√
Floor slab not cracked		√
Ventilation		√
Light – day and night	√	√
Door hung properly		√
Door that can close		√
Roof slant away from the door		√
Roof securely fastened		√
Roof that does not leak	√	√

C4. Is your non-flush toilet functional?

	From Ques	From photo
Can be used every day	√	
Contain human excreta		√
Access for pit emptying		√
Toilet pedestal with seat and lid		√
Upright walls		√
Floor slab not cracked		√
Floor does not flood (at least 100mm above surrounding ground)	√	√
Vent pipe with flyscreen		√
Ventilation		√
Light – day and night	√	√
Door hung properly		√
Door that can close		√
Roof slant away from the door		√
Roof securely fastened		√
Roof that does not leak		√

C5. Is your toilet appropriate?

	From Ques	From photo
Provides dignity	√	
Is private	√	
Accessible to all (men, women, children, elderly, disabled)	√	√
Is socially acceptable	√	
Is culturally acceptable	√	
Is environmentally suitable	√	√

C6. Is your toilet hygienic?

	From Ques	From photo
Cleansing material available	√	√
Smell	√	
Flies	√	√
Menstrual material management	√	
Handwash facility with water and soap	√	√
Hand drying material available	√	√
Solid waste pollution	√	√
Environmental pollution – waste leakage	√	√

C7. Is your toilet maintained?

	From Ques	From photo
Easy to fix	√	
Spare parts available	√	
Pit/septic tank emptied when needed	√	

The above summary shows that the two tools are complementary and should be used together as most information on the physical infrastructure could be obtained by analysing photographs and images, but the information on the functioning and the perceptions and needs of citizens could only be obtained through the questionnaire.

CHAPTER 7: PILOTING OF THE TOOLS FOR THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM

The piloting of the tools that form the CS-SHIP entailed publishing the questionnaire on KoboToolbox and inviting a number of households to complete the questionnaire. In addition, survey participants, supported by a Sustento fieldworker, were asked to send a suite of photographs of their facilities (as outlined in Figure 11 above). All inputs were made using the Sustento fieldworker's smartphone to avoid the households having to use their own internet access data for the piloting of the questionnaire.

7.1 PILOTING THE CITIZEN QUESTIONNAIRE

The questionnaire was developed on KoboToolbox, including an absolute minimum of questions to capture the key facility elements that the citizens in Deliverable 2 of the assignment, highlight as important for their sanitation and hygiene facilities. The questionnaire is thus focussed on capturing citizens needs for understanding the state of their sanitation and hygiene facilities. The survey questions in the pilot were designed to capture responses on the Android App for KoboToolbox, allowing responses to be capture using Android smartphones. The survey questions were repeated, reviewed, and the Android App capturing of response tested a number of times by the Sustento research team to ensure scientific credible and appropriate data were being collected, and that the manner in which the data was being reported and captured by the citizens was easy and understandable. The questionnaire can be accessed here: https://ee.kobotoolbox.org/x/yUSJiHnR. Further review and refinements of the elements will be required in the future development of the full CS-SHIP. The questions that were included in the citizen questionnaire are shown below:

1. **Number for the participant**
2. **Date**

3. Participation			
4. Are you willing to participate in the survey?		Yes	No
5. What is your gender?	Male	Female	
6. Do you have access to a toilet?		Yes	No
7. The type of toilet you use on a daily basis	Chemical toilet		
	Bucket toilet		
	Pit toilet		
	Ventilated Improved Pit toilet		
	Urine diversion toilet		
	Flush toilet (low flush, pour flush, full flush)		
	Don't know		
8. Where is the toilet located?	Inside the house		
	In the yard within 10 meters from the house		
	Inside the yard farther than 10 m from the house		
	Not in the yard		
9. Do you share your toilet with other households?		Yes	No / Don't know
10. Is there a hand washing facility near the toilet?		Yes	No / Don't know
11. What cleansing material is in the toilet?	Toilet paper		
	Soap		
	Bin for rubbish		
	Nothing		
12. How long have you been using the toilet?	Less than a year		
	1-2 years		
	More than 2 years		
	Do not use the toilet		

13. Who uses the toilet?	Everyone		
	Adults		
	Children		
	People living with disabilities		
	No one		
14. Can the toilet be used every day?	Yes	No	Don't know
15. Is it easy to keep the toilet clean?	Yes	No	Don't know
16. Is there cleaning materials (like bleach, soap, toilet brush, etc.) for the toilet?	Yes	No	Don't know
17. Does the toilet smell?	Yes	No	Don't know
18. Is there a light in the toilet during the night?	Yes	No	Don't know
19. Can you lock the door from the inside?	Yes	No	Don't know
20. Is it clean inside the toilet seat?	Yes	No	Don't know

Record the GPS location.

Very simply, the survey questions provide the information for the citizens' elements related to whether their sanitation facility is appropriate and acceptable.

7.2 PHOTOGRAPHIC IMAGE ANALYSIS IN THE PILOT

As the software is not yet developed to conduct the image analysis of the photographs provided by the citizens (outside the scope and budget for this assignment), the sanitation specialists on the research team conducted an assessment of the photographs using the checklist. The checklist was also developed to operate with the KoboToolbox App; hence the sanitation specialists and the project team could review the submitted photographs and input data into the App on their smartphones. The checklist can be accessed here: https://ee.kobotoolbox.org/x/KjTjwKtM.

The submitted data were downloaded from the KoboToolBox as an Excel spreadsheet and analysis was done using Excel Statistics and SPSS. This process of piloting the photographic image analysis provided insight into the specifications required for the AI software that needs to be designed/utilised in future for the CS-SHIP.

7.3 PILOT IN THE WESTERN CAPE

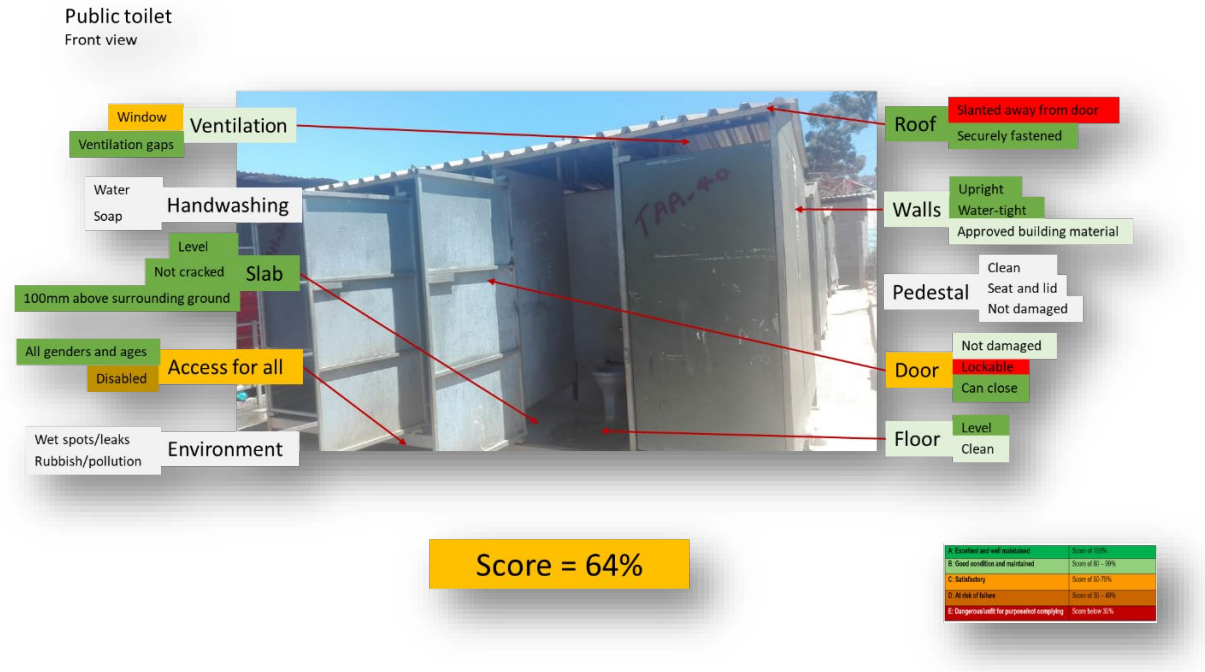
The piloting of the CS-SHIP tools occurred on World Toilet Day (19 November 2021) in Enkanini near Stellenbosch in the Western Cape. However, the toilets encountered were public toilets with no specific household responsible for the toilet.

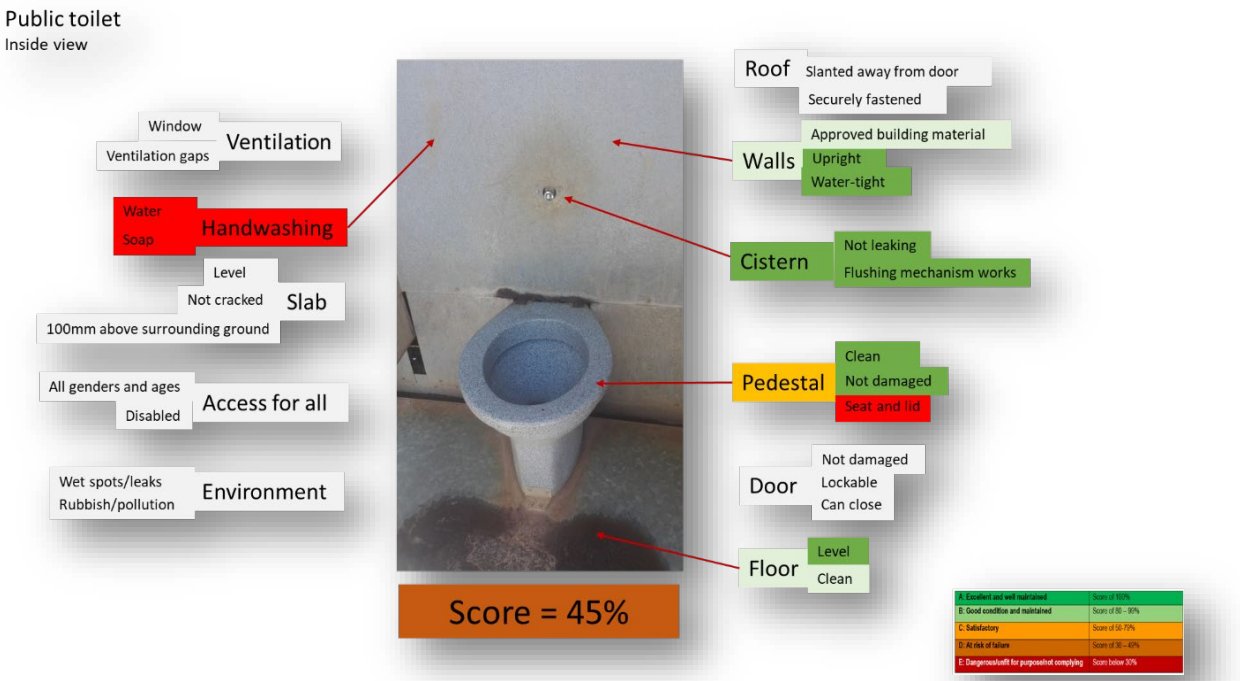
A visual assessment of the public toilets against the indicators set out in Section 6 of this report was done in situ, as well as taking photographs and uploading the photos to a central location with the project team to assess visually. No citizen survey was conducted as these were communal/public toilets, thus shared by a number of households and users. The photographic images provided were assessed, categorised and scored by the sanitation specialists to reflect a rating for the facility. The rating for the score were reflected as a letter of the alphabet, which aligns with the ratings of the SAICE Infrastructure Report Card.

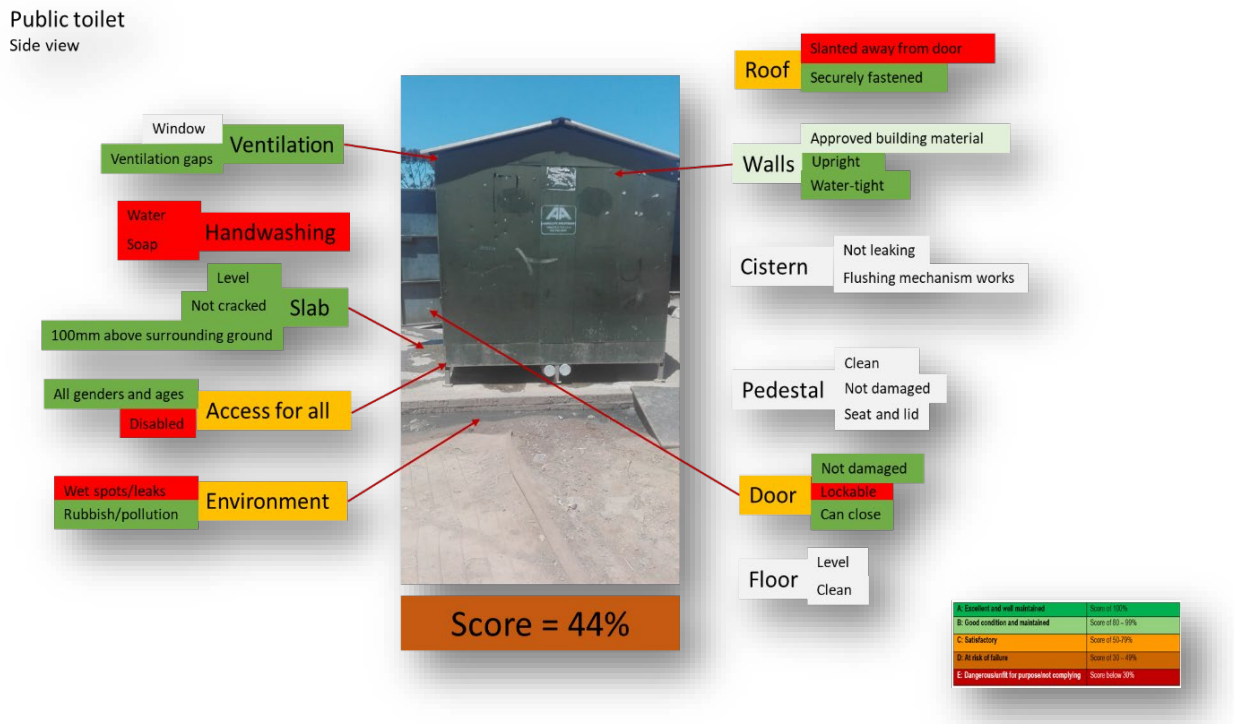
A: Excellent and well maintained	Score of 100%
B: Good condition and maintained	Score of 80-99%
C: Satisfactory	Score of 50-79%
D: At risk of failure	Score of 30-49%
E: Dangerous/unfit for purpose/not complying	Score below 30%

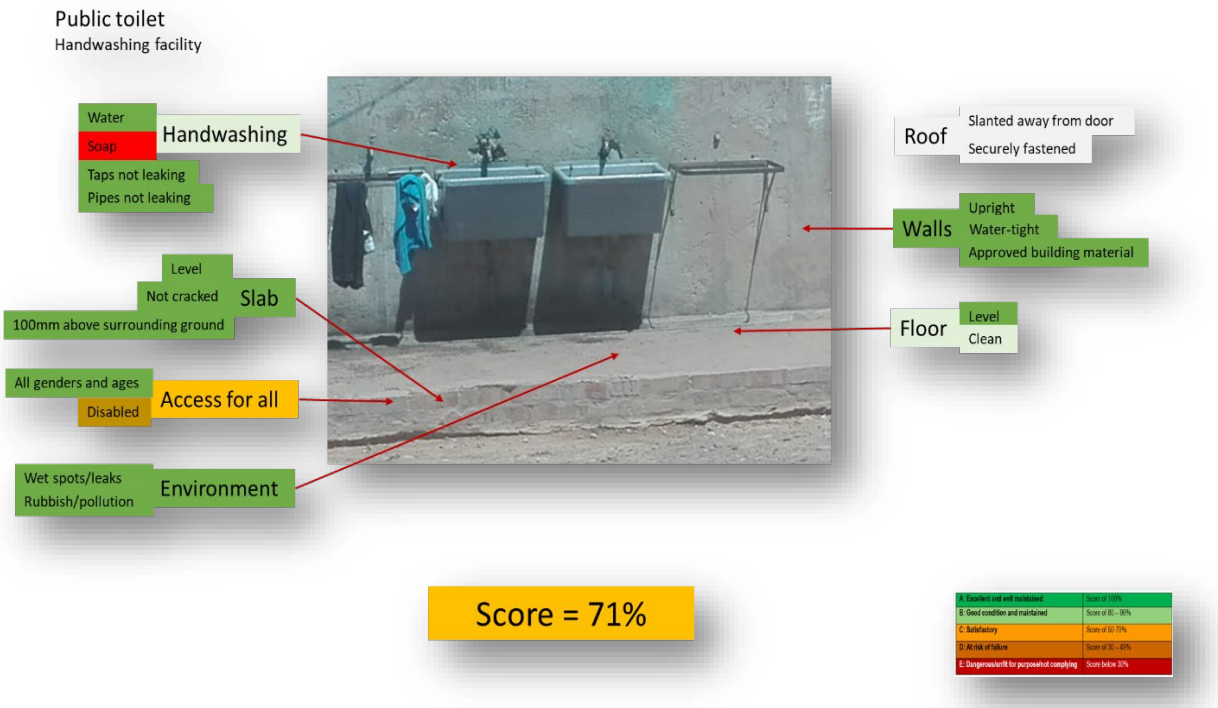
Below is an example of the assessments done by the sanitation specialist, which could be done by the AI, for a public toilet in future. The scoring was very much simplified for the purposes of the example with no weighting of the elements.

Public toilet 1









Total score for infrastructure **C: 56% (Satisfactory)**

According to the simplified scoring, this public toilet falls just inside the 'Satisfactory' category. The building and structure of the toilet fall in the 'At risk of failure' category, but the availability of a washing facility next to the public toilet falls in the higher part of the 'Satisfactory' category.

The intention is that this scoring will trigger a response to the owners/maintenance and management team of the public toilet with, inter alia, the following:

Your public toilet scored a C (56%), which is satisfactory. However, the following corrective actions must be taken to improve your toilet to comply with the minimum requirements:

Score	Corrective actions		
	Building	**Hygiene**	**Safety**
C	Improve the general condition of the infrastructure. Slant the roof away from the doors. Improve the accessibility for people living with disabilities.	Maintain the washing facility and make sure that water, soap and drying materials are available. Improve the accessibility for people living with disabilities.	Keep path clear and make sure the doors can close properly and lock from the inside. Improve the accessibility for people living with disabilities.

7.4 PILOT IN THE EASTERN CAPE

The pilot of the CS-SHIP tools was repeated in Tshabo 2 near Bisho in the Eastern Cape on 20 and 21 November 2021. Ten (10) households were invited by a student to complete the questionnaire by visiting these households in person. The KoboToolBox survey questionnaire was completed, together with the study, by each household and uploaded to the KoboToolBox system.

A visual assessment of the household's toilet against the indicators set out in Section 6.1 of this report was done in situ, as well as taking photographs and uploading the photos to a central location with the project team to assess visually.

7.4.1 Citizen Survey Results

The responses to the questions by the households in Tshabo 2 near Bisho in the Eastern Cape were analysed by applying the scoring system (each response with equal value) shown in Section 6.1. Table 12 shows the results of this analysis of the citizen survey, demonstrating that the VIP toilets largely failed in meeting the citizens' criteria for their facilities, apart from the appropriateness of the toilet.

Table 12: Sanitation facilities scores for the citizen priority elements, based on the survey

Priority	3. Quality				6. Acceptability		Acceptability Score	8. Appropriate	Appropriate Score	9. Hygienic		Hygiene Score
Household #	3.1 Safe (no health threats)	3.2 Hygienic	3.3 Technical safety, i.e. ventilated, light, protects	Quality Score	6.6 Sanitary materials	6.7 Aesthetics		8.2 Functional, i.e. operation; maintenance; reliable		9.1 Cleanliness of facility, i.e. cleaning materials	9.2 Odour	
1	75%	67%	50%	67%	0%	100%	20%	67%	67%	50%	0%	33%
2	75%	0%	50%	44%	0%	100%	20%	100%	100%	0%	0%	0%
3	75%	0%	50%	44%	0%	100%	20%	100%	100%	50%	0%	33%
4	75%	0%	50%	44%	0%	100%	20%	100%	100%	50%	0%	33%

Priority	3. Quality				6. Acceptability			8. Appropriate		9. Hygienic		
Household #	3.1 Safe (no health threats)	3.2 Hygienic	3.3 Technical safety, i.e. ventilated, light, protects	Quality Score	6.6 Sanitary materials	6.7 Aesthetics	Acceptability Score	8.2 Functional, i.e. operation; maintenance; reliable	Appropriate Score	9.1 Cleanliness of facility, i.e. cleaning materials	9.2 Odour	Hygiene Score
5	75%	0%	50%	44%	0%	100%	20%	100%	100%	0%	0%	0%
6	75%	67%	50%	67%	0%	100%	20%	100%	100%	50%	0%	33%
7	75%	0%	50%	44%	0%	100%	20%	100%	100%	50%	0%	33%
8	75%	0%	50%	44%	0%	100%	20%	100%	100%	50%	0%	33%
9	100%	0%	50%	56%	0%	100%	20%	100%	100%	50%	0%	33%
10	100%	0%	50%	56%	0%	100%	20%	100%	100%	50%	0%	33%

The above results can be automatically generated by the AI system. The results in their current format are, however, not really useful to the households. Hence, a combined score, with a report-back loop will be generated for each household. The score will be reflected by the images shown in Figure 31 to provide a user-friendly, interesting report to the citizen.

Score	Image in the Report to Citizens
0-50%	
51-75%	
>75%	

Figure 31: Images for reporting back to the citizens on the status of the sanitation facility

The feedback report is expected to be generated by the AI system that will send an almost instant report-back to the households for the survey submitted. Table 13 demonstrates examples of the report-back mechanism to the households.

Table 13: Examples of report-back to citizens on their toilet with an element of learning

Household 1		**Status of Your Toilet: Your toilet currently scored a C** Consider the following corrective action: - Add soap to your handwashing facility - Installing a light at night -Ensuring you have toilet paper, soap and a bin in the toilet, especially if there are women and girls in your home - Ensuring you have toilet cleaning materials (bleach) in the toilet - check the flyscreen is intact to minimise the smell and keep the toilet seat lid down when not in use
Household 2, 3, 4, 5, 7, 8, 9 and 10		**Status of Your Toilet: Your toilet currently scored a C** Consider the following corrective action: - Add a handwashing facility (basin&water; TippyTap) with soap to toilet area. Remember to change the water regularly - Installing a light at night -Ensuring you have toilet paper, soap and a bin in the toilet, especially if there are women and girls in your home - Ensuring you have toilet cleaning materials (bleach) in the toilet - check the flyscreen is intact to minimise the smell and keep the toilet seat lid down when not in use
Household 6		**Status of Your Toilet: Your toilet currently scored a B** Consider the following corrective action: - Add soap to your handwashing facility - Installing a light at night -Ensuring you have toilet paper, soap and a bin in the toilet, especially if there are women and girls in your home - Ensuring you have toilet cleaning materials (bleach) in the toilet

7.4.2 Photographic Image Assessment by Sanitation Specialists (AI in future)

7.4.2.1 Level 1 Results of the Tshabo 2 Photographic Image Assessment

One of the key components of the KoboToolBox survey is the capturing of the Global Positioning System (GPS) coordinates of the sanitation facilities being surveyed. Apart from capturing the actual site of the sanitation facility and confirming its position, these points can be utilised by the AI in future to verify any Level 1 assessment done for an area, with the AI learning and refining the accuracy of determining the presence of sanitation facility in a community.

Figure 32 demonstrates this in the Tshabo 2 sites of the pilot, where the sanitation specialist (in future the AI) has highlighted sites where potential facilities could be found (denoted as pt in the figure) and the sites captured through the KoboToolBox for households 1, 2, 5 and 6 that participated in the citizen survey.

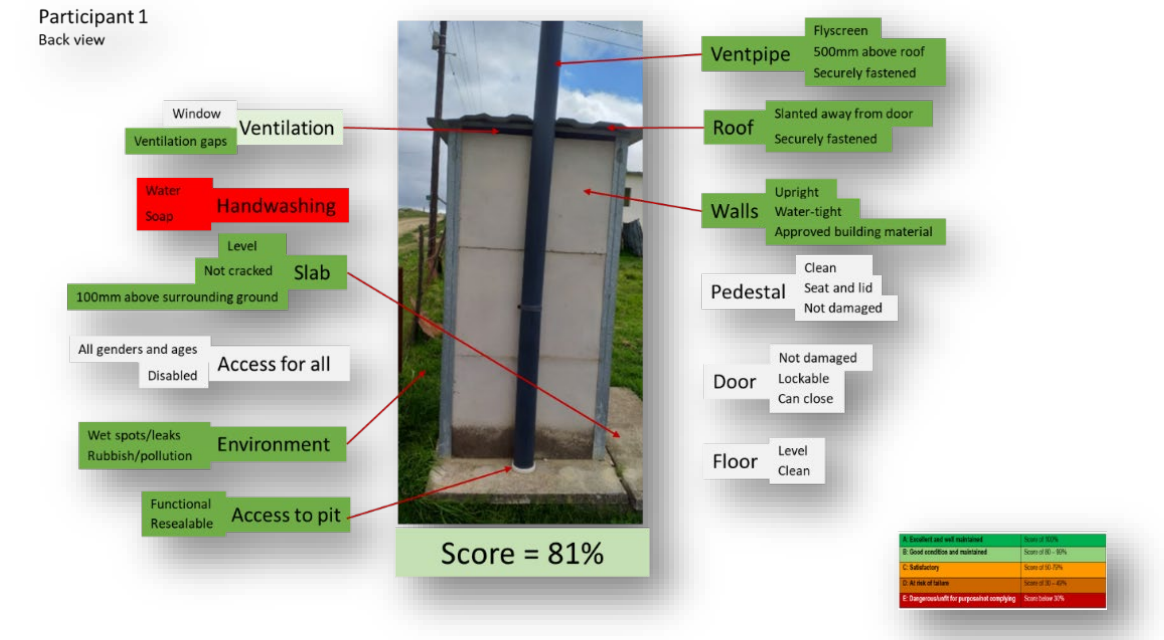
Figure 32: Example of how a sanitation specialists Level 1 assessment of a sanitation sites in a village can be verified by the KoboToolBox GPS of the citizen survey. Pt=potential toilet

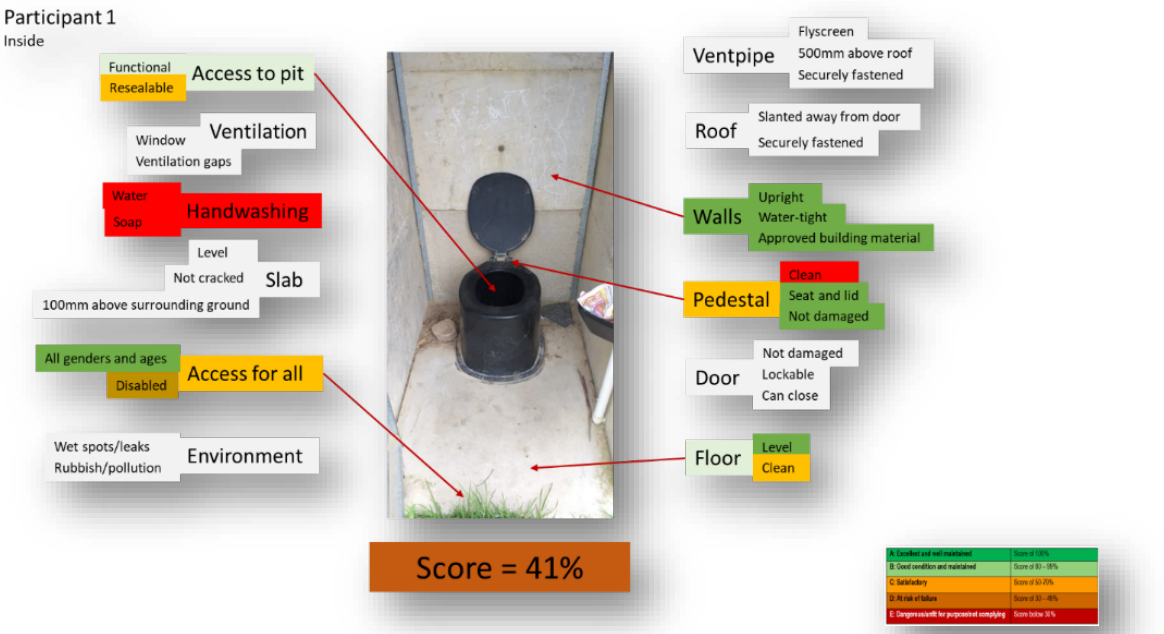
7.4.2.2 Level 2 and 3 Results of the Tshabo 2 Photographic Image Assessment

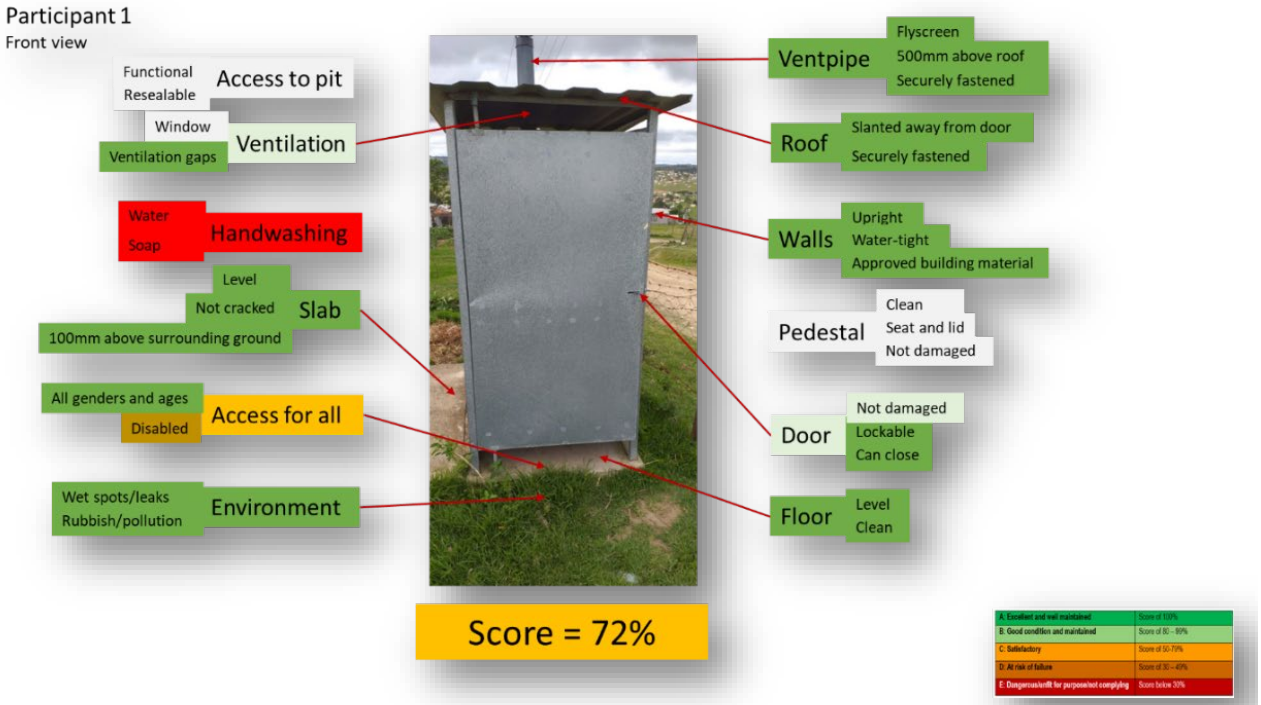
Apart from the visual in situ basic assessment of the toilets by the Sustento student, the photos and images provided by the citizens (with student support) needed to be assessed by the Sustento sanitation specialists using the measures set out in Section 6 of this report. A basic assessment checklist was developed on the KoboToolBox to assess the infrastructure from the photographs. Two sanitation specialists and a sanitation student conducted the KoboToolBox checklist assessment of the photographs provided by the citizens. The checklists were uploaded to KoboToolBox by the student supporting the citizens, downloaded from KoboToolBox as an Excel file, and analysed by using SPSS and Excel.

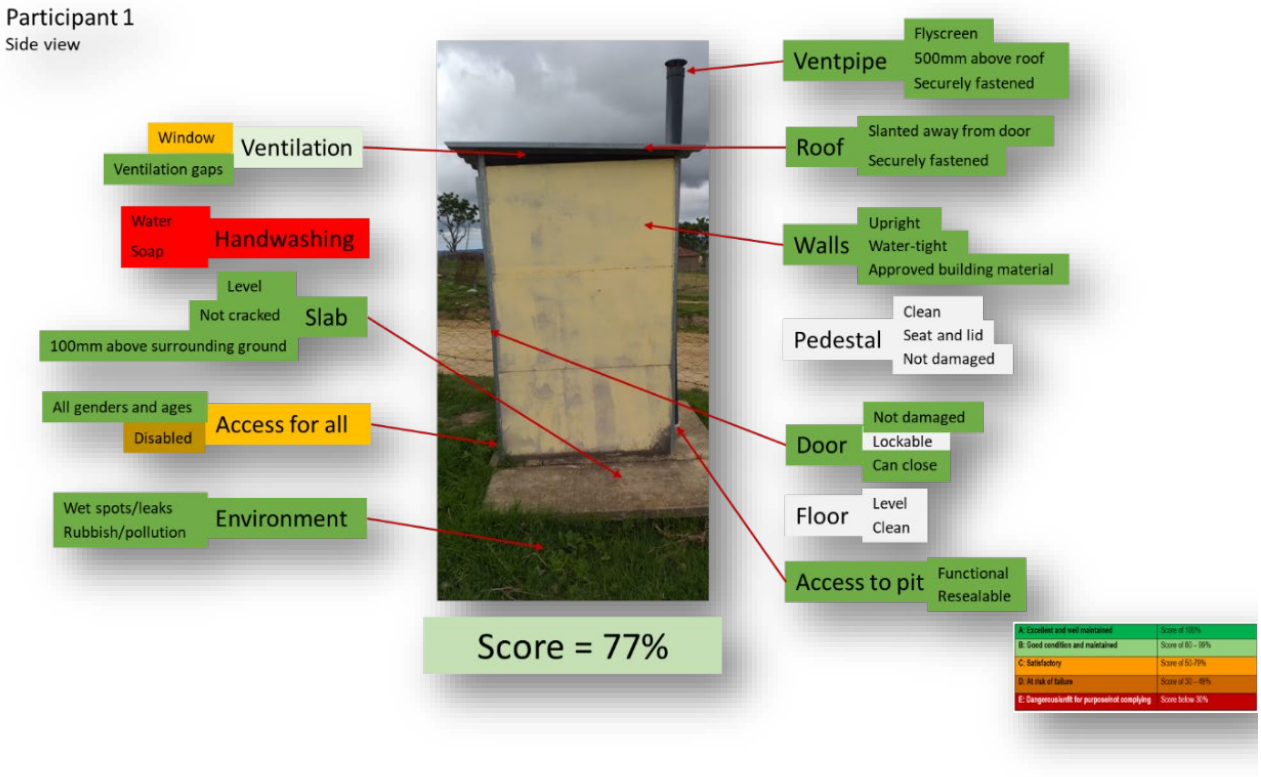
Since assessing the photos manually was very time consuming, the objective of the CS-SHIP development is to design and develop a computer vision process for analysing and scoring the photos of toilets, which can be done in split-seconds per photo. Below is an example of the assessments done by hand, which could be done by the AI, for Participant 1, using the colour-coding for easy reference. The scoring was very simplified for the purposes of the example with no weighting of the elements.

Participant 1









Total score for infrastructure **C: 67.75% (Satisfactory)**

According to the simplified scoring, this participant's toilet falls in the '**Satisfactory**' category. The building and structure of the toilet fall in the '**Good condition and maintained**' category, but the pedestal element falls in the '**At risk of failure**' category.

The intention is that this scoring will trigger a response to the household of the following:

Your toilet scored a C (67.75%), which is satisfactory. However, the following corrective actions must be taken to improve your toilet:

Score	Corrective actions		
	Building	Hygiene	Safety
C	Maintain structure and vent pipe are in good condition and properly maintained.	Obtain a handwash facility within 1 meter of the toilet and make sure you have water, soap and drying materials.	Keep path clear and make sure the door can close properly and lock from the inside

Table 14 shows the scores for all 10 citizens, based on combining of scores from the entire checklist. The results from the three assessors were averaged to get a single score per element for the households, ensuring that scores were more accurate for an element. As Table 14 shows, the facilities of households 1-2, 4-6 and 8-10 scored over 80% on the technical elements, while household facilities were assessed by the sanitation specialists as a C. Table 14 also demonstrates the use of the VIP algorithm from Section 6 of the report, showing a predicted score that could be generated for the facility based on the 9 elements highlighted in Table 13 above. Due to the overestimate of score by the algorithm, it estimated the score for household 3 and 7 in the higher category (B) as the actual score of the facility was in the higher side of the 70s.

Table 14: Calculates score for the sanitation facilities based on the image assessment conducted by the sanitation specialist and based on a generated score using a 9-element algorithm.

No.	Score using all elements	Symbol score for facility		Predicted Score Algorithm for this Sample	Symbol score for facility
1	83	B		87.2	B
2	83	B		86.0	B
3	79	C		85.7	B
4	83	B		86.0	B
5	83	B		84.5	B
6	84	B		87.2	B
7	78	C		92.5	B
8	82	B		81.3	B
9	85	B		86.0	B
10	80	B		84.5	B

What was perhaps the most interesting result was the significant disparity in the picture painted of a household's sanitation, based on the citizens survey results and the sanitation specialists' technical assessment of the photographs. The citizen survey results, which largely reflect the important elements of a toilet to the citizen itself, reflect the sanitation and hygiene facilities as performing poorly and effectively failing citizens' sanitation priorities. However, the photographic assessment, albeit basic, by the sanitation specialists of the same facility against technical elements, showed the sanitation and hygiene facilities as performing really well, with the majority of the facilities scoring over 80% compliance to policy and norms and standards for basic sanitation and hygiene facilities. This is a result that will need to be reflected on and be explored further when taking the CS-SHIP into the next stage of design, development and testing.

CHAPTER 8: ROLL-OUT OF THE CITIZEN SCIENCE SANITATION AND HYGIENE INFORMATION PLATFORM

Once all the elements and tools of the CS-SHIP were developed and tested (such as the computer vision, data storage, algorithms, etc.), the section below highlight the requirements for the roll-out of the CS-SHIP.

8.1 ROLL-OUT EVENTS

Water and sanitation related events or special days can be used as podiums for the CS-SHIP, such as:

- World Water Day (March every year)
- World Toilet Day (November every year)
- World Environment Day (June every year)
- Women's Day (August every year)
- Etc.

News agencies, social networks and print media will be used to advertise the CS-SHIP during the events.

8.2 ENSURING PARTICIPATION

Participation in data gathering information on sanitation facilities/toilets need to be constant and regular to be able to report back on indicators for reaching the SDG targets, as well as improving the quality of life of citizens. To ensure the sustainable participation of citizens, the following need to be implemented:

Raise awareness: Raise awareness about the roll-out of the tool through large media organisations, social networks and local news agencies.

Be inclusive: Develop/use a smartphone App that allow all, especially underrepresented groups (the poor, the disabled, etc.) to participate in the survey. Local government staff could be used to assist those who experience problems, as well as to do spot checks or even the survey at local level.

Motivate: Once participants provided information and data, etc., they have expectations of either receiving compensation for their efforts or have their sanitation situation be improved/changed. Understand the motivations and expectations of the participants and provide motivations for participation.

Incentivise: Provide incentives for participation through benefits that the participants want, such as free internet access (data plans) or vouchers for sanitation. For example, negotiate with Vodacom/MTN/CellC, etc., for free data allocations when a participant completed the questionnaire/submitted a photo. Or negotiate with manufacturers or retailers of cleaning materials and soap, such as PnP/Checkers, etc., to supply vouchers for soap or cleaning materials when a participant completed the questionnaire or submitted a photograph.

Maintain interest: A degree of competition, which is a part of many games, can act as a motivator and help sustain participant engagement. The degree of improvement over time of a sanitation facility can be compared with neighbouring facilities to boost the morale of the owners to improve their facilities and receive the honour for it.

Provide awards: Awards linked to the data plan (a larger data allocation) or voucher system (higher value voucher) can be provided to keep the participants interested in participating.

8.3 SHARING RESULTS

Empowering individuals and communities with information requires constant feedback and dialogue, as well as visible change or mitigation following participation. Bottom-up contributions should be supported, and top-down policy processes engaged to connect the two perspectives so that policymakers are ready to receive data and findings from participants and take action.

The learning gained through this research could also be applicable to other key issues in the country, such as water use, solid waste management, energy, safety and security, housing, and transport.

The long-term aim of the research is to gather information and data on sanitation through Citizen Science, and to explore the use of this information to produce a scientifically credible ‘State of Sanitation’ report at least every three to four years to support decision making on national and local government levels in the country.

CHAPTER 9: CONCLUSIONS & RECOMMENDATIONS

9.1 CONCLUSIONS

The globe, in a post-COVID-19 era, with a focus on a new digital age and the fourth industrial revolution (4IR), has highlighted the need for reinventing the manner in which knowledge is produced, distributed and acted upon. Citizen Science is one manner in which new knowledge can be produced and distributed while building new relationships between science and society. Citizen Science has a role to play in tracking progress towards the WASH SDGs, and bridging the current gaps in approaches, methods, tools and platforms for gathering, analysing and reporting high-quality, timely and accessible data. Citizen Science can be utilised as an efficient and effective approach to satisfy data gaps that currently exist in reporting the status quo of WASH services locally, provincially, nationally and internationally. For Citizen Science to be effective, however, it will need to be meaningful to individuals and communities that are providing information and data on their WASH services. Therefore, Citizen Science monitoring programmes would need to provide useful information to the citizens while reflecting the state of WASH infrastructure at different levels (from the smallest ward or neighbourhood to settlement/ community level, and local, provincial and national levels). Apart from reflecting the real WASH situation at various scales in the country and providing valuable insight to the citizen scientists on the state of their WASH services, Citizen Science research that directly involve members of the public can also increase the participants' (citizen scientists) awareness and scientific knowledge of WASH monitoring, as well as facilitate changes in their attitudes towards science, and their behaviour related to their WASH services.

To be able to develop and implement sanitation interventions and appropriate solutions, particularly in this time of COVID-19, it is necessary to be sure that the actual, in real-time state of sanitation in the country is known, that the daily challenges experienced with sanitation (toilets and handwashing) are being captured and reported, and that real-time information on the safety, hygiene, accessibility, equitability and reliability of sanitation services is known, especially in peri-urban and rural areas of a country. Although traditional data collection methods are well-established, gathering information for sanitation is generally too expensive in terms of human resources and running costs. The increasing availability of technologies such as access to the Internet, handheld personal digital assistant (PDA) and smartphones has made is easier for scientists and citizens to connect with each other and to gather and analyse data rapidly, cheaply and credibly.

The study's main aim was to explore the potential of employing Citizen Science as a novel way for real-time, ongoing monitoring and reporting of South Africa's state of sanitation infrastructure. It showed that Citizen Science can be used as an efficient and cost-effective way to reflect the actual state of sanitation and hygiene infrastructure on different levels (household, settlement, local, national) by applying the tools that were developed and tested for the Citizen Science monitoring platform. The tools (electronic questionnaire and photographs) of the CS-SHIP use existing hardware, i.e. computers, laptops, tablets, PDAs, and smartphones, that most people already have and use. The data provided by the citizens through the electronic questionnaires and photographs are analysed and feedback reports are compiled manually at this stage, which is very time consuming and costly. The ultimate intent and the next step for the CS-SHIP is to source funding to design, develop and utilise artificial intelligence (AI) and computer vision software to capture, store, analyse, score and report on the sanitation and hygiene information, with almost instant feedback reports of the results to the citizens. Reports may also be requested by local and national government, as well as interested stakeholders, on the state of sanitation and hygiene infrastructure in the country.

9.2 RECOMMENDATIONS

It is clear from the study that Citizen Science is applicable to monitoring sanitation infrastructure in the country. In fact, the inputs from the citizens in what they require a sanitation facility to be and do for them formed the foundation and the basis of designing the CS-SHIP.

The following recommendations are made for the following aspects:

- The CS sanitation and hygiene information platform (CS-SHIP)
  Funding for the development of the CS-SHIP, including the development of the Smartphone App and the computer vision software (AI), should be prepared and presented to donors/funders for furthering the application of the outputs of this study.

- Citizens
  For the CS-SHIP to be successful and work optimally in obtaining real-time, cost-saving, factual and objective data and information on sanitation facilities in the country, it will be necessary to ensure the inputs and participation of all citizens, meaning that the CS-SHIP is a citizen-based and citizen scientist-dependent system. Thus, the role and participation of the citizen need to be explored and central in the further development of the platform. In the CS-SHIP, the role of the citizen was to design and develop the platform, and also to provide the information necessary for the platform/system to stay operational in monitoring the sanitation situation of the country. This focus needs to be maintained in the further development of the platform. Models (incentives, benefits, awards, feedback loops, etc.) for sustainable and consistent participation of the citizens in the CS-SHIP by providing the data and evaluating the platform need to be explored.

- Local government
  Interaction and engagement with local government to ensure alignment of the platform and their sanitation planning and reporting needs and requirements.

- National government
  Interaction and engagement with national government to ensure alignment of the platform and their sanitation planning and reporting needs and requirements.

- Research and innovation
  Further research is necessary to fine-tune the algorithms based on the information provided as the sanitation score is a function of elements that influences the algorithms.
  The inclusion of the elements of menstrual health needs to be researched and added to the tools of the CS-SHIP.

The next step is to continue to engage with other experts in the water, sanitation and hygiene sectors regarding monitoring sanitation to ensure synergies and alignment of Citizen Science efforts in WASH and menstrual health.

Based on the results of the study, a proposal for funding of the development of a Smartphone App and the computer vision software (AI) will be prepared and presented to donors/funders for furthering the application of the outputs of this study. The proposal will request funding for the tool required to capture data at an individual level (using existing technologies such as cell phones), the detail specifications for indicators and elements that can be reported based on the data captured by citizens, and the data analysis protocol (computer vision/image recognition and analysis) to report the results of the analysis of the data captured by citizens to the citizens, and to local and national government.

The proposal will include, but not be limited to:

- designing a data analysis and reporting digital platform/software for sanitation (computer vision, image recognition software);
- developing a scientifically credible smart App that citizens can utilise to capture the data necessary to determine the state of their sanitation facilities;
- scoping, selecting and employing a data host;
- expanding the development of the tool to be applicable in all areas (urban, peri-urban, rural, deep rural) for all kinds of sanitation facility;
- negotiating with retailers and data services providers regarding incentives and rewards for participants; and
- the potential for compiling a ‘State of Toilets in South Africa’ report every three or four years using the data obtained through Citizen Science.

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APPENDIX A: STEPWISE REGRESSION

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.540[a]	0.292	0.290	7.413330236605710	0.292	127.371	1	309	0.000
2	.628[b]	0.394	0.391	6.866536862362930	0.103	52.172	1	308	0.000
3	.680[c]	0.463	0.457	6.479338176956380	0.068	38.911	1	307	0.000
4	.828[d]	0.686	0.682	4.960885753412300	0.223	217.698	1	306	0.000
5	.840[e]	0.705	0.700	4.815488335272760	0.019	19.758	1	305	0.000
6	.846[f]	0.717	0.711	4.728728873626310	0.011	12.295	1	304	0.001
7	.850[g]	0.723	0.717	4.683037214415060	0.006	6.961	1	303	0.009
8	.855[h]	0.731	0.724	4.623413609090090	0.008	8.865	1	302	0.003
9	.858[i]	0.736	0.729	4.582233656001430	0.006	6.452	1	301	0.012

a. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water

b. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof

c. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air

d. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet

e. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged

f. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside

g. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside, 32.VIP_Pedestal has seat and lid

h. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside, 32.VIP_Pedestal has seat and lid, 31.VIP_Damaged pedestal

i. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside, 32.VIP_Pedestal has seat and lid, 31.VIP_Damaged pedestal, 25.VIP_Fly screen damaged

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6999.964	1	6999.964	127.371	<.001[b]
	Residual	16981.857	309	54.957		
	Total	23981.821	310			
2	Regression	9459.828	2	4729.914	100.318	<.001[c]
	Residual	14521.993	308	47.149		
	Total	23981.821	310			
3	Regression	11093.401	3	3697.800	88.081	<.001[d]
	Residual	12888.420	307	41.982		
	Total	23981.821	310			
4	Regression	16451.042	4	4112.761	167.115	<.001[e]
	Residual	7530.779	306	24.610		
	Total	23981.821	310			

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	16909.198	5	3381.840	145.839	<.001[f]
	Residual	7072.623	305	23.189		
	Total	23981.821	310			
6	Regression	17184.114	6	2864.019	128.082	<.001[g]
	Residual	6797.707	304	22.361		
	Total	23981.821	310			
7	Regression	17336.777	7	2476.682	112.932	<.001[h]
	Residual	6645.044	303	21.931		
	Total	23981.821	310			
8	Regression	17526.283	8	2190.785	102.488	<.001[i]
	Residual	6455.538	302	21.376		
	Total	23981.821	310			
9	Regression	17661.764	9	1962.418	93.462	<.001[j]
	Residual	6320.056	301	20.997		
	Total	23981.821	310			

a. Dependent Variable: Final score for project

b. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water

c. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof

d. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air

e. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet

f. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged

g. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside

h. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside, 32.VIP_Pedestal has seat and lid

i. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside, 32.VIP_Pedestal has seat and lid, 31.VIP_Damaged pedestal

j. Predictors: (Constant), 37.HS8_6 - Ha1dwashing facility has water, 23.VIP_Vent pipe extends above roof, 16.Has openings for daylight and air, 15.Well ventilated toilet, 27.VIP_Concrete slab damaged, 34.HS8_2 - Toilet is clean inside, 32.VIP_Pedestal has seat and lid, 31.VIP_Damaged pedestal, 25.VIP_Fly screen damaged

APPENDIX B: STEPWISE REGRESSION FOR A VIP TOILET

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.579[a]	0.335	0.335	25.266718267961800	0.335	987.118	1	1956	0.000
2	.679[b]	0.462	0.461	22.748501494249100	0.126	458.020	1	1955	0.000
3	.845[c]	0.713	0.713	16.599426639963800	0.252	1717.691	1	1954	0.000
4	.867[d]	0.752	0.751	15.456634999393600	0.038	300.621	1	1953	0.000
5	.887[e]	0.787	0.786	14.329223734171700	0.035	320.411	1	1952	0.000
6	.890[f]	0.792	0.791	14.157704065144100	0.005	48.583	1	1951	0.000
7	.893[g]	0.797	0.796	13.993660323760400	0.005	47.010	1	1950	0.000
8	.895[h]	0.800	0.800	13.869150255576000	0.004	36.169	1	1949	0.000
9	.897[i]	0.804	0.803	13.751037698174600	0.003	34.625	1	1948	0.000
10	.898[j]	0.806	0.805	13.686222296976800	0.002	19.494	1	1947	0.000
11	.898[k]	0.807	0.806	13.641262652221900	0.001	13.855	1	1946	0.000
12	.899[l]	0.809	0.808	13.581063807159100	0.002	18.290	1	1945	0.000
13	.900[m]	0.810	0.809	13.547912134017400	0.001	10.530	1	1944	0.001
14	.901[n]	0.811	0.810	13.520792902429400	0.001	8.806	1	1943	0.003
15	.901[o]	0.812	0.810	13.493986814664600	0.001	8.727	1	1942	0.003
16	.901[p]	0.812	0.811	13.473387706675700	0.001	6.943	1	1941	0.008
17	.902[q]	0.814	0.812	13.438832261229600	0.001	10.995	1	1940	0.001
18	.902[r]	0.814	0.812	13.421823195934300	0.001	5.920	1	1939	0.015
19	.903[s]	0.815	0.813	13.407015924247400	0.001	5.285	1	1938	0.022
20	.903[t]	0.816	0.814	13.365391747005000	0.001	13.090	1	1937	0.000
21	.904[u]	0.816	0.814	13.349987996531200	0.001	5.473	1	1936	0.019

a. Predictors: (Constant), 24.VIP_Pipe has fly screen

b. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap

c. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water

d. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet

e. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high

f. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall

g. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside)

h. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof

i. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls

j. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m

high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet
k. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid
l. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside
m. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof
n. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls
o. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe
p. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside)
q. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door
r. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y. Has securely attached roof
s. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y. Has securely attached roof, 28.VIP_Sloped grou1d around toilet
t. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y. Has securely attached roof, 28.VIP_Sloped grou1d around toilet, 26.VIP_Toilet has concrete slab
u. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y.Has securely attached roof, 28.VIP_Sloped grou1d around toilet, 26.VIP_Toilet has concrete slab, 27.VIP_Concrete s lab damaged

ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	630183.371	1	630183.371	987.118	<.001[b]
	Residual	1248724.194	1956	638.407		

	Total	1878907.565	1957			
2	Regression	867206.169	2	433603.084	837.890	<.001[c]
	Residual	1011701.396	1955	517.494		
	Total	1878907.565	1957			
3	Regression	1340500.520	3	446833.507	1621.659	.000[d]
	Residual	538407.045	1954	275.541		
	Total	1878907.565	1957			
4	Regression	1412321.089	4	353080.272	1477.895	.000[e]
	Residual	466586.475	1953	238.908		
	Total	1878907.565	1957			
5	Regression	1478109.938	5	295621.988	1439.764	.000[f]
	Residual	400797.626	1952	205.327		
	Total	1878907.565	1957			
6	Regression	1487847.985	6	247974.664	1237.148	.000[g]
	Residual	391059.580	1951	200.441		
	Total	1878907.565	1957			
7	Regression	1497053.633	7	213864.805	1092.136	.000[h]
	Residual	381853.932	1950	195.823		
	Total	1878907.565	1957			
8	Regression	1504010.927	8	188001.366	977.375	.000[i]
	Residual	374896.638	1949	192.353		
	Total	1878907.565	1957			
9	Regression	1510558.223	9	167839.803	887.614	.000[j]
	Residual	368349.342	1948	189.091		
	Total	1878907.565	1957			
10	Regression	1514209.775	10	151420.978	808.386	.000[k]
	Residual	364697.789	1947	187.313		
	Total	1878907.565	1957			
11	Regression	1516788.010	11	137889.819	741.008	.000[l]
	Residual	362119.555	1946	186.084		
	Total	1878907.565	1957			
12	Regression	1520161.468	12	126680.122	686.817	.000[m]
	Residual	358746.097	1945	184.445		
	Total	1878907.565	1957			
13	Regression	1522094.290	13	117084.176	637.901	.000[n]
	Residual	356813.275	1944	183.546		
	Total	1878907.565	1957			
14	Regression	1523704.158	14	108836.011	595.344	.000[o]
	Residual	355203.407	1943	182.812		
	Total	1878907.565	1957			
15	Regression	1525293.290	15	101686.219	558.446	.000[p]
	Residual	353614.275	1942	182.088		
	Total	1878907.565	1957			
16	Regression	1526553.611	16	95409.601	525.580	.000[q]
	Residual	352353.954	1941	181.532		
	Total	1878907.565	1957			

17	Regression	1528539.272	17	89914.075	497.857	.000[r]
	Residual	350368.292	1940	180.602		
	Total	1878907.565	1957			
18	Regression	1529605.755	18	84978.097	471.720	.000[s]
	Residual	349301.810	1939	180.145		
	Total	1878907.565	1957			
19	Regression	1530555.793	19	80555.568	448.158	.000[t]
	Residual	348351.771	1938	179.748		
	Total	1878907.565	1957			
20	Regression	1532894.095	20	76644.705	429.061	.000[u]
	Residual	346013.470	1937	178.634		
	Total	1878907.565	1957			
21	Regression	1533869.425	21	73041.401	409.833	.000[v]
	Residual	345038.140	1936	178.222		
	Total	1878907.565	1957			

a. Dependent Variable: Final score for project

b. Predictors: (Constant), 24.VIP_Pipe has fly screen

c. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap

d. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water

e. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet

f. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high

g. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall

h. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Easy to clean pedestal (inside)

i. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Easy to clean pedestal (inside), 23.VIP_Vent pipe extends above roof

j. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Easy to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls

k. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Easy to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet

l. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Easy to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid

m. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside

n. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof

o. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls
p. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe
q. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside)
r. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door
s. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y.Has securely attached roof
t. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y.Has securely attached roof, 28.VIP_Sloped grou1d around toilet
u. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y.Has securely attached roof, 28.VIP_Sloped grou1d around toilet, 26.VIP_Toilet has concrete slab
v. Predictors: (Constant), 24.VIP_Pipe has fly screen, 38.HS8_7 - Handwashing facility has soap, 37.HS8_6 - Ha1dwashing facility has water, 36.HS8_5 - Ha1dwashi1g facility within 1m of toilet, 1.Has four walls at least 1.9m high, 19.VIP_Vent pipe fixed to the wall, 30.VIP_Eas y to clean pedestal (inside), 23.VIP_Vent pipe extends above roof, 8.Has vertical and straight walls, 40.HS8_9 - Leakage around toilet, 32.VIP_Pedestal has seat and lid, 34.HS8_2 - Toilet is clean inside, 11.Has a roof, 7.Has durable walls, 17.VIP_Has vent pipe, 4. Door latch (inside), 5. Has damaged door, 1 y.Has securely attached roof, 28.VIP_Sloped grou1d around toilet, 26.VIP_Toilet has concrete slab, 27.VIP_Concrete slab damaged