Ministry of Foreign Affairs

Opportunities for AI, Blockchain and Bigdata to contribute to more resilient, liveable, and sustainable urban environments in South Africa

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Final Report

ABBEL

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Final Report

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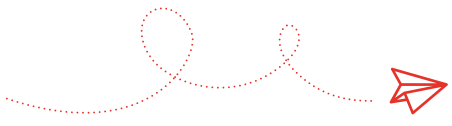


Executive Summary

"This [fourth industrial] revolution must be harnessed and placed at the disposal of the programme of transformation on which our country embarked in 1994." - President Ramaphosa, 2019[1].

Nowhere are the hopes and dreams of ordinary South Africans more starkly displayed than in South Africa's growing metropolises. Since 1994, millions have migrated to a small number of cities, and many have found success. Yet a quarter of a century into democracy our cities face many challenges. Some are old challenges that are due to the legacy of apartheid, and especially its spatial design which have not yet been overcome. Some are new challenges caused by global changes from which South Africa is not immune and unintended consequences of the success of large cities in attracting migrants from rural parts of South Africa and from the rest of Africa. Foremost amongst these is climate change which requires an urgent transition to a more sustainable path. This will require changes to many aspects of our urban environment, including the energy regime, mobility and transport, human settlement, and industrial production.

In this report we consider eight aspects of the urban environment in South Africa and what can be done to make cities smarter and more resilient by employing new digital technology, specifically, artificial intelligence (AI), blockchain and bigdata. In this regard the report considers the potential for leveraging a partnership with the Netherlands, a country which is at the forefront of development in these technologies. The eight aspects of the urban environment that are considered are: transportation and mobility, water management, waste management, energy, health, safety & security, communication, inclusivity, community involvement and citizen engagement, and urban governance and city planning.

An example of challenges around transport and mobility that can be addressed by these new digital technologies is the application of AI for detection and combatting of metal theft which is a major problem affecting city infrastructure. In terms of water management bigdata and AI can assist in better mapping of forecasted demand and supply of water thereby allowing optimisation of the water infrastructure system. Bigdata can be applied for situational awareness on containers and dumpster trucks and can enable better enforcement of bylaws and regulations.

The transition to a less carbon intensive energy regime will be associated with a more distributed electricity system where business and households become prosumers, using and producing electricity. Blockchain can be used for peer-to-peer trading of renewable electricity in this context. AI, and bigdata, has several applications for health and wellbeing including assessing health risks and predicting disease outbreaks and spread.

The responsible use of AI and bigdata can support crime prevention through detection of anomalous behaviour and situational awareness. As the urban spaces become more digital, new threats arise in the form of cyberattacks. AI can assist in early detection of abnormal network traffic and blockchain can be used to make critical systems more resilient in an environment of low trust.

In terms of more inclusive cities and higher citizen engagement bigdata can be used to understand community needs and blockchain can be used to implement tokenized incentives for positive civic action. In terms of urban governance and city planning the technologies come to fore through bigdata

[1] https://www.thepresidency.gov.za/speeches/address-president-cyril-ramaphosa-1st-south-african-digital-economy-summit%2C-gallagher

providing insight in resource usage, AI enabling simulations, forecasting future scenarios of proposed urban developments and blockchain for tracking public spending in a in a collaborative and transparent manner.

For each of the eight aspects examined in this study, relevant context is provided before challenges and trends are highlighted. This is followed by a table of the possible AI/Blockchain/Bigdata solutions. Although the emphasis in this report is on the potential that Dutch capabilities offer to contribute to smart and resilient urban environments in South Africa, it is also important to understand what the South African digital ecosystem looks like to clarify the potential for collaboration with local players and the context within which the application of Dutch technology would happen. For this reason, the report describes the South African digital ecosystem, with reference to AI, blockchain and bigdata.

Dutch AI/Blockchain/Bigdata landscape is described in terms of its strengths, solutions, and innovations. The Dutch strengths can be summarised as:

- Mature ecosystem, with world class universities, strong entrepreneurship with many start-ups/scale-ups, active involvement and commitment of the public sector collaborating with corporates & knowledge partners, active technology communities.
- Strong development of human capital.
- Use of technology for social challenges and adopting a Human centric technology approach.
- Excellent internet and data infrastructure (high speed connectivity, vast amount of storage capacity and (distributed) computation power (high performance computers).
- Good data protection policies and regulatory frameworks in place.
- Vast amounts of high quality data and data sharing across value chains.
- Frontrunner in international collaboration.

As part of the study two South African cities, Johannesburg, and Cape Town, have been examined as case studies in terms of their smart city strategies. These case studies are summarised in Appendices 1 and 2. The City of Johannesburg (CoJ) adopted a smart city strategy in 2014, updated in 2018, to achieve an inclusive and diverse city, which is sustainable, liveable, and resilient. With projects such as Joburg Connected, 4IR Citywide Skills Development, Smart Citizen, Safe Joburg, Co-Production Innovation Pipeline, Unified Data & Information Portal, Green, resilient and Sustainable Joburg, Digital Joburg & Smart Governance, Smart Integrated Nodal Economies, Services and Spaces, Smart Mobility, and Bigdata Analytics in the City. The City of Cape Town (CoCT) has a well-established digital economy and hosts many South African start-ups and venture capital companies. The CoCT's Digital City Strategy has four dimensions or pillars, namely: digital government, digital inclusion, digital economy and digital infrastructure that support the vision of Cape Town to be a prosperous city that creates an enabling environment for shared equitable economic growth and development, achieve effective and equitable service delivery and serve the citizens of Cape Town as a well governed and effectively run administration. The case studies provide practical insight on what is already taking place in South African cities and can point to further opportunities for the application of AI/Blockchain/Bigdata.

As part of the study several stakeholder interactions in South Africa have been undertaken which has informed the report and which are reported to provide further insight.

Finally, conclusions and recommendations are presented in the form of a mapping of challenges to opportunities and recommendations on the way forward.

Table of contents

1. Introduction

1.1 Purpose of the document

The purpose of the document is to provide a market scan to identify commercial opportunities for Dutch companies and knowledge institutes in the fields of AI, Blockchain and Bigdata to contribute to more resilient, liveable and sustainable urban environments in South Africa.

1.2 Objectives of the assignment

The objectives of the study have been to:

1. Map the commercial AI, Block Chain and Bigdata opportunities for Smart and Resilient Cities in South Africa
2. Determine the optimal next steps to realis these opportunities.

1.3 Scope of work

The scope of work for the study included:

1. Analysis of the **South African urban landscape** for X thematic areas and identifying promising organisations / context & conditions towards long term collaboration. The analysis was performed through a combination of desktop research and selected interviews with local experts and stakeholders.

   The thematic areas examined in the report include:

   a. Transportation and Mobility
   b. Water Management
   c. Waste Management
   d. Energy
   e. Health
   f. Safety & Security
   g. Communication, Inclusivity and Community involvement
   h. Urban Governance and City Planning

2. Analysis of the **Netherlands' capability in AI, Blockchain and Bigdata** to provide an inventory of available suitable technology and to identify the most promising players willing to invest in long term relationship with SA organisations. Through a combination of desktop research and interviews general strengths/opportunities in the 6three technology areas in the Netherlands have been identified and suitable technology providers/ research organisations and government funded organisations identified
3. **Mapping** of South African needs and Dutch capabilities
4. Recommended **next step**

2. Key Thematic Areas

3. South African Urban Landscape: An overview of the Market and Opportunities

3.1 Introduction – South Africa's changing Urban Landscape

South Africa has a growing and increasingly urban population. By 1990 more people were living in urban areas than in rural areas (see Figure 1) and it is projected that by 2050, 80% of the population of 72 million South Africans will be living in urban areas as depicted Figure 2. Most of the population growth is taking place in five metropolitan municipalities namely: Johannesburg, Cape Town, eThekwini, Ekurhuleni and Tshwane (See Figure 3). Three of these, Johannesburg, Ekurhuleni and Tshwane are located in South Africa's smallest province by size, Gauteng, but which has the largest population of South Africa's nine provinces. This area is projected to grow into a city region of over 20 million people by 2030.

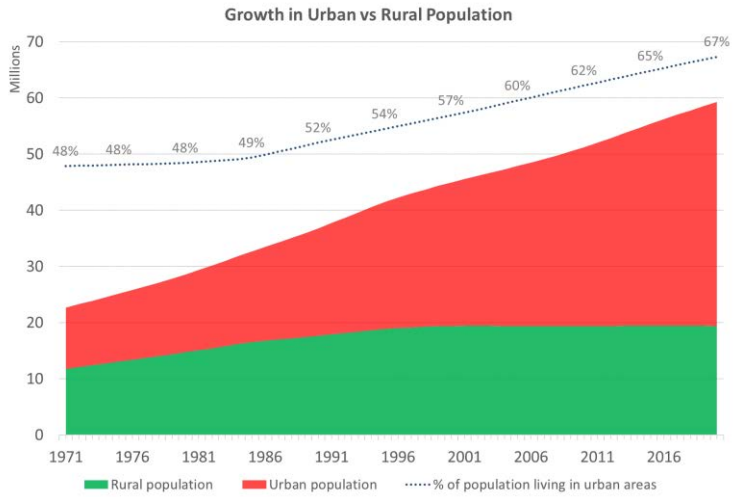


Figure 1 Growth in rural and urban population and urbanised population percentage in South Africa

The growth in South Africa's urban population has far-reaching social, economic, and environmental implications, both positive and negative. On the positive side large cities enable economic activity and make provision of infrastructure and services in urban areas is more cost-effective than in sparsely populated rural areas. Cities have therefor become the dominant centres of economic activity and employment and attract most domestic and foreign investment. On the negative side the provision of urban infrastructure has not kept pace with growing urban population. In addition, the low-density and fragmented spatial form of South African cities has negative social, economic and environmental consequences.

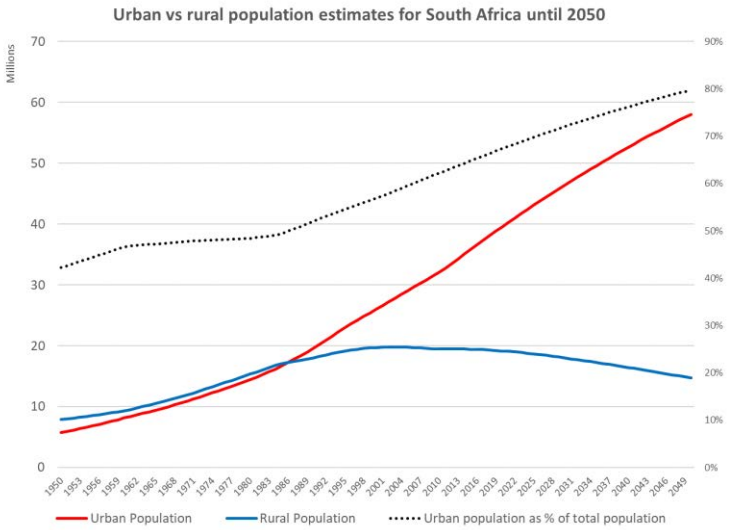


Figure 2 Urban vs rural population estimates for South Africa until 2050[2]

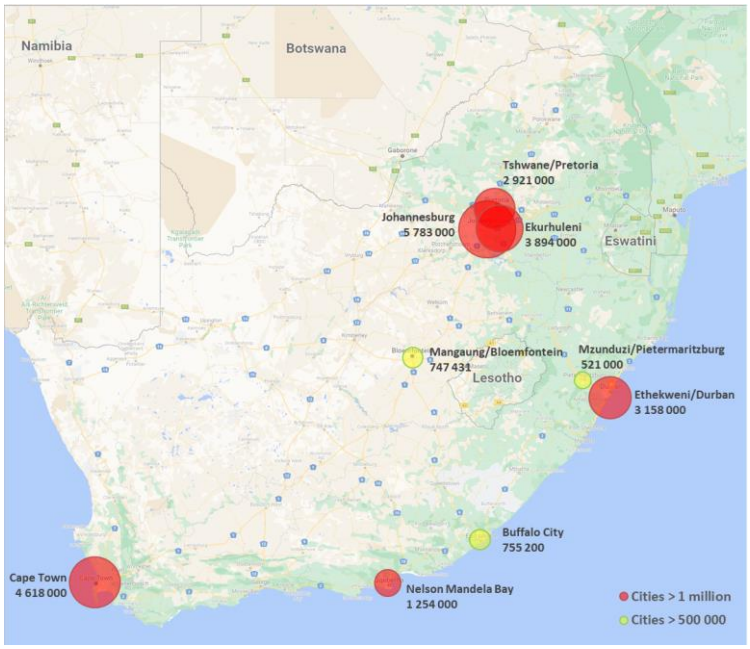


Figure 3 South African cities with a population greater than 500 000

Several historical factors and current trends impact on the challenges and opportunities for creating more resilient and smarter urban environments in South Africa. These include:

- Apartheid's spatial legacy
- Climate change
- Uncontrolled urbanisation
- Migration within and to South Africa
- Slow economic growth since 2007

[2] Source: own graph based on data from United Nations' World Urbanization Prospects 2018, https://population.un.org/wup/

- Infrastructure challenges esp. related to the electricity system which has been plagued by planned outages, known as load shedding, aimed at protecting the national grid from crashing due to demand outstripping supply
- Unemployment, poverty and inequality
- Growth in informal settlement especially around the periphery of large urban centres
- Aging infrastructure that has not kept pace with urban growth
- Carbon intensive economy

As indicated by the figure sin Table 1 South African cities control substantial budgets which are collected through a combination of taxes, fees for services rendered and an allocation from central government.

Table 1 The budgets of South Africa's major cities in 2020/21

City	Budget in 2020/21
Johannesburg	R65 billion
Ekurhuleni	R64.5 billion
Tshwane	R43 billion
Ethekweni	R52.3 billion
Cape Town	R56.5 billion
Nelson Mandela Bay	R15 billion

In the following sections, the South African landscape is analysed in more detail in terms of eight issues related pertinent to smarter and more resilient urban environments in South Africa.

3.2 Transportation and Mobility

3.2.1 Context

The shape of urban space - and its influence on mobility - plays a decisive role in the productivity of urban economies and the long-term financial soundness of city administrations. It also has a significant impact on the well-being of city dwellers, human interaction patterns, social inclusion, and efficient use of resources in a city, particularly transportation and service distribution. Nine urban transport modes characterise South African cities: walking, cycling, bus rapid transit (BRT) system, municipal busses, metro rail, Gautrain, Gautrain Bus, minibus taxi; and car (privately owned, metered taxis and ridesharing systems).

The spatial legacy of Apartheid and limited progress in spatially transforming cities since 1994 cause South African cities to be energy inefficient and costly with widespread reliance on private vehicles. Transport is typically responsible for at least half of South Africa's total energy consumption in urban areas and for around a third of greenhouse gas emissions in urban areas. Historically, transport planning in South Africa has largely focused on private vehicles, following the North American urban development model of the last century, and focusing on the creation of western street layouts, this despite the fact that the majority of South Africans depend on public transportation with only 26% of South Africans owning a car.

Inadequate coordination between local government space planners and transportation departments is widespread and persists in many urban centres. In addition, mandates related to transportation are spread across different areas of government, making integrated transportation planning difficult and ineffective. For example, the urban rail system is the responsibility of the national government, while

most bus services are controlled by local government. Furthermore, different areas of government are responsible for different categories of roads (national provincial and local), even within the limits of a city.

Figure 4 New PRASA train Cape Town

Access to quality and affordable public transportation can help address the socio-economic challenges that South Africa faces. Investments in public transport offer excellent opportunities to improve transport efficiency, improve energy efficiency, reduce traffic congestion, and lessen the carbon footprint of the transport and mobility sector, especially if supported by densification of transport corridors that enable the financial viability of public transport.

The National Treasury's urban network strategy aims to create efficient and high-performance urban centres through investments in specific infrastructure that will promote change in the patterns of urban space and improve the quality of life of citizens. Instruments and incentives for improved transport, land use, and settlement offer the opportunity for dense and mixed land use, as well as pedestrian and bicycle friendly neighbourhoods. In this context, public transport becomes a catalyst for spatial transformation and social integration.

Figure 5 Gautrain at OR International Airport station

One of the most visible recent investments in new mobility infrastructure in South Africa is the Gautrain highspeed rail system which connects the three largest metros in the Gautrain province. The state of

the art urban train system connects the OR International airport with the Sandton business district, the Johannesburg and Pretoria stations and the Hatfield station near the university of Pretoria. A recent impact study by found that the project contributed R5 billion to Gauteng's GDP during construction and R12.44 billion during operations between 2010 and 2019. Other impacts determined by the study include:

- 175,000 direct construction jobs and 68,000 new direct operations jobs over twenty years
- 70% of trips cross a city boundary
- Spurred increase of more than 1.6 million square meters of commercial floor space
- 45% increase in median sales value per square meter of office space around stations
- 32% increase in median sales values per square meter of retail space around stations
- 52% increase in median sales values per square meter of residential space around stations

3.2.2 Challenges

- **Low city density**: Apartheid era spatial planning has led to low density cities that favour road-based transport using private cars and minibus taxis. Some post democracy pro-poor policies have reinforced this trend by subsidising the cost of living on the periphery[3].
- **High cost of transport**: the sprawling nature of South African cities leads to high transportation costs especially for poor people living on the peripheries of cities.
- **Energy inefficiency and carbon intensiveness**: Low density and the orientation towards road transport means that the South African transport system is highly inefficient and carbon intensive.
- **Long travel times**: one study found that the average car trip in Tshwane is twice as long and the average trip by public transport and takes three times longer than in cities like Moscow, London, Tokyo and Singapore.
- **Vandalism & security issues**: transport infrastructure, especially rail infrastructure is subject to vandalism and metal theft (power and signalling cables, and rail tracks). The mini-bus taxi industry is plagued by power struggles and low adherence to traffic regulations.
- **Poor maintenance and aging infrastructure**: poor maintenance and outdated signalling systems have reportedly brought some rail networks close to collapse (Turok, 2012).
- **Lack of planning and coordination**: the slow shift from private to public transport are caused by the lack of institutional coordination within the local government and the lack of coordination between local, provincial, and national governments.

[3] For example, through operating subsidies to support commuter bus services operated by private companies

3.2.3 Trends in Urban Transportation and Mobility

Some of the interventions and investments underway in transport infrastructure in South Africa include:

- **Bus Rapid Transit (BRT)**: Although no South African city has a tram or underground metro system, several cities including Johannesburg, Cape Town and Tshwane are implementing rapid public transport networks in the form of BRT systems.
- **Improving rail passenger services**: The Passenger Rail Agency of South Africa (PRASA) is driving a turnaround strategy that includes new rolling stock and new signalling infrastructure. This investment is a critical component in improving public transport service provision at city level. In addition, in what has been dubbed 'Gautrain 2', the Gautrain expansion project will be expanded through an additional 149km of railway line and 19 new stations.
- **Non-motorised transport (NMT) infrastructure**: Several South African cities are trying to address the NMT deficit by increasing investments in cycling and pedestrian infrastructure (often linked to BRT investments), however, the current scale of such infrastructure is still limited.
- **Road infrastructure improvement programmes**: Major investments are being undertaken to improve road infrastructure, through the Presidential Infrastructure Coordination Committee (PICC) and other programmes, such as the Gauteng Highway Improvement Programme.
- **Spatial transformation**: Corridor densification, infill low-income developments, and mixed-use zoning is being implemented to reduce travel needs and to increase the viability of public transport.
- **Promotion of integrated public transport**: The 2016 Integrated Urban Development Framework (IUDF) is a step towards a rational and coordinated approach to spatial and mobility issues in South African cities.

3.2.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in urban transportation and mobility are summarised below:

Bigdata	• Leveraging bigdata sources such as mobile phones, online tools and platforms, including social media and online payment services, as a source for transportation and mobility data to supplement conventional databases. • Sensors and road/traffic cameras provide situational awareness. An Automatic Vehicle Location system can improve operational efficiency of public transport, manage operational control, and enhance overall quality of public transport services. It extracts data to track transportation units in real time by using GPS signals, detects problems to inform vehicles on any changes and manage alternative routes.
AI	• Smart mobility uses information of road users (detection, recognition, motion, prediction), environment information (signs), path planning. • Predicting passenger volumes in public transport. • Reduced and smoother traffic, by Demand Responsive Transport (DRT) allowing flexibility in routes, scheduling, and vehicles. It is applicable in contexts where

	regular fixed route and infrastructure services would not be financially viable. DRT has the potential to alleviate the reliance on personal vehicle transportation, common in rural and regional areas, providing a wide array of localised benefits to congestion, liveability, loneliness, and isolation (EIT Urban Mobility, 2021). • Automatic incident detection, image processing for traffic data collection and for identifying cracks in pavements or bridge structures and transportation equipment diagnosis. • Traffic demand modelling or modelling transportation infrastructure health as a function of traffic, construction, and weathering. • Smart signal control of traffic at road intersections, ramp metering on freeways, dynamic route guidance, positive train control on railroads. • Autonomous vehicles (AVs) for public passenger transport. • A digital twin is a virtual representation of a factory, product, or service. Producing an evolving profile of an asset or process in a plant, digital twins paired with AI captures insights on performance across the lifecycle • Decision making: o Deciding whether to build a new road, how much money should be allocated to maintenance and rehabilitation activities and which road segments or bridges to maintain, and whether to divert traffic to an alternative route in an incident situation. o AI can be used to create virtual models of transportation infrastructure and simulate traffic conditions to gain insights into how the new system will affect traffic conditions across the city, allowing to design public transport systems that minimise traffic congestions and make travelling more convenient.
Blockchain	• Better asset / fleet management, using maintenance records and part information. • Mobility as a Service (MAAS) the integration of various forms of transport into a single mobility service accessible on demand. The blockchain can be utilized as a single platform capable of withholding records and facilitating transactions. • Decentralized, non-traditional public transportation services, e.g. e-bike/e-scooter sharing programs. The blockchain could facilitate the rewarding riders with tokens, tickets, and other rewards for using public transportation • Universal transit payment for transport using crypto currencies. • Blockchain technology can facilitate rewards-based systems in which people receive money or other blockchain-secured items as a reward for using public transport.

3.3 Water Management

3.3.1 Context

South Africa's annual rainfall is only 492 millimetres which is about half the earth's average. South Africa is therefore classified as a water-stressed country. In the 20th century the country built a substantial water infrastructure including dams, canals and pipelines and South Africa has one of the cleanest water systems in the world. However, as cities in South Africa grow, there is an ever-increasing demand for clean, potable, and affordable water from residents and industries alike. Rapid increases in urbanisation and informal settlements within South African cities has led to high levels of pollution and bacteria which is caused by human waste in water resources. This is further compounded by industrial pollution from mines and heavy industry through which chemically contaminated wastewater enter the country's water system.

The national government, through the Department of Water and Sanitation (DWS), is responsible for water resources planning, development and management, with the role for Municipalities being that of "Water Service Authority" (WSA). DWS is responsible for the bulk water resources infrastructural systems that provide water to the WSAs, while the WSAs provide access to water services as prescribed in the National Water Act. Some municipalities have Water Service Providers (WSP) that provide water services in accordance with the Constitution, the Water Services Act, By-laws, and any specific conditions set by the respective WSA.

3.3.2 Challenges

- Ensuring **water availability, water quality and fitness for use** (issues like acid mine drainage have become increasingly prominent) in the context of increasing demand.
- Development and maintenance of **water infrastructure** to ensure its usability for people and the economy and maintaining the ecological services that water provides us (flood mitigation, water purification).
- **Providing, maintaining, and collecting revenue for water supply and sanitation** that balances the needs for infrastructure to new residents, maintaining existing infrastructure and collecting revenue to fund these services where many residents cannot afford to pay.
- Limited **skills and human capacity** in the water sector especially at local level.
- **Managing water usage** in South Africa within the available (scarce) supply.
- **Inadequately collected and/or treated wastewater** which can adversely affect the quality of water resources with effects on human health and reduced fitness for use of that water for cities and downstream communities.

3.3.3 Trends in Urban Water Management

Some of the interventions and investments underway in water management in South Africa include:

- The **National Water Resources Strategy** (NWRS) of 2013 provides a framework for the attainment of the social and economic goals of the country.

- The Department of Water and Sanitation (DWS) has divided the country into **Water Management Areas** (WMA) to reflect the variation in water availability and water requirements, the large spatial variations in climate, the level and nature of economic development and population characteristics.
- Eradication of alien invasive plants through the **Working for Water** programme which simultaneously creates employment for the most marginalised sectors of society.
- Public awareness through initiatives such as Rand Water's **Water Wise programme**[4].

3.3.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in urban water management are summarised in the table below

Bigdata	• Through gathering all sorts of water related data (quality, quantity, flow, usage, insight) over time and geographical areas allows increased insight in the demand/supply of water. • Smart water metering (across the entire water grid level) allowing for enhanced water infrastructure planning, maintenance and monitoring and can help avoid wastage by indicating leakages in the system. • Smart meter readings at end users level allows for new ways of real time billing and payment.
AI	• Mapping forecasted demand and supply considering water reserves, (non)-technical losses, treatment, distribution, and sanitation. • To tackle the issue of water pollution and for improving water quality, an IOT system with automatic smart sensors to detect water pollutants in water resources measuring the level of pollution while simultaneously informing concerned authorities to take corrective measures for the same. • Sensors can also identify water leaks from pipe bursts that can reduce significant water wastage. • Predictive asset management programs. AI helps to define optimal schedules for monitoring and replacing assets based on the useful life, criticality, and other variables, allowing active maintenance and replacement to support optimal service levels and minimize costs (ADB, 2020). • Energy savings. AI can guide energy savings in network by defining the most efficient operating procedures complying with minimum service levels given a predetermined configuration (ibid). • Early warning for flash floods disasters based on actual weather and forecast, 3D terrain landscape and soil type/conditions. • Water grid expansion design with optimal configuration. AI optimization tools give insight on the most efficient configurations based on cost minimization and takes into consideration the uncertainty of some design parameters, such as population forecast and spatial urban growth to support a more robust approach to decision making (ibid).

[4] http://www.waterwise.co.za/site/home.html

Blockchain	• Blockchain technology can be used to develop a decentralized and transparent system to ensure equal distribution of water over widespread geographic areas. Blockchain can be used to create a water trading system between consumer to consumer wherein a consumer having a license to collect water from natural water resources shares the excess water with other consumers at a controlled price (Blockchain Simplified, 2020). • Blockchain could be utilized for reporting, compliance, and audit review. Recording activities, as well as their yields changelessly in a blockchain, would make a review trail for controllers and streamline consistency (Sriyono, 2020). • Payment for water using crypto currencies.

3.4 Waste Management

3.4.1 Context

As South Africa's urban population grows and becomes more affluent the amount of waste generated by households increases. Poorly managed waste can have a major impact on human health the environment, and the economy and mismanagement of waste result in negative externalities and downstream costs, which are compounded if waste had not been properly managed in the first place.

Integrated Waste Management means employing several waste control and disposal methods i.e. reduce, re-use, recycle, incineration, and landfilling, to minimise the environmental impact of commercial and industrial waste streams.

As the volume of solid waste increases lower impact processes for disposal are required with greater focus on recycling, separation, and re-use of waste. The shift on reducing waste to landfill is forcing cities to look at suitable alternatives and reconfigure their planning for the future.

3.4.2 Challenges

In terms of Gross National Income (GNI) per capita, South Africa is classified as an "upper middle income" country. Being an "upper middle income" country, South Africa faces several challenges in terms of waste management:

- **Weak enforcement**: as with many African countries, South Africa has put laws in place to manage waste. However, lack of enforcement, as well as competing interests, undermines the effectiveness of the legislation to regulate waste management.
- **Weak governance**: in South Africa, local government has the primary responsibility of providing waste collection services. However, in municipalities there is limited capacity to fulfil this function.
- **Low public awareness and negative attributes**: South Africans in general have low awareness and a negative attitude towards waste management. This is a complex issue with many factors, such as local beliefs, perceptions of where the responsibility lies for waste management, general awareness and level of education.

- **Insufficient budgetary provision**: in some cases, municipalities' budget provision for wate management exceeds their budgeted revenues. Due to the under-recovery of costs, these municipalities have to subsidise the service from other revenue sources.
- **Service backlog**: an additional challenge that many municipalities face is the backlog in waste collection services. While significant progress has been made in addressing this backlog, there is still a lack of waste collection services in the peri-urban and rural areas.

3.4.3 Trends in Urban Waste Management

Some of the interventions and investments underway in urban waste management in South Africa include:

- South Africa lags on the **transition towards a circular economy**. 90.1% of all general and hazardous waste generated in the country is still disposed of in landfills. There is no legislative framework for reasonable waste recovery initiatives or the implementation and enforcement thereof (DST, 2014).
- A large and growing **informal waste sector** is estimated to collect 80% of glass, 90% of PET plastic and most recovered paper into the recycling economy.
- **Heavy reliance on landfilling** as a technology option in both the private and public waste sectors with low levels of composting and anaerobic digestion for organic waste.
- **Development and adoption of newer waste management processes** including new patents on waste management technology in areas such as high- and low-temperature waste to energy technologies and recycling.

3.4.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges urban waste management are summarised in the table below

Bigdata	• Provide public waste collection service with real-time information on containers and dumpster trucks so that they can always know whether they are full or empty. • When waste is collected by an evidence-based system, waste collectors are incentivized to collect waste as their activity can be tracked and traced. Citizens are currently complaining that waste has not been collected, which will be solved after further introduction of a smart waste management system.
AI	• Optimal routes for waste collection can be determined based on forecasting and actual container readings / and analysing video footage from cameras (on dumpster trucks as well as public market waste areas). • Video analysis to identify and eliminate (potential) safety hazards • Autonomous robots function as waste sorters to sort and match rubbish based on specified criteria.
Blockchain	• Crypto currency payments, recycling, and reuse rewards. Blockchain technology can facilitate rewards-based systems in which people receive money or other blockchain-secured items as a reward for bringing in waste items, which may then be reused or recycled. For example, rewards can be given for bringing

	plastic waste to recycling centres with a bespoke type of token as a financial incentive for recycling and companies then buy the recovered plastic from the "Plastic Bank" and recycle it to produce new consumables. This initiative creates a financial recycling reward mechanism accessible to those excluded from conventional banking systems (Steenmans et al., 2021). • Monitoring and tracking of waste, capturing data on waste collection and waste transactions to enable the provenance of resources and wastes to be made available. Blockchain technology can help trace responsibility, which may be used to support enforcement and compliance with regulations and standards. In addition, blockchain can be used to capture citizens' grievance about (non-)collection of waste to hold relevant entities accountable for collector neglect. Blockchain technology can help trace responsibility, which may be used to support enforcement and compliance with regulations and standards. For example, if resources are tagged in some way (using, for example, a barcode or QR code) and linked to a blockchain listing the producer and subsequent owners, then, if they are illegally dumped in the natural environment, the data on the blockchain can be used to identify who was responsible (ibid). • Payment for waste collection using crypto currencies.

3.5 Energy

3.5.1 Context

South Africa has a broad range of energy resources which is dominated by fossil fuels including domestically mined coal and liquefied fuels and gas derived from coal and oil and gas based fuels. Most electricity is generated through burning coal (81%), although the proportion of renewable electricity (9% solar, wind and hydro) has been increasing in recent years with the country having excellent solar and wind power potential.

Since 2007 the national electricity supplier, Eskom, has been unable to generate sufficient electricity to cater for residential and industrial demand which increased by 43% between 1994 and 2007. This resulted in a programme of controlled blackouts referred to as *load shedding*, to manage demand. Most businesses and many domestic consumers have installed diesel, petrol or battery powered back-up systems in the last decade but city infrastructure such as traffic lights remain vulnerable to blackouts caused by loadshedding.

Additional problem leading to electricity cuts in urban areas include cable theft and outages caused by inclement weather in areas with overhead cables where trees are not maintained causing shorts as well as aging and poorly maintained distribution infrastructure.

South African municipalities are obliged by legislation and national policies to implement Energy Efficiency (EE) and Renewable Energy (RE) initiatives. As a result, municipalities have initiated a variety of EE and RE projects with varying degrees of success. The National Energy Act defines EE as *"economical and efficient production and utilisation of an energy carrier or resource"*. The White Paper on Renewable Energy defines RE as *"electricity, gaseous and liquid fuels, heat or a combination of these deriving from naturally–occurring, cyclical and non-depleting sources of energy such as solar, wind, biomass hydro, tidal, wave, ocean current and geothermal energy."*

3.5.2 Challenges

- **Increasing electricity generation capacity** to ensure supply matches growing domestic and industrial demand.
- **Transitioning to a greener electricity system** through increased generation from wind and solar. This will involve a move to a more distributed generation system and may require utility scale storage in the grid.
- **Maintenance of the electricity distribution infrastructure** including aging infrastructure and skills loss in the sector.
- Combatting **cable theft** leading to localised outages.
- Addressing **non-payment** by final consumers and some local authorities.
- Managing **energy cost** while addressing historic under-pricing.
- **Collecting revenue** from electricity sales.

3.5.3 Trends in Urban Energy

Some of the interventions and investments underway in urban energy in South Africa include:

- **Diversification of energy sources** with a far greater portion of renewables and distributed generation
- **Storage solutions** to improve reliability of renewably generated electricity. In this regard South Africa is investing in battery and hydrogen technology as well as new pumped storage infrastructure.
- A move to **prepaid electricity** provision and metering to address non-payment.
- Gradual **replacement of overhead copper cables with aluminium** which are less prone to cable theft.
- Load reduction through greater **industrial energy efficiency** through initiatives such as the National Cleaner production Centre[5].
- To provide decentralised energy solutions, off-grid solutions for electrification such as **microgrids** have been identified as essential.

3.5.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in urban energy are summarised in the table below

Bigdata	• Outage detection and prediction using the influence of weather conditions on the power grid; the impact of the near-term asset values on the power grid; detecting possible outages by smart meter events; detecting outages in the specified areas; real-time filtering of outage inputs and recognition of the outage type. • Improving operational efficiency. Energy and utility companies use smart data application and software to detect the matters, operations and functions worth of

[5] https://www.csir.co.za/national-cleaner-production-centre-south-africa

	optimization. Real-time monitoring provides data concerning time, activity rate, state of some operations. The data is processed in combination with the external factors to define the average efficiency[6]. • Smart meter readings at end users level allows for new ways of real time billing and payment. • Energy theft detection using shift to Advanced Metering Infrastructures, which are capable of reporting on the energy use instances and remote controlling.
AI	• Energy efficient buildings: AI technologies assist to forecast energy demand and reduce a building's energy consumption by taking weather forecasts, building occupancy, and other environmental conditions into account. • Predictive maintenance plays a crucial role in the energy industry as the resources have to be managed carefully and efficiently. AI helps to identify defects like corrosion, cracks, inadequate insulation and helps prevent failures[7]. • With the increase in decentralization and digitalization of the power grid, managing many grid participants and balancing the grid is challenging, especially with an upsurge in the number of volatile power generation plants like solar and wind, it has become essential for power generation industries to respond intelligently to energy consumption. AI helps stabilize the power grid by detecting irregular consumption, generation, and transmission in real-time and developing appropriate solutions[6]. • Failure probability modelling: Forecasting and preventive maintenance allows energy suppliers to dispatch their resources better, prepare for demand in advance, predict issues, and save resources whenever it is possible. Proper resource management helps in an increase in efficiency and also lowers cost expenses[6]. • The supply chain in a particular energy sector is complex and tough decisions like purchase, purchase price, refining operations, gantry operations, and transportation have to be made continuously. AI helps helps predict the optimal demand blending, evaluate the prices, in proper planning and scheduling, enabling optimization of the energy price, creating an intelligent warehouse, maintenance of inventories, handling shipping operations for replacing assets, risk hedging, and improvising the delivery times & thus reducing the overall expenses[6].
Blockchain	• Decentralised / Microgrid / peer-to-peer trading of (renewable) electricity. Blockchain technology can facilitate trading interaction as it functions as a shared information and transaction platform for all market participants. For example, local electricity generation and local real-time demand can be recorded on a blockchain by automatically documenting executed transactions between the participants using internet-enabled smart meters. The technology's ability to make even small data transactions economically viable ultimately entails new degrees of participation and incentives (IRENA, 2020; Smart Africa, 2020). • Payment for energy using crypto currencies.

[6] https://activewizards.com/blog/top-10-data-science-use-cases-in-energy-and-utilities/]

[7] https://www.xcubelabs.com/blog/applications-of-ai-in-the-energy-sector/

3.6 Health

3.6.1 Context

South Africa has an estimated population of about 55 million, the majority of whom access health services through government-run public clinics and hospitals. South Africa's life expectancy dropped significantly in the mid-2000 due to the impact of the HIV/AIDS epidemic. The mass roll-out of antiretrovirals has turned this trend around and by 2017 life expectancy was above 1990 levels and is projected to continue to rise reaching 80 years for women by 2050 (see Figure 6).

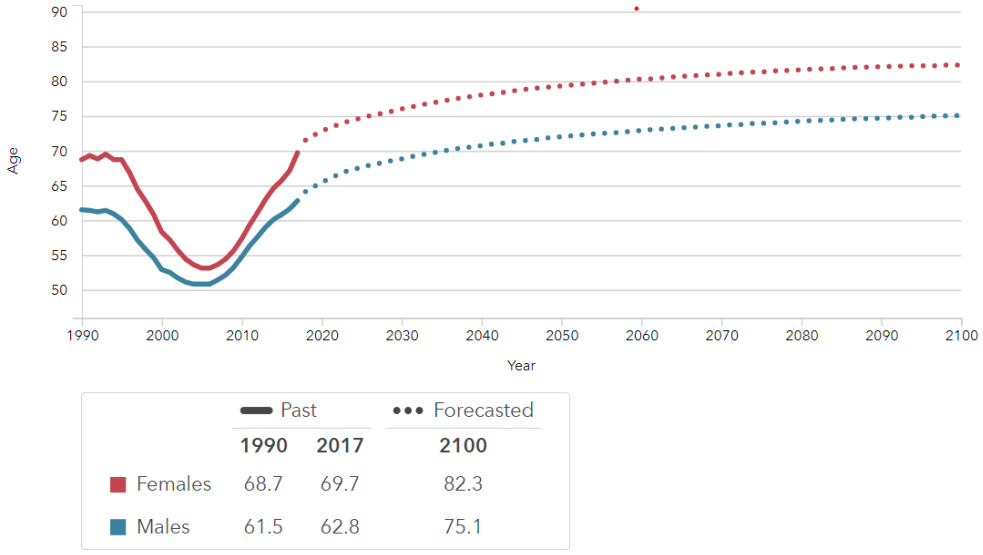


Figure 6 Life expectancy from 1990 to 2017 with projection to 2100[8]

Although HIV/AIDS remain the most important single cause of death, as illustrated in Figure 7, the rate of HIV/AIDS death dropped by 61.8% between 2007 and 2017. Figure 7 also illustrates the changing nature of disease with communicable, maternal, neonatal, and nutritional diseases dropping in terms of the number of deaths caused and in the burden of disease rankings whilst non-communicable disease dropped in number of deaths caused but are rising in burden of disease rank.Figure 1

[8] Reproduced from https://www.healthdata.org/south-africa

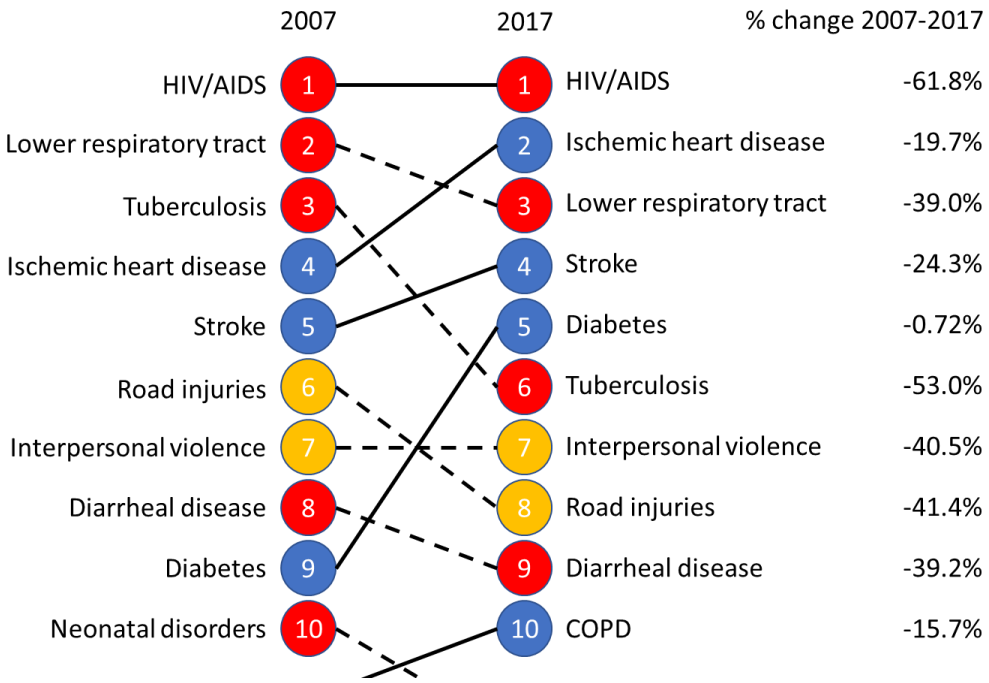


Figure 7 Change in the burden of disease in South Africa between 2007 and 2017[9]

The South African health system comprises the public sector (run by the government) and the private sector. The public health service is divided into primary, secondary and tertiary levels through healthcare facilities that are located in and managed by the provincial departments of health. The provincial departments are thus the direct employers of the health workforce while the National Ministry of Health is responsible for policy development and coordination.

South Africa's Constitution guarantees every citizen access to health services (section 27 of the Bill of Rights). Residents can access public and private health services, with access to private health services depending on an individual's ability to pay. The private health sector provides health services through individual practitioners who run private surgeries or through private hospitals, which tend to be located in urban areas.

3.6.2 Challenges

- In terms of **governance**, the healthcare system is hampered by corruption, lack of good governance and accountability, managerial and administrative deficiencies, and lack of effective coordination between national, provincial and district healthcare levels.
- **Inadequate healthcare workforce** to fill vacancies within the public healthcare sector. Excessive workload and other challenges in the public health system cause further attrition thereby exacerbating this problem.
- **Shortages of medical supplies** and **inadequate medical equipment**.
- **Geographical disparity** in healthcare delivery across provinces.

[9] Own graph based on data from https://gbd2017.healthdata.org/gbd-compare/

- Major **differences in access and quality of health care in the public and private health system** components
- **Lack of monitoring and evaluation** at the various healthcare system levels which causes a lack of timely and quality information dissemination across the entire spectrum of healthcare.

3.6.3 Trends in Urban Health

Some of the interventions and investments underway in health provision in South Africa include:

- Introduction of the **National Health Insurance (NHI),** a health financing system designed to pool funds to provide access to quality affordable health services for all South Africans irrespective of their socio-economic status. NHI is being implemented in phases over a 14-year period that started in 2012.
- **National Digital Health Strategy 2019-2024** aims to ensure that digital health interventions benefit patients (throughout the patient journey at either preventative, curative, palliative or a combination), healthcare workers and health systems managers. It seeks to use digital health technologies to augment the health system allowing more people to access quality health services whilst acknowledging that successful digital health implementation will require skilling and reskilling of the health workforce. The strategy anticipates AI, bigdata and predictive analytics supporting health system operation and evidence-based clinical decisions, and plans to develop a data science capability to guide technology adoption. The strategy's wider governance approach and objectives provide an important framework for guiding 12 the adoption of data-driven services, and more details are outlined in the text box below.
- **mHealth Strategy 2015-2019** recognises that mobile technologies, such as smart phones, provide new opportunities for collecting data 'where people live' and 'in real time' which can enable more effective and efficient health programmes. The strategy also notes that because personal data is now becoming more mobile, and not protected on relatively controlled central systems, that updated standards are critical.
- **The National Health Act, 2003 (Act 61 of 2003)** stipulates that the protection of patients' confidential medical information should be prioritised, including in the electronic transmission of personal medical information and data over networks. This protection of personal information is supported by the POPI Act and a variety of other pieces of digital and healthcare-related legislation which address the collection, usage, storage and processing of information.

Drone applications for health in a humanitarian context:
Zipline in Rwanda can deliver up to 500 deliveries of up to 1.8 kilogrammes of medical payload (such as blood for transfusion) in an 80 kilometre radius within 30 minutes or less. Health workers can order medical products by text message. These are then delivered by the drone by parachute airdrop138 139. Drones can also spot landmines by using thermal cameras to detect landmines after their internal explosives get heated up by the sun. This can help to make areas available for land use in post-conflict zones which cannot be cleared by traditional methods. The land can also be cleared of mines in a more efficient way140. Moreover, Africa already has the world's largest test corridor for drones in Malawi, with over 5,000 square kilometres. It is specifically dedicated to testing the humanitarian and development use of drones

Examples of artificial intelligence use cases in health care in Cameroon:
Since 2017, the Bonassama District Hospital in Douala has integrated SOPHiA (AI developed by Sophia Genetics, a multinational company) into the clinical workflow to advance patients' care.
By using this AI solution, the hospital now forms part of a larger network of 260 hospitals in 46 countries that share clinical insights using bigdata analytics across patient cases, feeding a knowledge base of biomedical findings to accelerate diagnostics and care. This allows the hospital to rapidly analyse genomic data and decide on the most effective care.
Another example of AI and machine learning for the healthcare sector comes from the Songhai Labs. The Yaoundé-based start-up is working on the DataREACH project in partnership with the World Health Organization (WHO) in Cameroon and a start-up from UCLA, California. Within this project, the HSPC polyclinic in Kumba, a private hospital in south west Cameroon, was provided with a digital application which helps it to compile data on patients for epidemiological surveillance via AI.

3.6.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in urban health provision are summarised in the table below

Bigdata	• Enabling remote patient monitoring and Telemedicine. • Improve population health management (hospital level, national level). For example, using health data for informed strategic planning, e.g. care managers can analyse check-up results among people in different demographic groups and identify what factors discourage people from taking up treatment[10]. • Electronic Health Records (EHRs). Every patient has his own digital record which includes demographics, medical history, allergies, laboratory test results, medical images, etc. • Improve supply chain management.
AI	• Medical imaging for diagnosis and patient triage, identifying early-stage disease, improving medical diagnosis. • Assess risks and predicting disease outbreaks, e.g. to track and model the spread of the COVID-19 virus as well as to forecast future COVID-19 outbreaks and hospitalisations.

[10] https://www.datapine.com/blog/big-data-examples-in-healthcare/#applications

Blockchain	• Managing electronic data via blockchain to support transparency and accountability. In particularly for identity verification; medical and pharmaceutical supply chain management; and managing dynamic patient consent and data sharing and access permissions (OECD, 2020). • Blockchain for identity management in health care. Accurate and verifiable identification of individuals (e.g. patients and providers) as well as organisations (e.g., hospitals, pharmacies, academia and other research institutions) is fundamental to good outcomes in the health sector. A blockchain can add integrity and transparency and combat differential versioning of identities, thus enabling secure identification (ibid). • Blockchain for management of patient consent and data access permissions. Blockchain can enable a transparent, auditable way for individuals, using their unique credentials and encryption key, to allow other parties to access their personal health data. A blockchain can create an immutable log of each time a data record is accessed or amended. Any amendment to a record can be crosschecked with separate electronic logs (ibid). • Blockchain for managing medical and pharmaceutical supply chains, e.g. to be used for Product identification (a unique product identifier may be validated more easily and quickly); Tracing (manufacturers, distributors or dispensers can use a distributed ledger that automatically verifies relevant information); Product verification (verifies the authenticity of a product and enables public and private actors to detect products suspected as counterfeit, unapproved, or dangerous); Notification and response (enable a secure system to notify regulatory authorities of non-compliant products or transactions); Other relevant product and transaction information (such as licensing) (Clauson et al., 2018).

3.7 Safety & Security

3.7.1 Context

The legacy of apartheid and continued high levels of inequality, poverty and unemployment contribute to South Africa's relatively high crime rate. According to the 2019/20 Victims of Crime Survey (VOCS) the most common crimes in South Africa were theft of personal property with 13.5% and 6% of households having experienced these crimes (STATS SA, 2020). The survey also indicated a high frequency of crimes where these was a threat of violence such as house robbery and street robbery experienced by 2.5% of households and 2.8% of individuals in 2019/20. This most recent survey also indicated a drop in housebreaking, home robbery, and deliberate damage to property. Nevertheless, the cost of violence in South Africa is amongst the highest in the world and it estimated that the cost of violence constitutes 19% of the country's GDP[11].

Before 1994, law enforcement and the justice system were focussed on preserving and entrenching the apartheid state. With the transition to democracy in 1994 a broader concept of safety and security was adopted that aligned to the new Constitution. Crime prevention in South Africa is based on the principles of community policing; that is, partnerships between the community and the SAPS.

[11] https://www.saferspaces.org.za/understand/entry/what-is-the-situation-in-south-africa

Consensus has grown in the recent decades around core principles for achieving safety in public spaces:

- **Participation not consultation**: Substantive, ongoing engagement with as wide a range of local stakeholders as possible is critical to resilient safety interventions in public space.
- **Local Context is Key**: A thorough understanding of the local context requires a deeper, ongoing participation process.
- **Integrated approach**: Siloed governance, especially at the local level, undermine integrated approaches, and is related to a fragmented understanding and management of public space.
- **Holistic Intervention**: The cross-cutting realities of safety and public space are unique and crucial aspects to consider, as they prompt the necessity of holistic approaches.

3.7.2 Challenges

Some of the challenges related to safety and security in South Africa include:

- High levels of **poverty, unemployment** (26% of the adult population) and **inequality** (Gini coefficient between 0.66 and 0.70).
- One of the highest **alcohol consumption** levels per drinker in the world, leading to fatal and non-fatal violence.
- A **culture of violence**[12], which needs to be interpreted in the context of an extremely violent past.
- Reduction in **propensity to report crime** as many victims of crime report crime only if they need to do so for insurance purposes.
- A **shortage of quality and safe public space** in many South African cities. This is partly due to the historical spatial injustices which left a legacy of inadequate public space in disadvantaged areas like townships and informal settlements.
- **Homelessness, informal trade, informal settlement, substance abuse, and criminality** are linked to structural problems such as inequality, poverty and unemployment
- **Loss of public space** through privatisation, fencing-off, and displacement of vulnerable people.
- Crime and fear of crime leading to a **retreat from public life** amongst rich and poor South Africans with the most vulnerable not having adequate private space to retreat to.
- **Crises such as the Covid-19 pandemic** have resulted in additional public safety challenges and have highlighted spatial inequality.
- **Increase of cyber security threats** due to (Accenture, 2020)
    - **lack of investment in cyber security** to combat increasing cyber security threats rates.

[12] A culture of violence refers to a greater tendency than average within a specific society to resort to the use of violence in day to day life. (https://www.saferspaces.org.za/understand/entry/what-is-the-situation-in-south-africa)

- South Africa has been **slow to adopt cybercrime legislation** and has a **shortage of capacity** and trainings for the African Police Service.
- **Poor public knowledge of cyber threats** despite huge investments in new tech startups and temploying technological solutions to achieve a vast array of business and social needs.

3.7.3 Trends and Developments in Urban Safety and Security

Some of the interventions and investments underway in safety and security in South Africa include:

- 2016 **White Paper on Safety and Security**, a policy on safety, crime and violence prevention that promotes an integrated and holistic approach to safety and security. The policy focusses on the prevention of crime and violence to increase South African's feelings of safety and security.
- 2016 **White Paper on Policing** aims to develop an accountable, professional, competent, and highly skilled police service. Important shifts in the White Paper are to distinguish the policing function from the broader safety and security issue and the provision of civilian oversight of policing.
- **Integrated Social Crime Prevention Strategy** (2011) aims to create a framework for a targeted and coordinated response by government to crime and violence and to extend crime and violence prevention beyond policing to and involve organs of state at the national, provincial, and local level.
- **Community Safety Forums Policy** provides a framework for integrated, localised safety planning and co-ordination that is aligned to national and provincial priorities.
- **Integrated Urban Development Framework** (2016) has a vision to create "Liveable, safe, resource-efficient cities and towns that are socially integrated, economically inclusive and globally competitive, where residents actively participate in urban life."
- **Activated Public Space** are generally safer because the increased presence of users serves as a form of social surveillance. Activation strategies are frequently centred around sports, arts and culture and include employment generation and social development infrastructure such as shelters and lockers for homeless people.
- **Crime Prevention Through Environmental Design (CPTED) principles** guide practical interventions to improve safety. This includes lighting, surveillance, improved sightlines and visibility, clearer access-points and pedestrian routes through spaces, and services including ablutions and sanitation.
- **Homegrown public space** that leverages the relatively chaotic and types of informality of many African public places as strengths.

3.7.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in urban safety and security are summarised in the table below

Bigdata	• Analysis of a wide variety of data sources (security cameras; microphones/ mobile phone usage; car movement analysis/ social media monitoring / communication) to detect abnormalities and detecting possible risks.
AI	• Facial recognition technology as a measure to enhance public safety (live facial recognition versus retrospective facial recognition) can assist the police to detect and prevent crime, as they attempt to identify individuals that have been associated with crimes in the past. • Creating crime prediction models. Public safety and law enforcement agencies combine different sources of data to create a single model- like one that might help them predict potential criminal behaviour. With the massive amounts of data these agencies now have access to, public safety workers might now be able to predict a spike in crime and the areas in which it could occur. An agency acting proactively could then divert their resources towards making sure that that spike doesn't happen[13]. • Histories of online behaviour build profiles on users, movements, assets, and networks, allowing AI to detect and respond to deviations from established norms (EIT Urban Mobility, 2021). • AI is also a critical technology in information security because it can quickly analyse and identify many different types of threats such as malware exploiting zero-day vulnerabilities (a software security flaw that is known to the software vendor but does not have a patch in place to fix the flaw). Automated attacks and so-called 'advanced and persistent threats' (APT) require security developments from equally advanced defence systems equipped by AI capabilities (ibid).
Blockchain	• Blockchain strengthens the Chain of Custody (is a way ensuring the physical or electronic control of evidence). The blockchain acts as an evidence locker and stores encrypted data across different cloud-based servers. Not only does this help protect data in terms of privacy but it also keeps track of how the data is accessed and by whom. Blockchain technology can help improve policing and in turn increase public safety is through accountability[14]. • Combat cybersecurity, e.g. decentralizing Domain Name System (DNS) entries blockchain technology can help prevent Distributed Denial of Service (DDoS) attacks; decentralising administration of security systems to prevent hack attacks; and blockchain technology can be used to verify activities like patches, installers, and firmware updates[15].

[13] https://www.kovacorp.com/4-ways-public-safety-agencies-using-big-data

[14] https://ark.io/blog/how-blockchain-technology-can-improve-policing-and-public-safety-bd5fab4f95f8

[15] https://www.itbusinessedge.com/security/potential-use-cases-of-blockchain-technology-for-cybersecurity/

3.8 Communication, Inclusivity, Community Involvement and Citizen Engagement

3.8.1 Context

The Integrated Urban Development Framework states that the status quo in South Africa is characterised by the following conditions (COGTA, 2016):

- Most of South Africa's city dwellers live in townships and informal settlements associated with insecurity, inadequate and insufficient public infrastructure, and low economic services with minimal industrial activity. This disadvantage of location, coupled with a lack of resources, prevents them from participating fully in civic, social, economic, and other decision-making processes.
- Many youths and children drop out of school and become involved in gang life and substance abuse or fend for themselves after school hours because of the absence of quality and affordable childcare or recreational facilities.
- Significant public investments have been made in low-income neighbourhoods. These include free basic services, no-fee schools and clinics, tenure and social security, and transportation subsidies to reduce the cost of looking for or traveling to work. However, these investments have not resulted in higher living standards, which would have led to increased economic activity, reinvestment, and so on.
- Public participation in planning processes has become routine, and do not foster constructive, mutually beneficial initiatives. People are not placed at the centre of the process and are not empowered to be architects of their own lives by participating in the planning, design, and management of their spaces.

The Integrated Urban Development Framework however sees opportunities for communication, inclusivity, community involvement and citizen engagement such as:

- Government commitment to co-production of services at local levels through structures such as ward committees, community policing forums, parent-teacher associations, community health committees and home-based care networks, and programmes
- Municipalities have the framework for structuring public participation that enhances, rather than impedes, the delivery process.
- Despite the problems listed above, townships are also characterised by vibrant cultural and social capital and resilience.

3.8.2 Challenges

Creating a South Africa characterised by a set of shared values, an inclusive society and economy, increased interaction between South Africans from different social and racial groups and a mobilised, active and responsible citizenry means dealing with the following challenges:

- **Limited capacity within municipalities** to engage with communities and building social confidence, promote a sense of civic pride and ownership.
- Civil society organizations have **few solutions for service delivery** crises.

- There is a **lack of dedicated institutional mechanisms** to foster local government/civic collaboration at the neighbourhood level and existing structure do not function well.
- The **existing service delivery model mitigates against co-creation** of innovative solutions due to the way policies are interpreted and applied.
- **Poor understanding of government structures and operations inhibit** citizen participation which is exacerbated by low level of education and training, poor health, and the short life expectancy of many city dwellers.
- **Under-utilisation of forums that enable participation and social cohesion**.
- **Inadequate quality public spaces that** encourage interaction of people from different backgrounds.

3.8.3 Trends in urban Communication, Inclusivity and Community involvement

Some of the interventions and investments underway in communication, inclusivity and community involvement in South Africa include:

- **Government co-production of services** at the local level, through structures such as ward committees, community policing forums, parent-teacher associations, community health committees and home-based care networks, and programmes (e.g. Community Works Programme and the Extended Public Works Programme). Existing community forums, community- and faith-based organisations are other possible structures that could be used.
- City and province **initiatives to enable citizen engagement** such as the e Gauteng City-Region Observatory (GCRO) and the City of Cape Town's Open Data Portal.
- "The **Back to Basics Programme** supports local government's continuing transformation and is aimed at achieving more effective governance and management" (COGTA, 2016).

3.8.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in communication, inclusivity and community involvement are summarised in the table below

Bigdata	• Share community relevant data in an easily accessible manner (e.g. via visualisations, games and simulations) to community members to support of community-based decision-making and action(blue ventures, 2021). • Extend and deepen engagement and participation of citizens and firms through open data. Open data initiatives can enable more inclusive and democratic spaces for citizens to participate in local government to build social capital and trust. This can also leverage the creativity of individuals and firms to enable electronic service delivery (PAN, 2020).
AI	• Explainable AI (XAI): Explaining the results of the Artificial Intelligence solution that can be understood by humans. • Human centric AI, is an inclusive approach that puts the human in the centre to provide trustworthy and reliable AI to protect the interest of humans and society that includes societal awareness, legislation awareness as well as experimenting and learning.

Blockchain	• Community action often relies on volunteer engagement for a wide variety of tasks, from beach clean-ups to user research. Using blockchain based tokenized incentives as rewards for these kinds of tasks can empower people as well as encourage community participation[16]. • Securing Non-profit Donations. With blockchain, you can track a transaction along every step of the way, so you can see where it ends up and how it got there. This way, if you give to a charity, you can rest knowing your money did, in fact, go towards the cause[11]. • Protecting Democracy. Blockchain can even help optimize the democratic process. Voting via blockchain can make elections more stable and quantifiable and incorruptible. Voter fraud could become a thing of the past, making democracy more democratic[11]. • Financial inclusion: Blockchain technology can play a pivotal role when it comes to boosting financial inclusion toward the unbanked and underbanked, and there are significant opportunities on the horizon[17].

3.9 Urban Governance and City Planning

3.9.1 Context

UN-Habitat (2002) defines urban governance as "the sum of the many ways individuals and institutions, public and private, plan and manage the common affairs of the city. It is a continuing process through which conflicting or diverse interests may be accommodated and cooperative action can be taken. It includes formal institutions as well as informal arrangements and the social capital of citizens".

In South Africa, the Constitution is the main legislation that describes the obligations of municipalities to provide urban services and residents' entitlements to receive such services (UN-Habitat, 2002). It states that service delivery is a central objective of local government and that the objects of local government are – (a) to provide democratic and accountable government for local communities; (b) to ensure the provision of services to communities in a sustainable manner; (c) to promote social and economic development; (d) to encourage the involvement of communities and community organisations in the matters of local government. Services must be delivered consistent with South Africa's developmental goals and the principles of sustainability, accountability, and participatory democracy.

In the introduction to the *Smart Governance in South African Cities* series, Wilson and Guya (2020) state that the key lessons for smart governance of South African cities are:

1. Effective **data management and systems** allow for the proactive use of evidence-based decision-making in cities and should be the foundation of smart city developments.
2. Cities should drive an **open data agenda** to increase transparency, accountability, and communication with citizens.

[16] https://gritdaily.com/7-ways-blockchain-can-be-used-for-social-good/

[17] https://www.unicef.org/innovation/InnovationFund/blockchain-financial-inclusion-cohort

3. **New models of governance** are needed within smart cities that place citizens at the centre and go beyond purely information dissemination to active collaboration and participatory citizenship.
4. Smart city development plans must **align with existing city strategies**, such as the Integrated Development Plan (IDP), to find resonance at a municipal level and drive implementation.
5. An **ethical framework** needs to be developed that protects the rights and values of citizens within smart city development and avoids increasing inequality and exclusion.

3.9.2 Challenges

In *Laying the Foundations for Open Data in South African Municipalities*, Boyle (2020a) summarises the challenges for smart city governance in South Africa as:

- Increasingly complex mandates of city governments
- Social inequalities
- Pressure to achieve economic growth in a context of unprecedented environmental and economic uncertainty
- Inappropriate technology targeting the wrong problems.
- Poorly built technology
- Lack of data maturity inhibits smart governance by undermining the ability of local and national government to make informed, empirical-based decisions. Reasons for the lack of data maturity include:
    - limited emphasis placed on using data for decision-making;
    - not working hard enough to make data and information available to the citizens (lack of transparency and openness);
    - few data champions;
    - limited ICT systems;
    - inefficient (and often manual) data collection; and
    - no measuring of data progress.

3.9.3 Trends in Urban Governance and City Planning

Some of the interventions and investments underway in urban governance and city planning in South Africa include:

E-governance and involvement of the public in decision making process is the most important aspect of smart governance. The tools used to achieve them are following:

- **Use of Information and Communication Technology which** involves the use of computers, the internet, telecommunication, digital equipment's for collecting, processing, sharing and retrieving of data.
- **E-Consultation**: People participation is the main feature of smart governance and is enabled by proper channels of interaction between government and citizens so that citizens' voices are

heard regarding their opinions, feedback, and ideas about government programs, schemes etc..

- **E-Data**: Easy access to government funds, expenditure and investment data and public information must be available online. Except for critical information pertaining to security and safety of citizens, data must be provided freely and openly. This will make government more accountable and citizen participative in government's functioning [18]. The global Aid Effectiveness Agenda promotes that partner country institutions should have a strong role in development cooperation. However, donors have developed their own customised procedures designed to minimise risks for the disbursement of development aid. Partner countries are left with the onerous task of collecting financial data and coordinating various donor requirements. As a consequence, the structural impact of development cooperation remains limited, as local systems struggle to adequately absorb funds. Blockchain-based workflow tools can allow for efficient project implementation by offering functionalities to track expenditures in a collaborative and transparent way. They can help to coordinate the implementation of donor-funded investment projects by providing a shared and up-to date view on project-related expenditures and by allowing multiple parties to lock transactions in real time.

3.9.4 Opportunities for the use of AI/Blockchain/Bigdata

The opportunities for the application of AI, blockchain and bigdata to the challenges in urban governance and city planning are summarised in the table below

Bigdata	• Through bigdata analytics, urban planners can get accurate insights on how city resources are being used and use these insights to allocate resources to areas where they are most needed[19]. • Data analytics allows urban planners to share their insights with city dwellers and encourage them to participate in designing efficient cities by giving ideas on how to improve certain aspects of urban living, like public transport and waste disposal[14]. • Evaluation the Quality of Life based on metrics such as area of public recreation space within a city; air quality– in terms of particulate matter; Important water quality metrics, commute times; average cost of living, crime rates.
AI	• Decision making: o Artificial intelligence enables simulations that give an accurate representation of how proposed urban developments will affect the lives of millions of city dwellers[14]. o Techniques to quantify the value of the improved decision are crucial.
Blockchain	• Transparency in land registration. Blockchain technology can deliver the needed infrastructure to provide digital proof of claim of land ownership and legal

[18] https://wlv.openrepository.com/bitstream/handle/2436/622263/Keshvardoost_et_al_Issues_and_challenges_of_smart_cities_2019.pdf?sequence=1&isAllowed=y

[19] https://seleritysas.com/blog/2021/10/16/data-analytics-in-urban-planning-whats-the-future-of-the-industry/]

	personal identification. Blockchain technology can increase the transparency of ownership changes reducing the possibility of manipulation of existing titles (Smart Africa, 2020). • Tracking public spending in a in a collaborative and transparent manner. Blockchain based workflow can help to coordinate the implementation of investment projects by providing a shared and up-to date view on project-related expenditures and by allowing multiple parties to lock transactions in real time (ibid).

4. The AI/Blockchain/Bigdata Ecosystem in South Africa

The section on the South African landscape is concluded with a summary of the AI, blockchain and bigdata ecosystem in South Africa.

4.1 Introduction

In South Africa AI, Blockchain and Bigdata are being pursued under the banner of the fourth industrial revolution (4IR), first mooted by Klaus Schwab (2017). To this effect the Presidential Commission on the Fourth Industrial Revolution (PC4IR) was established and is chaired by The President of South Africa. The commission is tasked with setting out the country's strategy for the 4IR and recommending the institutional framework for 4IR. In October 2020 the Minster of Communications and Digital technology published the Report of the Presidential Commission on the 4th Industrial Revolution (PC4IR) in the Government Gazette (PC4IR, 2020). The commission recommended that South Africa:

- Invest in human capital development;
- Establish an Artificial Intelligence Institute;
- Establish a platform for advanced manufacturing and new materials;
- Secure and avail data to enable innovation;
- Provide incentives for future industries, platforms and applications of Fourth Industrial Revolution (4IR) technologies;
- Build 4IR infrastructure;
- Review and amend (or create) policy and legislation; and
- Establish a 4IR Strategy Implementation Coordination Council in the presidency.

In October 2019 South Africa signed an agreement with the World Economic Forum that led to the establishment of the Centre for the Fourth Industrial Revolution South Africa (C4IR SA)[20] as part of the global network of the centres for 4IR (C4IR Network). The purpose of the C4IR SA is to create a collaborative platform for its business partners creation and adoption of 4IR technologies, to build national capability in technology governance, showcase inclusive digital transformation, and catalyse industry **transformation**. In an opinion piece commissioned by UNIDO, Jegede (2021) argued that South Africa must complement its domestic efforts on 4IR with time-tested strategies for building technological capability for industrialization including foreign direct investment, acquisition of external knowledge, trade of technology-intensive products, reverse engineering and imitation and participating in R&D and technology consortia.

In Figure 1Figure 8 the relationship between the key technologies enabling the 4IR are illustrated.

[20] https://www.c4ir.co.za/

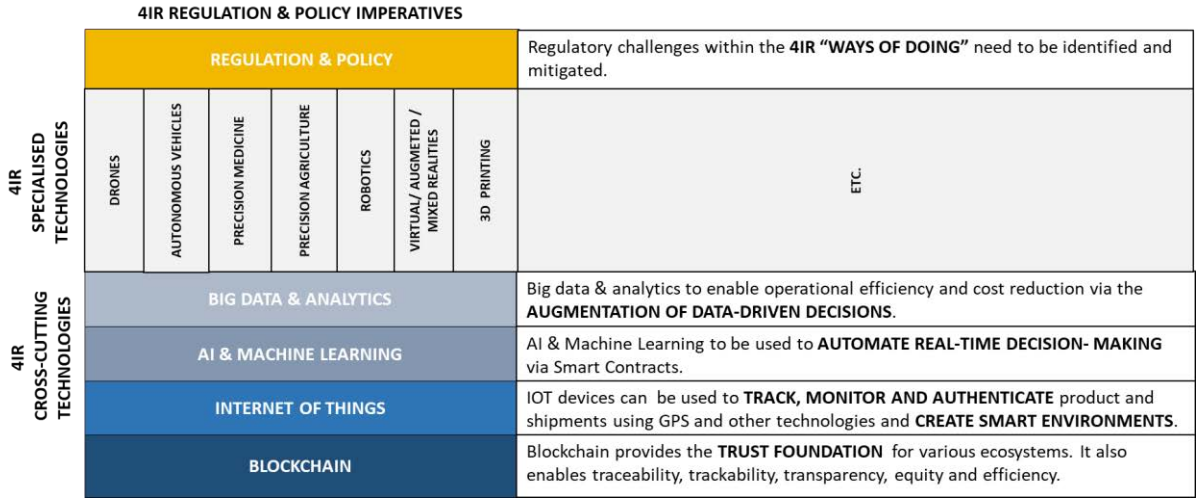


Figure 8 4IR Framework

Table 2

Table 2 Key Institutions related to South Africa's digital ecosystem

Institution	Description
Centre for Artificial Intelligence Research (**CAIR**)	A distributed South African research network with nine established and two emerging research groups across eight universities funded primarily by the Department of Science and Innovation (DSI). It is virtually hosted and coordinated by the Council for Scientific and Industrial Research (CSIR). https://www.cair.org.za/
Centre for the Fourth Industrial Revolution South Africa (**C4IR SA**)	A multi-stakeholder hub that works with its business partners to develop internal tools and governance frameworks for their innovations and influence regulatory policy; and with government and its entities to develop policy frameworks and governance protocols to create an environment that opens the doors to new economic opportunities and accelerates the development and adoption of disruptive technologies. https://www.c4ir.co.za/
Centre for High Performance Computing (**CHPC**)	the CHPC is mandated to provide high performance computing (HPC) resources and domain specific support to both public and private sector users. In 2016, the CHPC introduced a peta-scale machine, with almost 33 000 cores. The machine was the fastest supercomputer in Africa and at launch was ranked 121st amongst the world TOP500 supercomputers. https://nicis.ac.za/chpc/
Data Intensive Research Initiative of South Africa (**DIRISA**)	Promotes, enables and coordinates a data intensive research ecosystem in support of national science and strategic priorities through provision of a robust and advanced national data infrastructure and services, the promotion of sound data stewardship practices and the development of underpinning expertise in data management and data intensive research. https://nicis.ac.za/dirisa/
Digital Council Africa	An independent, not for profit organisation that seeks dialogue with all stakeholders to discuss how to maximise the societal benefits of digital and data-driven technologies to increase equality and inclusivity, wellbeing and digital adoption https://www.digitalcouncil.africa/
Council for Scientific and Industrial Research (**CSIR**)	A leading scientific and technology research organisation that researches, develops, localises and diffuses technologies to accelerate socioeconomic prosperity in South Africa. https://www.csir.co.za/

ICT SMME Chamber	The ICT SMME Chamber plays a critical role in engaging with government and other ICT stakeholders, and in lobbying government on behalf of the ICT small businessman and woman on all matters of ICT SMME development and ICT sector transformation. The ICT SMME Chamber is committed to supporting the aims of the BBB-EE ICT Sector Council and its associated ICT Charter. https://ictchamber.org.za/
Joburg Centre for Software Engineering (**JCSE**)	A Centre at Wits University with a vision to develop processes that will support digital transformation and people who will lead Africa's digital future. It works towards this vision by playing a convening role, consulting and coaching, coordinating supporting collaboration development of systems. https://jcse.org.za/
mLab Southern Africa (**mLab SA**)	A digital solutions laboratory and startup accelerator that provides entrepreneurs and developers with the support to develop their technology and grow their businesses. https://sanba.co.za/
South African National Blockchain Alliance (**SANBA**)	SANBA drives blockchain adoption in South Africa. By linking in government, academia, the private sector and civil society, it creates a pre-competitive space for research, development and innovation in blockchain technology. It focuses beyond the traditional fintech and cryptocurrency use cases to tackle many challenges in the country. https://sanba.co.za/

4.2 Bigdata

In terms of bigdata and associated data science there is significant activity in South Africa with several companies and universities active in the field. From a policy perspective the Department of Communications and Digital technology (DCDT) published a draft National Data and Cloud Policy in April 2021 (DCDT, 2021). The purpose of the policy is to enable South Africans to realise the socio-economic value of data through the alignment of existing policies, legislation and regulations and to put in place a conducive and enabling environment for the data ecosystem to thrive. Its objectives are to:

- Promote connectivity and access to data and cloud services;
- Remove regulatory barriers and enable competition;
- Ensure implementation of effective cybersecurity privacy, and data and cloud infrastructure protection measures;
- Provide for institutional mechanisms for the governance of data and cloud services;
- Support the development of small, medium, and micro enterprises (SMMEs); and
- Provide for research, innovation, and human capital development.

One of the flagship government interventions on data is the Data Intensive Research Initiative of South Africa (DIRISA). DIRISA forms parts of the National Integrated Cyberinfrastructure System (NICIS) and supports research data management and data intensive research. It does this through the provision of a robust and advanced national data infrastructure and services, the promotion of sound data stewardship practices and the development of underpinning expertise in data management and data intensive research. DIRISA operates as an overarching national data organisation and as such, advocates research data sharing, coordinates publicly-funded initiatives and advises on a strategic agenda for data intensive research.

The Centre for High Performance Computing (CHPC) is another leg of NICIS and is South Africa's national supercomputing centre. CHPC provides high performance computing (HPC) resources and domain specific support to both public and private sector users. The CHPC promotes the development of strong high-performance computing capabilities and supporting large-scale science projects.

4.3 Artificial Intelligence

A healthy AI ecosystem rests on success in five dimensions 1) universities and research institutes, 2) startups, 3) large enterprises, 4) policymakers and 5) multi-stakeholder partnerships (Accenture, 2021). South Africa has elements of a vibrant AI ecosystem in each of these dimensions as summarised below:

- **Universities and research institutes** – several universities and research institutes in South Africa are active in research and teaching of AI. Many of these have come together in the Centre for Artificial Intelligence Research (CAIR) which has four research groups focussing on different aspects of AI:
    - **The Adaptive and Cognitive Systems Lab** investigates architectures and frameworks for self-learning cognitive systems that can adapt to an evolving environment.
    - **AI and Cybersecurity** focuses on the combination of the two disciplines, Cybersecurity and Artificial Intelligence.
    - **AI for Development & Innovation** performs research on Applied AI within information systems, data science, socio-technical development, sustainable development, and, semantic technologies and applied ontology.
    - **CAIR Deep Learning** performs basic and applied research in machine learning focussed on applications in speech and language processing, and space weather prediction.

  The top AI research institutions judged by AI publications are: University of Cape Town, University of Pretoria, Stellenbosch University and University of the Witwatersrand.
- **Startups** – South Africa has a considerable number of startups focussing on areas like fintech, health, advertising, human resources etc. A few are depicted in Figure 9.

Figure 9 AI startups in South Africa

- **Large Enterprises** active in AI in South Africa include multinationals like Accenture, Deloitte, PWC and IBM[21].
- **Policymakers** – although South Africa does not have a distinct AI government policy, AI is a key focus area of the PC4IR and the C4IR SA.
- **Multi-stakeholder partnerships** are still nascent but the C4IR SA is multi-stakeholder hub created to foster collaboration on 4IR technologies and applications including AI. In addition, 4IRSA[22] is a platform that formed by a number of universities, the DCDT and large companies that aim to support dialogue, understanding and action towards a coherent 4IR plan for South Africa.

4.4 Blockchain

As in the case of AI, South Africa R&D and innovation agenda for Blockchain contained in the country's 4IR policies and strategies whilst the Reserve Bank is expected to issue crypto currency regulation in 2022. The South African National Blockchain Alliance (SANBA) was created in 2019 and officially launched on 3 April 2020 to address gaps in the existing blockchain ecosystem, as follows:

- To create an umbrella body with the buy-in of all the ecosystem players in South Africa, to ensure better coordination and community support.
- To work together as "Team South Africa" (business, government, civil society and academia) for the short-to-medium-term in a pre-competitive and collaborative environment that will benefit all.
- To share resources, skills and knowledge to benefit the whole blockchain ecosystem in the country by creating a network effect.

[21] https://research.ibm.com/labs/africa/

[22] https://www.4irsa.org/

- To use the ecosystem approach to open up new opportunities by linking the traditional R&D players from universities and research organisations to market and commercialisation opportunities and vice-versa.
- To facilitate the transfer of knowledge, open discussions and execution of business cases to government in order to support service delivery in the country.
- To create a trusted, legitimate body, consisting of representatives of government, academia, business & civil society to work together towards widespread blockchain adoption.

SANBA has four main objectives:

1. **Connecting** academia, civil society, business, and government into a pre-competitive collaboration space to support research, development and innovation in blockchain technology and its application in these sectors.
2. Facilitating **skills development, advocacy, and education** on "all things blockchain".
3. **Catalysing blockchain adoption** in all sectors of South Africa.
4. **Leveraging the blockchain ecosystem as a lobbying platform** to tackle issues blocking blockchain adoption in South Africa.

Proof of concept (POC) and opportunities currently pursued by SANBA include:

- **ILIMA** - Taking a farm-to-fork approach to connect small-scale farmers and agro-processors to markets , enabling traceability, food safety, provenance, delivery and other digital options.
- **Digital Credentials** - A POC to demonstrate digital credentials / qualifications to DHET (Department of Higher Education and Training), by linking it to a platform that is being developed for merSETA to accredit skills development for apprentices.
- **Digital Identity Innovation Ecosystem** - An initiative to leverage the excellent digital identity expertise in SA to research, innovate, develop, and implement digital identity solutions that are suited to our needs.
- **Open Data Collaboratory** - Taking advantage of SA's "digital gold" to create an environment where data can be accessed and traded in a trusted and immutable way.
- **eProcurement** -Blockchain-based eProcurement system (local/provincial/national).

5. Dutch Landscape: Strengths, Solutions, and Innovations

5.1 Introduction

Technological, economic and social development are evolving due to the digital transition. Digitalisation is changing production and services, communication, and societal processes. It is making things easier, faster, cheaper, and better. However, it also requires companies and institutions to reinvent their business models and markets because they are being shaken up by new types of players. At a global level large incumbent digital platform players that occupy a position of power can hinder companies' ability to compete. Digitalisation has gained momentum in many sectors and affects everyone. During the COVID-19 pandemic that started in 2020, the digitalisation of crucial societal processes in areas such as healthcare, education and public administration has been fast-tracked.

The Netherlands has been among the frontrunners of digital transformation in Europe (Bughin et al., 2019). The Netherlands has several advantages in this new digital era, including: a world-class network, companies that are innovative in their use of digitalisation, a public that is taking advantage of digital opportunities, and government authorities that are increasingly using digital resources to improve their services, enforcement and supervision. In order to maintain its leading position, the Netherlands developed a national digitalisation strategy providing a joint agenda across government departments to make the most of the social and economic potential of digitisation (Ministerie van Economische en Klimaat Zaken, 2019).

The Dutch Ministry of Economic and Climate Affairs has supported, through the Dutch Digital Delta[23], the national platform "Connect and Create" as the networking place for business, government and science to stimulate innovation through collaboration. Several key technologies ("sleutelgebieden") have been identified, among which are bigdata, cybersecurity, artificial intelligence (AI), blockchain and wireless communication (5G). To strengthen collaboration, for these key technologies communities and coalitions have been established, such as the NLAI Coalition, the Dutch Blockchain Coalition, Digital Society Alliance, the Data Sharing Coalition, and Commit2Data community.

The Dutch Digitisation strategy has identified the following seven priorities: Artificial Intelligence; Data; Digital skills and inclusion; Digital connectivity; Digital resilience; Digital government; Operational level: digitalisation at all levels.

Via the "Good Growth Fund"[24], the Netherlands is investing heavily in the digital transition at national level in the coming years. For example, 276 million Euros has been allocated to research and innovation of Artificial Intelligence in the "AiNed" program.

Digitalisation plays an essential role in tackling social challenges [Source: (Ministerie van Economische en Klimaat Zaken, 2019)

- **Agriculture**: Towards a safe and sustainable food supply. Digitalisation makes a significant contribution towards sustainable and economically viable agriculture, robust nature and a sustainable food supply.

[23] https://dutchdigitaldelta.nl/

[24] https://www.advanceconsulting.nl/financing/concessional-loans/dutch-good-growth-fund-dggf/?gclid=Cj0KCQiAi9mPBhCJARIsAHchI1x70ujrjohwLUWmOSIxAj2C4QNSpK5iy1SUs5C8KNvs-Jy156I00vMaAjxBEALw_wcB

- **Healthcare**: For good, accessible, reliable, and affordable health care. Digitalisation supports the development of new and better health care, to ensure that appropriate care is provided in the appropriate seeing and to encourage appropriate use. The effective and timely exchange of information with patients and between health care providers is important for good-quality health care.
- **Education**: Digitalisation offers opportunities for high-quality education that is accessible to all. Adaptive learning tools and digital identities can contribute to personalised learning, educational flexibility and distance learning; and to reducing teacher workload. Digitalisation requires digital skills and literacy for all. Developing digital skills should be accessible and achievable for everyone to ensure that everyone is able to participate.
- **Research**: Better and faster results can be achieved through reusable, sharable and machine readable research data, faster and more powerful (super)computers and up to date data services, such as connections and storage.
- **Industry**: Innovation through digitalisation enables industry to continue to contribute to growing prosperity and reducing the consumption of raw materials and energy, even though labour productivity is under pressure due to a shrinking workforce and the limited availability of well-trained staff.
- **SMEs**: The broad SME sector is struggling to keep up with economic changes and to cope with growing competition. Digitalisation reinforces this effect. It is therefore important that SMEs are encouraged to invest in digitalisation, so that they can continue to other their products and services.
- **Energy**: In the transition to a sustainable energy supply, digitalisation is essential for the development of flexible energy networks, for the efficient use of the energy system, and to limit the costs of this transition.
- **Mobility**: Good accessibility, traffic flow, sustainability and road safety can be achieved with an integrated and multimodal mobility system in which the movement is central. Quality and availability of data play a major role in this.
- **Government**: The government is always responsible for good governance, including in emergency situations, and an effective provision of information to the public. Digitalisation plays an increasingly important role in this context, but consideration must be given to continuity, accessibility, and basic rights.

To address the Dutch strengths and business opportunities regarding Smart and Resilient Cities as per objective of the assessment, we focus in to the three identified technology areas: 1. Artificial Intelligence and Bigdata; 2. Bigdata and 3. Blockchain.

Applying AI and bigdata to cities enables smarter cities, in the sense that utilising the available information for better decision making means: do more with less; do it better and do new things. In the figure below, a digital representation (also called digital twin) of the real world is obtained through sensing and modelling using vast amount of data from a wide variety of domains, sources and timelines (historic / real time). AI not only helps to understand the current situation but also allows for forecasting, simulations and planning.

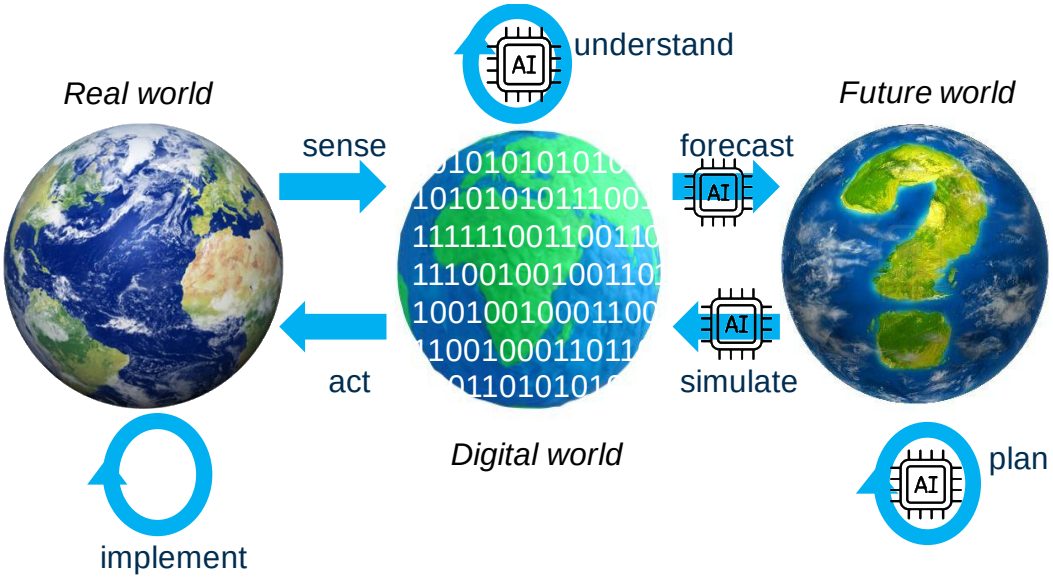


Figure 10 Enabling a better world though AI and Bigdata

5.2 Bigdata

Data is the foundation of the digital economy and society and the fuel for Artificial Intelligence. The volume of data, its potential applications and therefore its value are growing exponentially (hence the term Bigdata). Technologies such as the Internet of Things, sensors, digitization of collections, and social media lead to enormous amounts of collected data. The value ascribed to this bigdata is found in unexpected patterns hidden in the data, and the causal relations, predictive powers, and decision support that can subsequently be attained.

Data has the unique characteristic of being an easily shareable and re-usable asset. The same dataset can support an unlimited number of applications at the same time. This means that one dataset can create economic and societal value in multiple contexts simultaneously. The true value of data can therefore only be unlocked if it is shared across sectors and domains and re-used throughout the digital economy and can make an important contribution to the emergence of smart cities. For example, due to the large-scale roll-out of smart meters in the Netherlands, measurement and consumption data is much more detailed and more rapidly available. As a result, new applications are possible, and supply and demand can be coordinated better. End users can be informed faster and in greater detail about their consumption and costs, and the financial settlement process can be refined.

Useful (in term of representative, verifiable and shareable) data is crucial to develop high-quality and reliable AI applications. By combining different types of data from different parties, valuable new data sets can be created that enable new AI applications. To capitalize on that potential, public, private and social organizations must be able to share more data with each other while respecting relevant privacy rules and preferences.

An AI application requires high quality data. Aspects such as accuracy, completeness, reliability, representativeness, and topicality affect the quality of data. Businesses and governments benefit from high-quality AI applications for economic, ethical and security reasons. In addition, low-quality data can cause bias and imbalances in AI: bias when the data itself contains biases (because people also have them), bias due to biases in the algorithms, and imbalances when data is not representative. The

required quality of an AI application, and therefore of the data that is used, is context-dependent. The required quality of data cannot be determined unambiguously, there is no single generic quality requirement that is optimal for every AI application. For example, in some cases, such as data for a self-driving car, the need for high-quality data is significant, because this is an AI application with a potentially large impact including loss of life in the case of a fatal accident. Lower quality requirements may apply to data used for an AI application that predicts the fastest queue in the supermarket.

Common principles such as the internationally verified and accepted FAIR principles (Findable, Accessible, Interoperable, Reusable) are ideal for each domain or sector to form the basis for own standards, tools and training. Through application of the FAIR principles, data can be made suitable, or their suitability can be determined for reuse (sharing) by both humans and machines under clearly described conditions. In this respect, the Dutch government has adopted the FAIR principles for data. In addition to the right conditions for the use and exchange of data, there is also a need for secure and reliable data storage and processing facilities.

The Commit2Data[25], a €154 million National Public-Private Bigdata Research and Innovation Program has been successfully implemented. 227 organisations participated in the Commit2Data initiative, including 15 Government organisations, 22 Knowledge institutes, 27 societal organisations and 185 private companies implementing 60 projects in the areas of healthcare, smart culture, cybersecurity, agro food, sports and exercise, as well as data handling, and data analytics. To validate and experiment with bigdata, 6 regional data hubs have been established, each with their specific offerings in terms of platforms and services[26]:

- **Bigdata Value Center (Almere)**: Unique open innovation platform where (big) data can be safely experimented with.
- **Data Federation Hub, (Groningen):** This hub connects and fosters groups that support scientists to deliver innovative research
- **IoT en AI Bigdata Hub (Twente):** A platform accommodating various pilots and services around the fusion of AI and IoT. There are pilots in the area of smart agriculture, smart cities, predictive maintenance, logistics, and smart mobility.
- **Wageningen Data Competence Center (Wageningen):** Support developments in (big) data and data innovation in the field of research in agriculture, food, environment, social sciences, and health.
- **Data Value Center Smart Industry (Brabant):** Entrepreneurs in the high-tech manufacturing industry can go here for information about the possibilities of bigdata, open data and their own data; a quick scan for tailor-made advice.
- **Bigdata Innovation hub (Zoetermeer):** helps organizations to make their production more efficient, improve processes and contribute to solutions for societal challenges through data analysis.

In addition, there are other regionally oriented data factories to stimulate collaboration between companies and knowledge:

- **Bigdata Value Center Almere,** involves among others TNO, various bigdata companies, Windesheim, KvK, SURFsara;

[25] https://commit2data.nl/en/

[26] https://commit2data.nl/en/datahubs

- **Data Science Alkmaar**, involves among others city of Alkmaar, companies, VU, innovation hotspot "de Telefooncentrale";
- **The Hague Campus**, involves among others city of The Hague, Yes!Delft, VNO-NCWest, innovation hotspot Leiden;
- **Bigdata Eindhoven**, involves among others cities of Eindhoven and Den Bosch, Fontys, ZLTO;
- **Dutch Game Garden**, involves among others Media Park, KvK, Economic Board Utrecht/ Hilversum, companies, University Utrecht, Hogeschool Utrecht, HKU. iMMOvator;
- **Target**, involves among others Astron, RUG, city of Groningen;
- **Amsterdam Creative Industries Network** with nine application labs. Involves among others applied science universities, big and small digital data driven companies such as Digitas LBi, Cisco, Bell Labs Europe and Info.nl.
- The Royal Netherlands Meteorological Institute created the **KNMI Datalab**[27] to facilitate and coordinate innovations in the fields of climate change, weather forecasting and seismology. The KNMI Datalab brings value and support to collaborating partners by sharing its knowledge in these research fields and by providing access to the data available at KNMI. Bigdata management, data analytics including machine learning and deep learning are becoming increasingly important in the supported projects of the DataLab.

The Data Sharing Coalition[28] is a collaborative initiative that aims to unlock this value by enabling organisations to share data across domains and sectors easily. As part of the coalition, existing data-sharing initiatives, industry associations, knowledge institutions, companies, scientists, and experts are working to create a generic system of agreements to share data across sectors. This initiative has an international dimension and is open to members from all countries. The "Data Sharing Canvas" (Data Sharing Coalition, 2021) provides a useful overview of the Trust Framework for cross-Domain Data Sharing.

In the Table 3 below key issues around bigdata are summarised. To gain the most from data, a country or city should address all these items in parallel. To do so requires qualified professionals (including data scientists, analysts, and data engineers), with proper (data analytic and management) tools.

Table 3 Key issues for bigdata

Data property	Challenges/ Key issues
Volume, Velocity and Heterogeneity:	• Finding meaning and causality • Find the most relevant data (combinations)
Quality and Variability	• Self-learning and predictive analytics
Management and protection	• Interoperability and standardization • Ownership and access to and sharing • Data privacy and security • Digital resilience
Impact and value	• Value of the data (combinations) • Storytelling and Design (explanations)

The Netherlands' strengths in Bigdata according to Commit2Data are:

[27] https://datalab.knmi.nl/en/)

[28] www.datasharingcoalition.eu

- World class data science universities
- Many bigdata and data analytics related start-ups/scale-ups
- Vast amounts of high quality data
- Excellent data infrastructure (high speed connectivity, vast amount of storage capacity and (distributed) computation power (high performance computers)
- Good data protection/policies/frameworks in place

5.3 Artificial Intelligence

The European commission uses the following definition of the Artificial intelligence

> *Artificial intelligence refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals. AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications).* (European Commission, 2018)

As highlighted in the Dutch Strategic Action plan for Artificial Intelligence, the Netherlands has a unique approach to AI (Ministerie van Economische en Klimaat Zaken, 2020):

Collaboration via public-private partnership for research and innovation utilising the Quadruple helix (government, private industry, education and research, and citizens) is an important key to the Dutch AI successes. Collaboration is established across the entire value chain (suppliers and customers); across the disciplines (technical, economic, social sciences) and is dynamic (today's competitors can be tomorrow's partners). That the collaboration is successful can be seen through growth of the Dutch AI Coalition (NLAIC), a community that has more than 400 member organisations from business, science, government and education sectors. See https://nlaic.com/en/coalition-participants/ for an up to date list of the NLAIC member organisations. Most member organisations are AI start-ups, scale-ups and SMEs, as well as public-private research labs at universities, see Figure 11(source NLAIC, 2021).

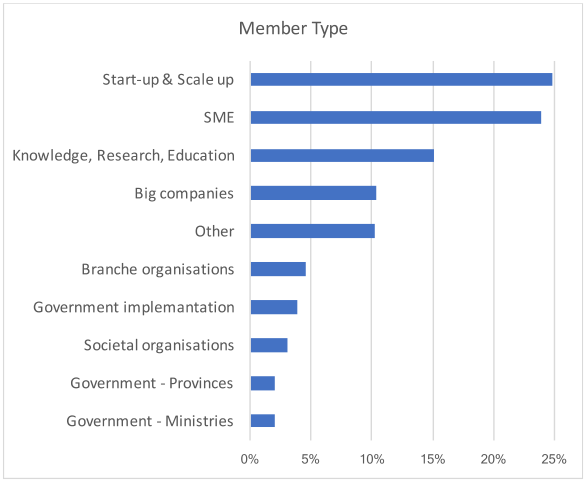


Figure 11 Dutch AI coalition membership

The member organisations are active in different working groups, see the figure below (NLAIC, 2021).

- *Application areas:* Agriculture and Nutrition; Built Environment; Culture and Media; Defense; Education; Energy and Sustainability; Financial Services; Healthcare; Mobility, Transport and Logistics; Port and Maritime; Public Services; Security, Peace and Justice; Technical Industry; and
- *Building blocks* for AI: Data Sharing; Human Capital; Human Centric AI; Research and Innovation; Start-ups and Scale-ups.

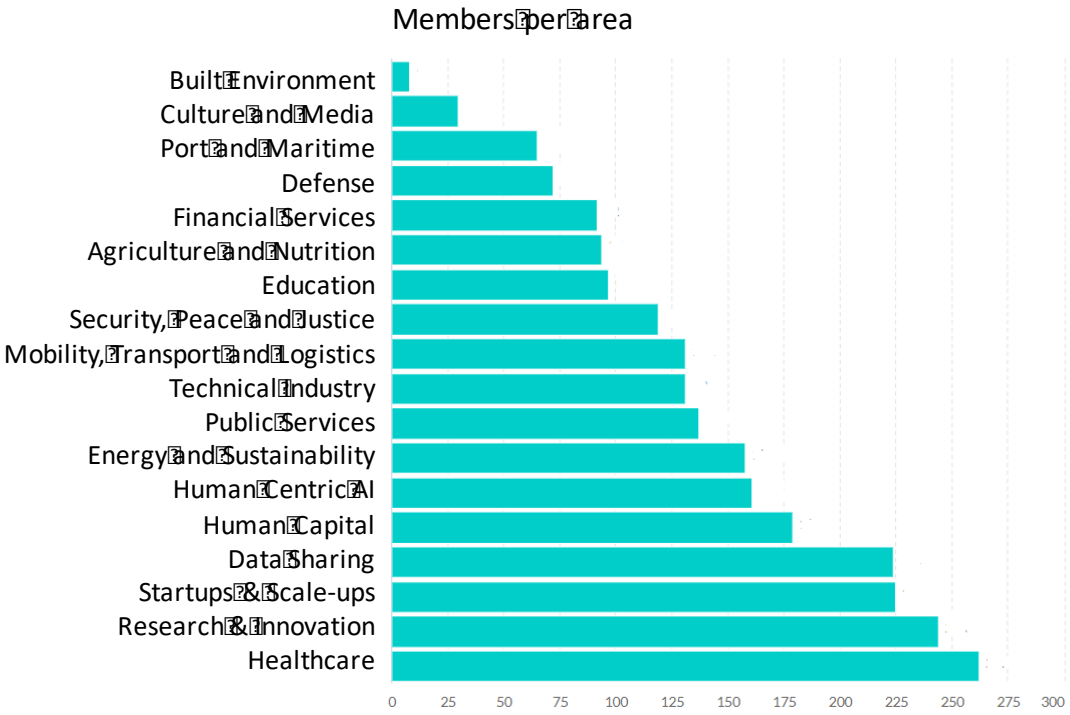


Figure 12 Dutch AI coalition membership per area

Besides national collaboration, the Netherlands is fully engaged in International Collaboration especially with European Partners. Partnering of international organisations with the NL-AIC offers:

- Quick start for partners on the AI learning curve: Legislation, frameworks, interpretation, data sharing approaches, Training, Developing human capital, Innovation projects across the value chain
- Ease of finding partners in the value chain: Including knowledge (such as universities, start-ups, etc.)
- Front edge of innovation. NL is a front runner in AI: Dutch AI start-ups and scale-ups represent 10% of the total number of companies in the EU. Per capita, NL has the highest density of AI start-ups in the EU. (453 AI start-ups according to Tracxn[29]).

Combining **AI and domain knowledge** though utilising the experience of sector specialists to train AI algorithms improves the effectiveness of the AI technology. This approach combines the two basic forms of AI systems way of applying intelligence: data driven and knowledge-driven differing in the way

[29] https://tracxn.com/explore/Artificial-Intelligence-Startups-in-Netherlands

in which intelligence or knowledge, see also the box below (NLAIC, 2020).

Data-driven AI systems automatically learn e.g. through statistical and machine learning methods. Learning often happens using historical data, which as training data contains the relationship between properties - features - of data subjects and the resulting "outcome". The result is a model which summarises information from the training data in a limited number of parameters (model data).

In knowledge-driven AI systems, the knowledge is obtained by consulting domain experts. Gaining expert knowledge is called knowledge elicitation, for which there are many available methods, such as interviewing, case study and role play. Knowledge can be obtained and expressed in different ways: from "if-then" rules to mathematical functions.

Focus on **Human centric AI**, which is an inclusive approach that puts the human in the centre to provide trustworthy and reliable AI to protect the interest of humans and society that includes societal awareness, legislation awareness as well as experimenting and learning. In order for humans to trust the AI solution, the AI algorithm must be transparent and explainable in understandable language. To deal with liability and legal consequences, the AI applications must be verifiable especially when they have a major impact on people or society, or when the possibilities for human intervention and control are limited. Some AI techniques, such as black box algorithms, are inherently very difficult to explain, see the textbox below. As AI now plays a prominent role in society, trust and transparency become increasingly crucial. Using a human centric AI implies that machine learning endeavours today try to balance both black and white box approaches to achieve both interpretability and accuracy.

The Netherlands AI coalition has developed the concept of ELSA labs (ELSA refers to Ethical, Legal and Societal Aspects) to enhance synergies between research, education and organisations on human-centric AI., (see https://nlaic.com/en/news/all-the-signs-are-in-place-for-elsa-labs-and-human-centred-ai/). Amsterdam's AI register (in partnership with the city of Helsinki): Amsterdam and Helsinki have launched open AI register (see https://algoritmeregister.amsterdam.nl/en/ai-register/) that track how algorithms are being used in the municipalities.

Black box AI is where AI produces insights based on a data set, but the end-user doesn't know how. Machine learning programs reach conclusions from the data provided, but it's not clear how the program came to them. The outputs of black box AI tend to be very accurate. This accuracy comes from the algorithms' complexity like deep learning algorithms. The underlying neural networks can be so complex that humans can't explain the outcomes, even if they prove accurate. The problem however lies in practical, legal, and theoretical consequences and end-users are less likely to trust and cede control to machines whose workings they do not understand (Burrell, 2016).

White box AI is transparent about how it comes to its conclusions. A data scientist can look at an algorithm and understand how it behaves and which factors influence its decision-making. As people have grown increasingly suspicious of black box AI, these models have risen in popularity. White box AI tends to be more practical for businesses. Since a company can understand how these programs came to their predictions, it's easier to act on them. Businesses can use them to find tangible ways to improve their workflows and know what happened if something goes wrong. Since white box AI insights tend to be more linear, they are often less radical or disruptive. They can still lead to reliable and helpful predictions but usually won't provide out-of-the-box, game-changing ideas. While they may not be as technically impressive, their transparency does provide a higher level of reliability and trust for the end user.

Example of an innovative Dutch AI company:

- Geronimo AI: The start-up Geronimo AI has helped the Central Government Real Estate Agency to provide insight into 45,000 hectares of leasehold land. AI is used to connect and analyse satellite images and data on crop growth curves, making it possible to see what is growing and thriving in each $10m^2$ enabling to enforce and issue building plans and to safeguard the soil quality and food supply for the future.

An overview of promising AI start-ups and scale-ups can be found on ai.nl[30], a Dutch community for artificial intelligence, innovation, digital transformation, data science and machine learning and on tracxn[31].

Example of AI applied in different areas:

- **Agriculture and food:** AI offers major opportunities in agriculture, horticulture and food supply, for example through further automation, precision agriculture, selection of new varieties, cultivation space without daylight and system integration. AI is also increasingly being used to better visualize purchasing and consumption behaviour.
- **Energy transition:** energy source selection in buildings, the role of electric cars in the energy system, fault detection in electricity networks and providing insight into the energy networks down to the core.
- **Mobility**: The use of AI is increasing rapidly in the automotive world, from under the hood (predictive maintenance) to the environment. Cars are evolving into self-driving programmable, connected platforms full of sensors that exchange data with other vehicles and with the infrastructure.
- **Water***:* to analyse water quality measurements in rivers (as done by the Dutch Water Partnership (see https://www.netherlandswaterpartnership.com/) a network of Dutch organisations, including government agencies, from the water sector with the goal to collaborate on developing sustainable water solutions); or obtaining objective real-time models describe the behaviour of the river bottom to predict the shallowest parts in a river up to several days in advance.
- **Healthcare**: medical imaging for diagnosis; to assess risks and flatten the COVID-19, e.g. to track and model the spread of the virus as well as t forecast future COVID-19 outbreaks.

The Netherlands has different regional economic development agencies (ROMs). The Innovation Quarter, representing the Province of Zuid-Holland, has conducted a mapping of the AI start-up/scale-up ecosystem for the province of Zuid-Holland (see the Figure 13 Figure 13below) covering 150 start-ups, about 25% of all AI start-ups in the Netherlands.

[30] https://www.ai.nl/ai-startups/

[31] https://tracxn.com/explore/Artificial-Intelligence-Startups-in-Netherlands

Figure 13 Data science and AI: Start-ups & Scale-ups Rotterdam - The Hague area[32]

An example of another regional development and innovation imitative dedicated to Artificial intelligence is the AI-hub Brainport[33] that brings companies, education and knowledge institutions and public organisations in the province of North-Brabant together to strengthen and connect activities around AI. It focusses on the sectors: Industry, Mobility and Health and covers more than 500 regional SMEs and internationals developing and applying AI, as well as world class knowledge institutes (Jheronimus Academy of Data Science, Tilburg University, TNO and TU/e (EAISI institute).

In addition to these regional initiatives there are several local initiatives, ranging from practical citizen oriented AI applications, like is done in the Amsterdam Intelligence Initiative[34] as well as research oriented initiatives, like the National Innovation Center for Artificial Intelligence (ICAI) [35] who strengthened the knowledge position of the Netherlands in AI.

The Dutch AI strengths are summarized in Figure 14.

[32] Source: https://www.innovationquarter.nl/greater-rotterdam-the-hague-area-hotspot-for-mission-driven-ai/

[33] https://brainporteindhoven.com/

[34] (https://www.amsterdamintelligence.com

[35] https://icai.ai/

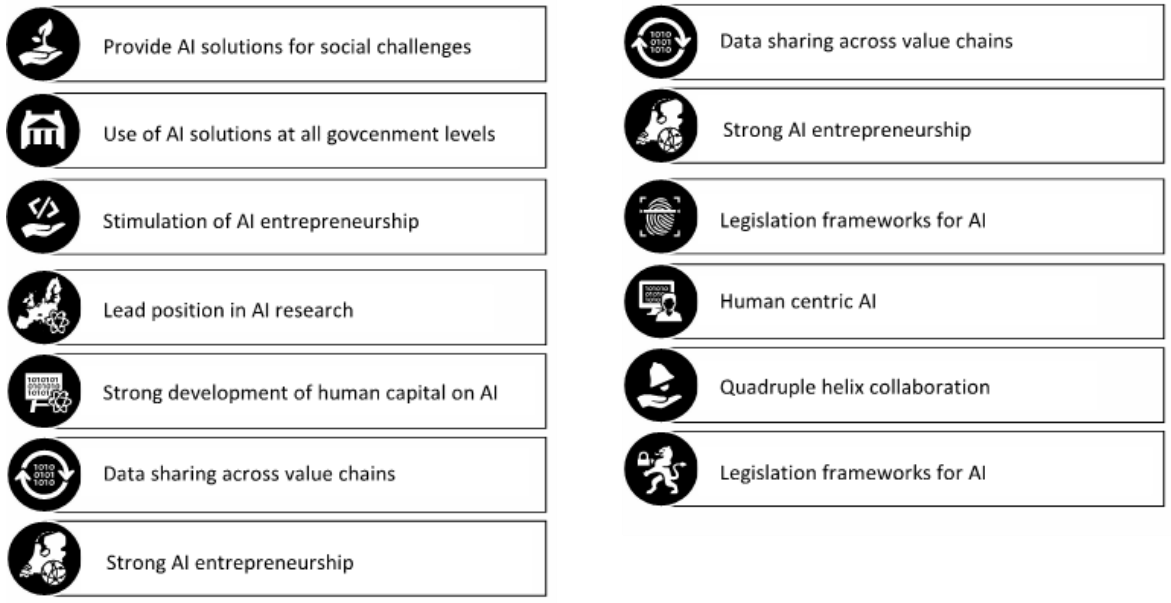


Figure 14 Dutch AI strengths

According to Oxford Insight[36] the Netherlands ranks 9th out of 172 countries with respect to AI readiness, and score exceptionally well on Vision, Data Representativeness and Data Availability (see Figure 15).

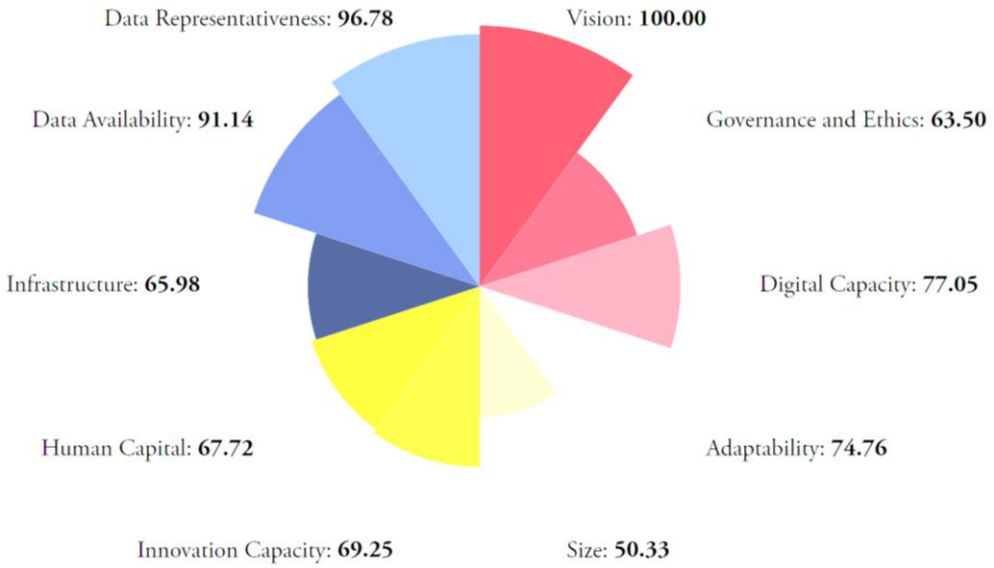


Figure 15 Netherlands AI Readiness[37]

Considering South Africa's AI readiness ranking of 59th collaboration between the Netherlands and South Africa will allow fast-tracking of the developments and usage of AI in South Africa. The relative scores for the two countries are summarised in Figure 16.

[36] https://www.oxfordinsights.com/government-ai-readiness-index-2020

[37] Source: https://www.oxfordinsights.com/government-ai-readiness-index-2020

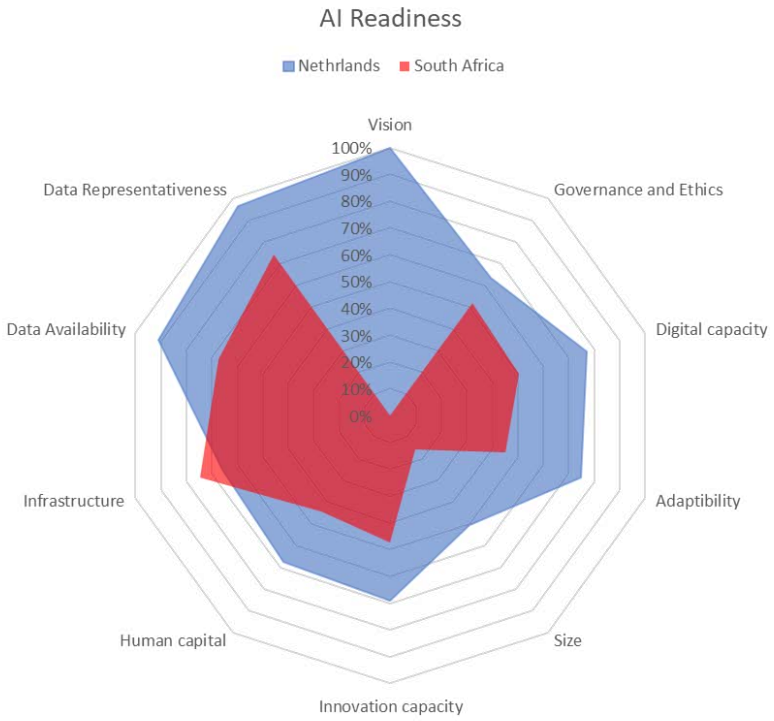


Figure 16 AI Readiness for The Netherlands and South Africa[38]

Other international AI rankings of countries, like The Global AI index[39], provide similar results with Netherlands ranked 8th and South Africa 55th. The Netherlands is also one of the frontrunners on AI publications. In terms of the number of AI scientific publications the Netherlands is ranked the 8th country of the world[40].

Dutch cities are leveraging AI for smarter and more resilient cities

An example how AI is applied in the area of resilient cities is the city of **Rotterdam**[41]. The Rotterdam Port Authority and the Municipality of Rotterdam have embraced the application of AI in the maritime sector in support of social goals, such as reducing Co2 reduction and other harmful emissions and improving air quality in the City and the Port. AI technology is essential for ensuring all information and handling of the physical flow of goods in the Port of Rotterdam can be dealt with completely digitally before 2030. Working towards smart - possibly autonomous - logistics transport solutions in the Port of Rotterdam and its hinterland, significant improvements can be realized in efficiency, energy consumption, air quality and, for example, environmental noise.

Another illustrative example is the use of AI in Rotterdam by the start-up "Energy Intelligence", they combined the data from the Basic Administration of Addresses and Buildings (Dutch BAG), satellite images, and aerial photographs, to map out Rotterdam's roof landscape for existing solar panels as well

[38] Own graph based on data from https://www.oxfordinsights.com/government-ai-readiness-index-2020

[39] https://www.tortoisemedia.com/intelligence/global-ai/

[40] https://aiindex.stanford.edu/vibrancy/

[41] https://www.resilientrotterdam.nl/en/

as the potential for additional solar panels as illustrated in Figure 17.

Figure 17 Mapping Rotterdam's roof landscape in terms of existing solar panels and the potential for additional solar panels by Energy Intelligence[42]

The City of **The Hauge** housing its (inter)national courts of justice and security organisations, is well known as 'the international city of peace and justice' and hosting the national Centre of Expertise Cybersecurity. The Hague has adopted Artificial Intelligence (AI) to apply it to different aspects of safety and security, ranging from digital security (confidentiality, integrity, availability of digital systems), physical security (safe citizens, physical infrastructure), and political security (freedom of speech, access to information). AI is used to detect, prevent, protect and to respond.

The city of **Amsterdam** has been named as one of the world's most AI-ready cities in the small cities category (less than 3 million citizens) in the Global Cities' AI Readiness Index[43]. Amsterdam has a world leading position applying Artificial intelligence in the fields of health (life sciences), business innovation (fintech) and ethics (human-centred approach to AI). Illustrative is the "AI Technology for the People" initiative designed to help the city develop and deploy responsible tech in the field of AI, and focuses on serving people working in health, business innovation and citizen support.

Dutch Companies also work overseas to strengthen other cities in their strive to be smarter and more resilience. For example, Royal Haskoning DHV, applies smart technologies and infrastructure to reduce

[42] Source: https://www.sobolt.com/solarsearch/

[43] (see https://www.oliverwymanforum.com/city-readiness/global-cities-ai-readiness-index-2019.html#)

the water risks and their impact shaping Smart Places and creating resilience in cities.

5.4 Blockchain

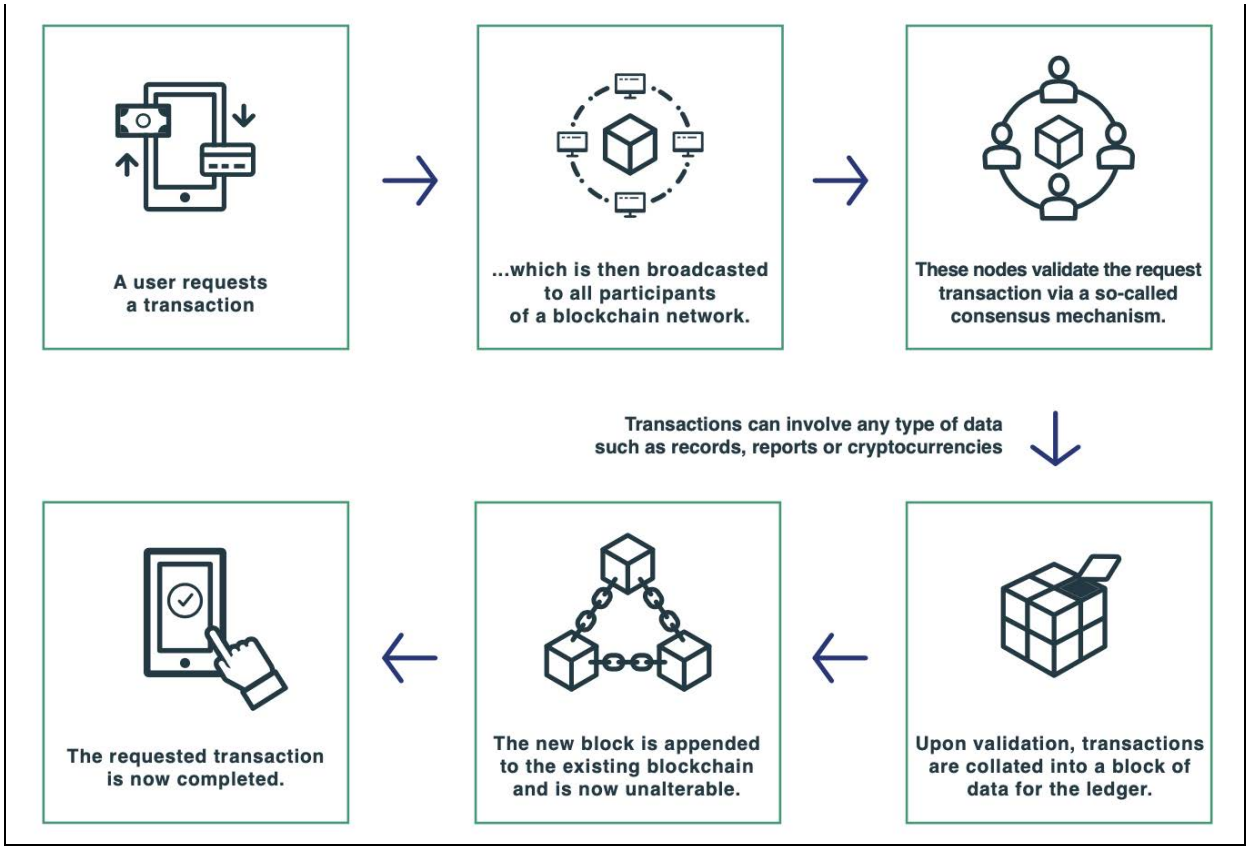
Another promising novel technology where the Dutch are frontrunners in Europe is Blockchain. Blockchain technology, introduced in 2008, can be used to build more sustainable, secure and reliable digital infrastructure. It makes it possible to manage data with complete security and without the need for a central authority (a central server). Blockchain technology refers to a specific form of distributed ledger architecture, which stores transactions in a list of blocks, which are linked cryptographically. Blockchain therefore also is often called distributed ledger technology.

What is Blockchain? [Source: (Smart Africa, 2020)]

As Blockchains are designed to be physically dispersed, the entries on a blockchain do not sit on a single server, but are at the same time distributed across many computers that form a network. This means that original copies of the same data are stored in different locations. Even if part of the network goes down, the ledger remains accessible to all other participants in the network. In fact, unless all nodes in the network go down, the integrity, availability and operability of the ledger as a whole is maintained. This is a strong resilience property. In order to ensure that these copies of the same data are fully identical and synced in real time, Blockchain technology makes use of various consensus mechanisms. This enables participating parties of the network to computationally find consensus on what information is stored on the blockchain, and, thereby, put trust in the system and in one another without actually having to know the other participants in the network. Thanks to these consensus mechanisms - and depending on their formulation - blockchains work without a centralised entity.

There are different types of blockchain technologies: public (open access: anyone can read/write) or private (restricted access) and permissionless (anyone can verify) or permissioned (trusted validators only). Choosing an appropriate Blockchain technology has to balance three interlinked aspects: scalability, security and decentralization (also referred to as the Blockchain trilemma).

Once a transaction is confirmed by the participating parties and written into the ledger, the protocol does not allow for any changes to be made after-the-fact. New information is saved in self-referencing blocks that are added to an add-only chain [see Figure below]. Previously stored information is not overwritten, and retrospective manipulation is nearly impossible in public and permissionless blockchains.



A first successful implementation of Block Chain technology is Bitcoin, a digital currency. However, Bitcoin is just one of the many applications of Blockchain technology. A more recent successful application is where refugees in war zones deposit their identity and diplomas on a Blockchain. Another application is using blocking to increase transparency for agro food producers and consumers regarding production methods and price-selling within the chain.

Other major use cases are:

- **Oil & Gas industry, post-trade settlement** (e.g. "VAKT": a consortium of oil companies and banks (BP, Gunvor, ABN-AMRO, Equinor, Koch, ING, Shell, Mercuria and Societe Generale);
- **Electronic bills of lading in shipping industry** (e.g. Wave; TradeTrust: a Dutch initiative from Port of Rotterdam and the BlockLab using a public Blockhain that connects governments and businesses to enable trusted interoperability exchanges of electronic trade documents across digital platforms to facilitate smooth international logistics collaboration)
- **Tracking the supply chain of food** (Fairfood, Scantrust)

Worldwide Blockchains for Money (financial gain, private property) and Blockchains for Control (collection of data, state control) are growing rapidly, but Blockchains for Good (public interest, collective ownership) are lagging (Dutch Blockchain Coalition, 2018).

Through the use of smart contracts (programmable transactions that run on and are part of the blockchain) offers new types of use cases become possible that automate and speed up the handling of

contracts with two or more parties dealing with digital assets at a fraction of the cost. Examples of smart contract blockchain uses cases are in property including the recording of the change of property ownership, handling mortgage transactions, processes for dealing with insurance claims, dealing with patient health records in a secure way, securing electronic voting process by validate voter's identity and record their vote.

Advantages of using Blockchain technology include:

- No trust needed in central authority, peer-to-peer verifiability
- Full transparency of all transactions: traceability and trackability
- Permanent, auditable record: certifiability
- Eases cross-border, only requires internet
- Strong resilience, no single point of failure
- Automated contracts at high speed and low cost.

According to the EU Blockchain Ecosystems Developments Report (EU Blockchain Observatory and Forum, 2020) the Netherlands has very strong Blockchain communities (20 000 participants in various Blockchain meet-ups), being among Europe's top performers when measured by the amount of funding secured by crypto asset and Blockchain start-ups (150+ startups secured €337+ million). The Blockchain start-ups work in a wide variety of areas, including payments, fintech (e.g. Finturi, a blockchain-powered trade finance platform), healthcare, education, supply chain location services (e.g.UNL), decentralised marketplaces (SingularityNET) and entertainment (iCasting). A large share of Blockchain startups operate on the intersection between Blockchain and other cutting-edge technologies, such as Internet of things and Artificial Intelligence.

In general, the Dutch government supports the adoption of Blockchain technology. Types of support include financing research and participating in public-private partnerships. Furthermore, the government has shown a willingness to reconsider the existing legal frameworks if they are not sufficiently flexible or do not mitigate the risks of technology to the extent required. In addition, there are several dedicated Blockchain educational programmes, like the Blockchain Summer School by the University of Utrecht School of Law and Blockchain masterclasses from the University of Amsterdam.

Examples of Blockchain use cases for the Dutch government are ship registers; grant administration automation; smart contract adoption; hazardous waste tracking and data protection. During the COVID-19 pandemic, Tymlez launched a project to support the government's transparency in medical supply chains through Blockchain technology. Dutch agriculture is also renowned for its efficiency. For example, there are projects in this area such as Blockchain for Agri-food that is financed by the Dutch Ministry of Agriculture, Nature and Food Quality to improve agri-food supply chains.

Example of Dutch Blockchain startups

- *Bitfury*: Designs and produces mobile bitcoin mining datacentres powered by custom semiconductor chips and proprietary liquid cooling appliances
- *Finturi*: Blockchain-powered trade finance platform acts as an intermediary between businesses who can use it to obtain financing backed by receivables and financiers.
- *UNL*: Mapping and navigation services provider. Data about the Earth surface and indoor spaces is stored on a Blockchain. Data is accessible through an API based on a virtual location IP address.
- SingularityNET: Aims to create a marketplace that connects AI algorithm developers and AI data providers and algorithm users. Developers can protect their intellectual property by wrapping

it into a smart contract.

- *Attrace*: Creating a smart contract-based affiliate marketing tracking system. The system will introduce transparency and auditability to the currently opaque process of advertising measurement
- *Aurus*: Creators of a gold-backed digital assets underpinned by Etherium Blockchain. The digital assets can be used both as a medium of exchange and as a store of value.
- *ICasting.com*: Blockchain-based platform that matches actors, models, extras, singers and dancers with the companies representing the world of entertainment. The talent matching process is based on both models' looks and their skills. Users include TV production companies, media groups, brands, media agencies and small business owners.
- *ReCheck*: Developer of Blockchain middleware. Stores and secures documents using Blockchain, and can be used to audit authenticity of documents and transfer ownership of the data.

However, as Blockchain technology is also very complex, and is still in its infancy: it has some limitations and challenges that are being researched intensively, the full potential can only be realised through open collaboration. In the Netherlands Dutch Blockchain Coalition is the leading collaborative platform in the area of Blockchain technology and usage.

The Dutch Blockchain Coalition is an innovation network, a collaboration of diverse partners from different universities, government institutions, and companies from different sectors, all of which were already busy experimenting with implementing the Blockchain technology at the start of the coalition. The DBC has more than 55 partner organisations[44].

The mission of the Dutch Blockchain Coalition is to realise fully reliable and socially accepted Blockchain applications, to create the best possible conditions to allow Blockchain applications to arise, and to facilitate the use of Blockchain as a source of trust, well-being, prosperity and security for citizens, companies, institutions and government bodies. The Dutch Blockchain Coalition mainly acts as a catalyst and facilitator in this process and activates its large public-private network for this purpose. (Dutch Blockchain Coalition, 2018).

Areas these partners cover with block chain use cases include: Mobility, Energy and sustainability (e.g. Peer-to-peer trading of electricity); Safety and security; Health and care, Agriculture and food (e.g. Tracing agricultural supply chains); Water; Digital Identity; Digital claims of identity and ownership (land registration; Verifiable digital education credentials, certificates and diplomas); Logistics (e.g. Trade facilitation by electronic trade documents).

The Netherlands is fully engaged in International Collaboration, e.g. with Germany, South Korea and Singapore. Partnering by international organisations with the DBC offers sharing Dutch best practices on decentralised public-private collaboration, while allowing to connect at multiple levels: Legal and regulatory; Governance frameworks for decentralized applications; Business models; Decentralized technology; Move from pilots to actual production.

Benefits of applying blockchain technology for cities include:

- Increased transparency and connectivity: Cities can interconnect using Blockchain vertical services, such as mobility, energy or security, through a single open, accessible, transversal system that is able to exchange data with their inhabitants in real time.

[44] https://www.dutchblockchaincoalition.org/partners

- Direct communication: Blockchain makes it possible for government departments and the public to interact digitally, without the need for intermediaries. This would speed up, for example, bureaucratic procedures at registries, town halls, etc.
- Participation: Blockchain guarantees the security, reliability, transparency and anonymity of public consultations, such as elections, surveys, referendums, etc.
- Integrity over information: With Blockchain technology it is possible to encrypt a file totally or partially in order to share only the part that is of interest, privately, securely and without the risk of its being manipulated by a third party.
- Efficient management: Blockchain allows both the public and city officials to know the origin and destination of each resource. In addition, the latter can find out how city services are being used without compromising people's privacy.

The Netherlands' strengths in Blockchain, according to the Dutch Blockchain Coalition, are:

- Mature ecosystem
- Regulatory framework in place
- Many blockchain related start-ups/scale-ups
- Front runner of developing block chain building blocks as well as realizing the conditions for actual use of block chain
- Excellent human capital development for block chain technology, and applications
- Implemented different real life block chain projects and has lot of best practices insights
- Active involvement and commitment of the public sector, that collaborates with corporates & knowledge partners in the triple helix
- Very active blockchain community with many thousands of participants
- Frontrunner in international collaborating on blockchain and cross border usage of blockchain technology.

6. Conclusions and Recommendations

6.1 Mapping Challenges to Opportunities

In Table 4 some of the most promising opportunities for the application of Dutch AI, blockchain and bigdata solutions to challenges in South African cities have been mapped. For each challenge or opportunity potential partners are listed. The table does not include specific companies but rather intermediary organisations that could provide links to appropriate partner companies as well as potential clients. To identify specific companies to partner with a good starting point is the companies already doing business with South African metros detailed in Table 5 in section 6.2 or the AI start-ups featured in Figure 9 in Section 4.3.

Table 4 Mapping challenges to opportunities

Sector	**Challenges**	**Opportunities**	**Partners**
Transportation and Mobility	Vandalism & security issues	AI for detection of metal theft	South African Metropolitan City Councils[45]
	Poor maintenance and aging rail infrastructure	AI for prioritizing preventive maintenance	Transnet PRASA CSIR
	Lack of planning and coordination	AI for improved decision making: create virtual models of transportation infrastructure and simulate traffic conditions to gain insights.	South African Metropolitan City Councils[45] CSIR COGTA
	Improving rail passenger services:	AI for: Predicting passenger volumes in public transport	PRASA
	Trends	**Opportunities**	**Partners**
	Non-motorised transport (NMT) infrastructure	AI for: Autonomous vehicles (AVs) for public passenger transport.	C4IR South Africa
	Road infrastructure improvement programmes	AI for: Prioritizing predictive maintenance, as a function of traffic, construction, and weathering. Smart signal control of traffic at road intersections, ramp metering on freeways, dynamic route guidance, positive train control on railroads.	SANRAL South African Metropolitan City Councils[45] CSIR

[45] Johannesburg, Cape Town, Tshwane, Ekurhuleni, eThekwini, Nelson Mandela Bay

	Promotion of integrated public transport	Blockchain for: mobility as a Service (MAAS) the integration of various forms of transport into a single mobility service accessible on demand.	South African National Blockchain Alliance (SANBA)

Sector	Challenges	Opportunities	Partners
Water management	Availability	Bigdata for: smart water metering AI for: Mapping forecasted demand and supply	CSIR
	Development and maintenance of infrastructure	AI for: Prioritizing predictive maintenance AI for: Predictive asset management programs. AI for: Water grid expansion design with optimal configuration.	C4IR South Africa
	Inadequate sanitation services	Blockchain for: utilizing reporting, compliance, and audit review.	SANBA

Sector	Challenges	Opportunities	Partners
Waste management	Weak enforcement	Bigdata for: evidence based waste collection	South African Metropolitan City Councils[45]
	Weak governance	Bigdata for situational awareness information on containers and dumpster trucks	South African Metropolitan City Councils[45]
	Low public awareness and negative attributes	Bigdata for: evidence based waste collection and feedback to citizens	South African Metropolitan City Councils[45]
	Service backlog	AI for prioritizing optimal waste collection activities based on forecasting and actual data	South African Metropolitan City Councils[45]

Sector	Challenges	Opportunities	Partners
Energy management	Availability	Bigdata for: smart energy metering AI for: Mapping forecasted demand and supply including smart purchase of blended supply	South African Metropolitan City Councils[45]
	Energy theft	Bigdata for advanced energy metering infrastructure	South African Metropolitan City Councils[45]
	Development and maintenance of infrastructure	AI for: Prioritizing predictive maintenance	South African Metropolitan City Councils[45]

		AI for: Predictive asset management programs. AI for: Energy grid expansion design with optimal configuration.	
	Trends	**Opportunities**	**Partners**
	Decentralized / off-grid energy solutions	Blockchain for peer-to-peer trading of (renewable) electricity.	SANBA

Sector	**Challenges**	**Opportunities**	**Partners**
Health	Lack of capacity, supplies, equipment	Bigdata for: smart supply chain management	South African Metropolitan City Councils
	Lack of Monitoring and evaluation	AI for: assessing health risks and predicting disease outbreaks	South African Metropolitan City Councils[45] CSIR National Department of Health Department of Planning, Monitoring and Evaluation (DPME)
	Trends	**Opportunities**	**Partners**
	Digital health	AI for improved diagnosis Bigdata for: Electronic Health Records (EHRs) and improve population health management Blockchain for: identity verification; supply chain management; managing dynamic patient consent and data sharing and access permissions	National Department of Health Provincial health departments CSIR C4IR South Africa SANBA
	M-health	Bigdata for: Enabling remote patient monitoring and Telemedicine	mLab SA Silicon Cape

Sector	**Challenges**	**Opportunities**	**Partners**
Safety and security	Lack of safety in public space	Bigdata for: situational awareness AI for detecting abnormal behaviours /situations	SaferSpaces CSIR
	High crime rate	AI for: facial recognition AI for: predictive crime models	CSIR SANBA

		AI for: assessing health risks and predicting disease outbreaks Blockchain to act as an evidence locker	
	Increase in cyber security threats	AI for: detecting attacks and abnormal network traffic Blockchain to: Combat cybersecurity threats	South African Banking Risk Information Centre (SABRIC) SANBA

Sector	**Challenges**	**Opportunities**	**Partners**
Communication, Inclusivity and Community involvement	Insufficient skills and experience within government to engage with civil society	Bigdata to: Share community relevant information in an easily accessible manner	SA Cities Network South African Metropolitan City Councils[45]
	The lack of innovative, co-produced solutions to service delivery dissatisfaction	Blockchain based tokenized incentives as rewards to empower people as well as encourage community participation.	SANBA
	Inadequate use of forums to promote participation and social cohesion	Human centric AI, is an inclusive approach that puts the human in the centre to provide trustworthy and reliable AI to protect the interest of humans and society that includes societal awareness, legislation awareness as well as experimenting and learning.	SA Cities Network South African Metropolitan City Councils[45]
	Inadequate provision of quality public spaces	Bigdata to: Share community relevant information in an easy accessible manner	SA Cities Network South African Metropolitan City Councils[45]
	Trends	**Opportunities**	**Partners**
	Initiatives to enable citizen engagement	Bigdata to: allow citizens to provide feedback and for the city to share relevant information via a mobile accessible city portal / application.	SA Cities Network South African Metropolitan City Councils[45]

Sector	**Challenges**	**Opportunities**	**Partners**
Urban Governance and City Planning	Poor planning	Bigdata for: insight in resource usage AI for: simulations, forecasting future scenarios of proposed urban developments.	SA Cities Network South African Metropolitan City Councils[45]

	Lack of transparency in tendering	Blockchain for: Tracking public spending in a in a collaborative and transparent manner.	SA Cities Network South African Metropolitan City Councils[45]

6.2 South African ICT Companies

South Africa has a well-developed ICT sector that includes several multinational and local companies. To assist Dutch companies in selecting potential partners in South Africa recent tender awards have been analysed in three of South Africa's major metros: City of Johannesburg, City of Cape Town, and eThekwini. The result of this analysis is presented in Table 5.

Table 5 Recent ICT tender awards by mjaor South African metros

Name of Company	Metro	Name of Project	Year
Med-e-Mass (a Division of Altron TMT)	CoJ	Appointment of a Suitably Qualified Service Provider to Supply, Install, Maintain and Support an Electronic Health Record (HER) System for the City of Johannesburg Health Department	2016
EOH Mthombo (Pty) Ltd	CoJ	Appointment of Service Providers for the SAP Implementation/Upgrade	2016
Gijima Holdings (Pty) Ltd			
Propsperosa Consulting (Pty) Ltd	CoJ	Appointment of a Service Provider for Tourism Web-Hosting, Further Development, Maintenance and Support of the Tourism Websites and Digital Platforms including online Marketing activities and SEO	2016
Dimension Data (Pty) Ltd	CoJ	Request for Proposals for Outsourced Information Technology Services	2016
Advanced People and Projects	CoJ	Upgrade of CoJ data centres (renovate, supply, install, commission of the data centre facilities for a period of 6 months and support for a period of 3 years	2016
SGH Media	CoJ	Appointment of Service Provider for Upgrade, Re-design, Maintenance and Hosting, Content Development and Management of Rea Vaya Website	2016
Vukani Technologies	CoJ	The Appointment of a Supplier(S) To Supply, Deliver And Maintain ICT Hardware On An As And When Required Basis Over a Period Of 24 Months	2017
Transport Telematics Africa (Pty) Ltd	CoCT	Provision of Professional Services: Supervision of final design, supply, installation, testing and commissioning of the Automated Fare Collection (AFC) System and other related services	2020
Transport Telematics Africa (Pty) Ltd	CoCT	Provision of Professional Services: Supervision of maintenance (including	2020

Name of Company	Metro	Name of Project	Year
		installation and commissioning) of Advanced Public Transport, Information and Security Management System on Buses, Stations and in the Transport Management Centre	
Tzars Security Solutions (Pty) Ltd	CoCT	Supply, installation and maintenance of security alarm systems	2020
Dimension Data (Pty) Ltd as the primary service provide	CoCT	Provisioning of network monitoring services for the City of Cape Town	2020
Dimension Data (Pty) Ltd and Altron Nexus (Pty) Ltd t/a Bytes System Integration	CoCT	Provision of System Integration, Project Management and Managed Networks Services for the City of Cape Town	2020
Dimension Data (Pty) Ltd	CoCT	Maintenance and Installation of Integrated Facility Management Enterprise System for the City of Cape Town	2020
SP Practice Consulting Services (Pty) Ltd t/a SPPRAC-Specialised Project	CoCT	Provision of SAP Services – Schedule C Implementation Services (Panel of Partners)	2020
Storage Technology Services (Pty) Ltd, Dynamic Recovery Services (Pty) Ltd, IT Naledi Solutions (Pty) Ltd t/a IT Naledi Infosec, and Nclose (Pty) Ltd	CoCT	Supply, support, maintenance, of ICT security related infrastructure, software, supply, support, maintenance of ICT security related infrastructure, software, services and licensing	2020
First Technology (Pty) Ltd; Datacentrix (Pty) Ltd; Altron TMT (Pty) Ltd; Xon Systems (Pty) Ltd; and Dimension Data (Pty) Ltd	CoCT	Data Network Devices and Services	2020
Xon Systems (Pty) Ltd (Primary Service Provider)	CoCT	Maintenance of Telecommunications Facilities for the City of Cape Town	2020
Public Discipline and Integration t/a PDIT	CoCT	Maintenance of CCTV Systems and Equipment for the CT Metropolitan Police Department	2019
Universal Knowledge Software (Pty) Ltd	CoCT	Supply, Installation, Migration and Support of a Integrated Library Management System	2019
Systems Technology (Pty) Ltd		Procurement by the Telecommunications Branch of Proprietary Licenses as well as License upgrade and update support for the GE Smallworld Geographical Information System (GIS) Spatial Planning Tool	2019
TMT Services and Supplies (Pty) Ltd	CoCT	Design, supply, installation, commissioning, maintenance and operational support of the MyCiti Advanced Public Transport Management System (APTMS)	2019
CityWorks (Pty) Limited	eThekwini	Procurement of maintenance and support services for the	2020

Name of Company	Metro	Name of Project	Year
		revenue management system	
ABB Power Grids (Pty) Limited	eThekwini	Upgrade and enhance ellipse enterprise asset management system from version 8.4 to version 9 for the electricity department - Addendum report	2020
Senreques (Pty) Limited	eThekwini	Ethekwini Corporate website design, develop, deploy and migrate content	2020
Freshmark Systems (Pty) Limited	eThekwini	Procurement of supply, deliver and commission trading systems software and database management services and support for bulk trading operations	2020

6.3 Recommendations on way forward

A good starting point for Dutch companies to be prepared for doing business with South Africa partners is the official South African website about doing business in SA[46] and the overview "Doing Business in South Africa" (2021), Commissioned by the Netherlands Enterprise Agency[47], see the box below for the key points.

Key points from "Doing Business in South Africa" (2021)"

- The Dutch government also provides a number of support instruments to assist Dutch businesses in South Africa. In addition: there are regular trade missions and visits to South Africa organized by RVO and/or third parties and the Embassy & Consulate General regularly organise networking events for Dutch businesses with South African counterparts.
- High Potential sectors for doing business: Agriculture, raw materials & horticulture; Water; Transport & logistics; Life sciences & Health; Energy; Creative Industries
- A good personal relationship will provide a solid foundation for further cooperation and will make doing business in South Africa easier.
- The first step to take when starting up a business in South Africa is applying for a business permit.
- South Africa has different business entities: Public (name ends in "Ltd") or private ("Pty Ltd") company, Personal Liability Company ("Inc"), Partnership, Business trust, Sole proprietorship and External company (branch of a foreign company).
- Use the BizPortal platform developed by the Companies and Intellectual Property Commission (CIPC) to offer company registration and related services in a simple seamless digital way which is completely paperless (see www.cipc.co.za)

[46] https://www.doingbusiness.org.za/

[47] https://www.rvo.nl/sites/default/files/2020/11/Doing-Business-in-South-Africa-2021_1.pdf

- Comprehensive tax information is available on the website of the South African Revenue Service (SARS) (www.sars.gov.za).
- South Africa's labour laws are procedurally cumbersome. A good working knowledge of the relevant legislation is therefore a prerequisite, but given the complexities thereof, the assistance of labour lawyers or consultants is also advised. The relevant acts as well as practical guidelines are freely available on the Department of Labour's website (see www.labour.gov.za).
- Issues affecting business in South Africa: Skills deficit and inflexible labour laws; Corruption; Government decision-making processes; Service delivery; Crime; HIV/AIDS.
- Companies do require a Corporate Social Responsibility (CSR) policy to contribution to socio-economic development, i.e. 1% of net profit before tax should be spent on social development.

In order to do business with a South African City/Municipality for a Dutch company, there are some aspects to take into account:

- Broad Based Black Economic Empowerment (BBBEE) is a government policy aimed at the economic transformation of South Africa through the increased participation of previously disadvantaged people at all levels of the economy. BBBEE aims to redistribute management, ownership and control of economic and financial resources in order to decrease income inequalities. BBBEE is enforced through a system of preferential procurement; companies that do business with government therefore prefer to buy from BBBEE compliant businesses[47].
- Procurement is done via tendering by cities, but for companies to be eligible they first have to quality / been selected to be part of a shortlist of approved (preferred) suppliers where to buy goods/services from. This will be periodically opened up. See for example, the Tender Process for the City of Johannesburg[48] and general information about tendering in South Africa[49].
- In addition to the procurement / approved list, cities can do business with SA government entities, state owned enterprises or research institutes. This would require companies to register on the Central Supplier Database (CSD), which is a database of organisations, institutions and individuals who can provide goods and services to government[50]. The CSD will serve as the single source of key supplier information for organs of state from 1 April 2016 providing consolidated, accurate, up-to-date, complete and verified supplier information to procuring organs of state.
- In case there is a NL-Government to SA-Government agreement (like was the case between Department of Science and Technology and the Netherlands Government in 2015) or City-to-Government (Dutch city with SA Government) then the city can utilize this mechanism.

As there is currently no such bilateral Government to Government agreement in place, it practically means for a Dutch company to:

1. Enter into a partnership with companies/organisations that already are on the approved supplier list of the City/South African Government.
2. Establish a presence in South Africa (with the requisite BBBEE representation), by starting a legal enterprise and apply to become an approved supplier for the city.

[48] https://joburg.org.za/work_/Pages/Work%20in%20Joburg/Tenders%20and%20Quotations/Tenders-and-Quotations.aspx

[49] https://www.sa-tenders.co.za/hint-tips-and-news-categories/procurement-regulations

[50] https://secure.csd.gov.za/]

3. When being able to prove that the Dutch company's solution is a sole source solution (only the Dutch company can supply the commodities, technology and/or perform the services required), the tendering process can be avoided, the city can engage in a specific procurement process directly with the Dutch company. The Dutch company however needs to provide proof that there's no one else in the market that has their type of solution. In reality, South African city's only have a limited number of sole source contracts.
4. Use the city's data, via their open data portal process, to utilize the companies innovative ideas to take them into the Dutch company's commercial space(s). City's will have specific requirements when using their open data, like it should benefit their citizens.

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Appendix 1 Smart City of Johannesburg Case Study

1.1 Smart City of Johannesburg

The City of Johannesburg (CoJ) has a Smart City strategy developed in 2014, which was updated in 2018, to address the needs of the City for the following ten years. The Smart City specific outcomes are to achieve an *inclusive and diverse city,* which is *sustainable, liveable, and resilient*. The Smart City of Johannesburg strategy is based on the following pillars:

- Citizen centric/ Smart Citizen;
- Connected Intelligent City;
- Safe city; Smart Governance;
- Smart institution;
- Sustainable Liveable and Resilient City;
- Smart Services (24/7); and
- Digital/Smart Economy.

Figure 18 Panorama of the City of Johannesburg with the Nelson Mandela bridge in the foreground

1.2 Strategic Aim

The aim of the CoJ's Smart City Programme is to substantially improve the city's benchmarks and establish a well governed and managed City that is efficient and responsive in a transparent way. The aim is derived from the National Development Plan (NDP) and the Gauteng Provinces Transformation, Modernisation and Reindustrialisation (TMR) programme which emphasises the need to effectively deal with poverty, inequality, and unemployment. The Integrated Development Plan (IDP) process allows for the alignment of these objectives to ensure genuine transformation. The local government mandate is guided by the relevant legislation, however, there is a constant need for review and reflection on strategy, structures and systems which are optimal for efficient service delivery. This is the basis for the

strategic agenda of the City of Johannesburg, as outlined in the Joburg 2040 Growth and Development Strategy (GDS) and the Integrated Development Plan.

1.3 Objectives, Aims and Priority areas of the Smart City Programme

The objective of the Smart City Priority is to grow Johannesburg's ability to provide services that are easy to access and use, while being efficient and responsive in a transparent way. If implemented in full, this priority will establish a 'fully fledged smart' city targeted to achieve the following **key outcomes**:

- Improved social development (e.g. through the provision of internet access in places of learning);
- Service delivery efficiency (e.g. via smart-metering for water and electricity services, e-services, and widespread access to broadband);
- Better decision-making (e.g. through the integration of city-wide data into a single view – allowing for holistic planning, preventative actions and improved responses in the context of areas such as safety and mobility);
- An increase in economic activity (e.g. through providing the necessary technology and connectivity for businesses and entrepreneurs to thrive);
- Active citizen participation and engagement (e.g. through a 'single city wide' user-friendly Joburg mobile as well as web Application); and
- The creation of a sustainable and liveable environment (e.g. via technological options that improve resource use, and that allow for planning aligned to urban trends and pressures).

To date, the city has focused on establishing a clear roadmap for delivery of the smart city programme, with emphasis placed on a holistic, multi-disciplinary, citizen- and people-oriented approach – supported by the necessary infrastructure, connectivity and resources.

Underpinning this vision for the Smart City is also the **priority areas**, which are:

- Affordable internet access (broadband/Wi-Fi)
- Integrated e-Services (e-Government)
- Smart mobility (intelligent public and private transport, and traffic management)
- Smart green infrastructure (smart electricity grid and renewable energy, smart water and sanitation management, smart waste management, etc.)
- Smart public safety (smart policing, smart emergency and disaster management, and resilience

1.4 Smart City Projects

The Smart City Projects are deemed as Catalytic Projects/Programmes, which is defined as a project of significant scale (i.e. its reach) and scope (i.e. impact on employment, services, economic and social investment, and/or rates), thereby displaying some or all of the following **characteristics**:

1. It makes a substantial impact,
2. It provides leverage and/or creates multiplier effects,
3. It has the power to radically activate development (social, economic or both),

4. It significantly impacts spatial form,
5. It creates jobs, and increases land value; and
6. contributes to the achievement of the vision and goals of the City

It is also acknowledged that projects cut across these goals and objectives and seldom only contributes to a single goal or objective. It is for this reason that it is imperative for prioritisation purposes, to give specific preference and attention to projects that impacts on as many as possible of the strategic goals of the City.

It is further recognised that there are different categories of Catalytic Projects. Some are mostly government projects driven through social need and demand, whilst others are largely private sector driven to capitalise on economic development opportunities.

In this context three types of **catalytic projects** have been identified:

- Game Changers
- Major enablers
- Major Needs (of a high order or significant magnitude)

Game changers and *Major enablers*, are inherently considered catalytic projects because they act to catalyse upstream and downstream economic and social activities. Major Needs/Projects are not necessarily catalytic and must fulfil other objectives to be considered catalytic. This however does not detract from Major Needs projects being significant, or needing to be prioritised.

A dedicated Smart City office oversees the Smart City Integrated Implementation Plan (SCIP). Through the SCIP, the city of Johannesburg has defined 10 catalytic programmes that form the backbone of the Smart City of Johannesburg:

1) Joburg Connected: (Broadband, Wi-Fi, Fibre to Home, Networks & Citizen Access)

The aim of the Broadband/WiFi Network project is to ensure the availability of affordable broadband connectivity throughout the City, which will support socio-economic development through accelerated growth, expanded productivity and enhanced quality of life for all. The city has established the broadband network for the purposes of lowering its own costs and increasing access to telecommunications services for residents in the city thereby stimulating economic development and improving city service delivery. The broadband assets of the City are housed in municipal owned entity, known as MTC. The network WiFi/broadband will be a combination of wired (fibre) and wireless (WiFi). Besides the wired (fibre), wireless broadband infrastructure plays an important role to connect the last mile, for example to traffic lights, streetlights, Close-Circuit Television (CCTV) cameras and any other sensors, but also to provide people access while on the move, for example, in the connected buses. The broadband assets and capability of the city assists it in a number of different areas, such as:

- Broadband enables changes in how the citizens access educational resources, collaborate in the educational process, conduct research and continue to learn anytime, anyplace and at any pace.
- Broadband can also help bring communities together and improve public safety, create a greener planet, and make our transportation systems more resilient and efficient.
- Broadband enables new business models, creates business efficiencies, drives job creation, and connects manufacturers and store-fronts to clients and partners worldwide.

The target for the city is to eventually have full access to affordable Internet services across city-owned buildings (across all libraries and clinics) and significant rollout of wi-fi access. The WiFi/Broadband Access program deals with the roll out of affordable Internet connectivity (wired and wireless) as well as utilizing technology to eradicate the digital divide. The improved access to broadband throughout the City also enables economic growth. The aggressive rollout of free Wi-Fi services to the City's residents is on track, with provision of free Wi-Fi to all identified economic nodes, townships, and informal settlements.

Furthermore, the objective of the WiFi/Broadband Access programme is to:

- Increase the competitiveness of business.
- Increase the usage and penetration of high-speed broadband connectivity.
- Facilitate the growth and development of new and existing ICT businesses.
- Improve the marketability of CoJ as an attractive investment destination.
- Increase and accelerate access to the benefits of Internet based communication.
- Achieve digital inclusion.
- Reduce the costs of CoJ and improve service delivery

2) 4IR Citywide Skills Development Programmes

The City has initiated a citywide programme to initiate and implement 4IR projects across the city. The two major universities located within the city region are also driving these initiatives (University of Johannesburg and University of Witwatersrand), both of which have made significant investments in this space. The city also promotes Skills development of own staff which is crucial for a smart institution. Different departments and Municipality entities require that their staff need to be capacitated to deal with the changes Smart City programs that will bring. This ensures that dependency on outside expertise is kept at a minimal whereby the departments and agencies stimulate staff up-skilling programs as soon as possible.

Some of the initiatives that the City is promoting are:

- Skills Programmes access in the entire city of Johannesburg through online courses and universities.
- Integrated bi-directional citizen engagement (one stop shop) allow seamless online interaction via e-services, with enhanced feedback.

3) Smart Citizen: (Digital Literacy, Data & Device Access)

The Smart Citizen program has three major projects: ICT literacy, Public Access to Internet, Innovation and research support, and Citizen engagement. To promote ICT literacy by providing personal assistance/guidance via e-learning programs in public spaces, (including libraries) that are equipped with terminals that are connected to the broadband Internet. The goal is to bridge the digital divide by enabling communities to participate in the knowledge economy (access to email, global information) providing free access to electronic information to technology-poor communities.

E-Learning initiatives and online education services (distance learning, online classes, e-Registration to tertiary institutions, digital content for school children) removes the high material costs for students and therefore contributes to a more cost effective learning solution. This opens up the opportunity for more people to study consequently improving their skills especially those from disadvantaged communities and provides flexible learning (students determine where and when to study).

In addition to providing free Public Access to the Internet, access to information and dedicated services is provided as well as learning in a safe and secure environment with regulated usage (for different age groups and restricted time per turn). The project provides training interventions to ensure that community members are techno-literate (computer and information literacy skills) as well as train selected youth who will assist community members especially children in navigating electronic resources.

The project will bridge the digital divide by providing technology and free access to electronic information to technology-poor communities and by promoting e-Government initiatives through encouraging meaningful participatory governance / two-way dialogue between City and its citizens.

Citizen engagement requires the city to have a proper strategy of how to reach out to its citizens, without competing between the different departments and Municipality Entities that want to have their own communication channels to their customers, like via an own mobile application.

Development of an application environment that enables platforms that promote active engagement with citizens as co-creators, improved communication, accessible information, and services, such as:

- Citizen engagement driven innovation (living lab)
- Smart Delivery and management of Electricity, Water, Billing & Payment, Digital Policing, Social Benefits, Waste
- Public Safety incl. preventive
- City wide e-health patient records interoperable with national Department of Health
- Integration and centralisation of Public Safety information at the IOC leading to enhanced crime prevention.

4) Safe Joburg – People, Infrastructure, Assets: (Technology Enabled Safe City Programmes)

CoJ has piloted a Safe City Programme that uses a combination of smart devices, such as cameras to enhance Safety and security (services to keep citizens and businesses safe and secure) including emergency response and disaster recovery. The aim is to increase the levels of public safety and sense of security experienced by residents of the City. This includes smart police cars that are linked to the Integrated Intelligent Operations Centre. The Programme also piloted the use of wearable technology on police offices, such as body cameras to further increase the trust of citizens in the police. The Programme was trialled in one area of the City and further expansion was planned in line with budgetary considerations.

5) Co-Production Innovation Pipeline

The City has planned a co-production innovation pipeline that will enable citizens in co-creating solutions with the city. Part of this Programme is driven by the City and the Tshimologong Precinct, which is a digital innovation ecosystem in Braamfontein, Johannesburg, that propels entrepreneurship and grows the skills pipeline for the digital economy through collaboration with academia, corporates, government and entrepreneurs. It provides skills and on-the-job training for unemployed youth while accelerating the growth of digital enterprises at every stage of their business and creates a pathway for

students and entrepreneurs to showcase their work publicly and access commercial opportunities. The City has run an annual co-creation programme with the Precinct and as part of that, there is an annual awards ceremony for the best innovation in the City.

The implementation of the Smart City concept is a never-ending journey to become smarter all the time, hence it is a continuous process. Innovation and research play important roles to keeping up with the latest knowledge, insights and the application of novel technical possibilities.

Within the City, Innovation and research is methodologically supported, with proper testing and piloting before launching and scaling up. A staged gate funnel approach is used for this in combination with an urban living lab (in partnership with universities) to get buy-in of the citizens.

The stage gate phased approach, covers the discover, develop and deployment phases, where each transition to the next phase is controlled by a stage gate, selecting the most promising project to be passed onto the next phase.

6) Unified Data & Information Portal

The Intelligent Operations Centre (IOC) is aimed at providing an integrated view on the city's strategic and operational issues through effective information gathering, processing and efficient dissemination of intelligent information allowing for well-coordinated, integrated and responsive service delivery. The IOC should leverage information to make better decisions, engages with people to co-define "what is important", coordinates resources and processes to operate effectively and anticipate problems to resolve them proactively and manage risk.

The IOC will allow databases and manual processes to be automated across all city departments, including setting data standards and create a dashboard to deliver a single view of data/information across departments. The IOC provides a common operational picture: a dashboard view of the city utilizing using all available input (ranging from CCTV cameras to citizens call reports), supports trend analysis & decision support as well as predictive analytics. It allows for effective dispatching of services across the city (real-time, planned maintenance) as well as opportunities to up-skill and train staff via simulations and scenarios.

The Unified Data and Information Portal Programme seeks to deliver the following:

- Smart Institution implemented
- Establishment of good processes and practices
- Better decision-making (e.g. through the integration of city-wide data into a single view – allowing for holistic planning, preventative actions and improved responses in the context of areas such as safety and mobility).
- In house Data Analytics, Monitoring & Evaluation
- Asset management & e-maintenance
- The rollout of the City's Work seekers' Database which is fully operational Work seeker's Database accessible to all City residents

7) Green, resilient and Sustainable Joburg: (Infrastructure, Energy, Water, Waste, Food, and Climate Change

One of the goals of the city is to provide a reliable, quality supply of electricity, water and sanitation to residents and businesses on the grid. A large amount of (Capex) is spent on refurbishment of electrical

and water infrastructure. One part of the Programme focuses on Smart Utility meters. The goal of the smart electricity meters' project is to replace for certain categories of customers their conventional meters with smart electricity meters. These smart meters will allow remote monitoring and reading and alarms will be sent to the Power department if meter tampering occur.

Smart electricity meters has clear benefits for the electricity utility provider and the city, increasing revenue and reducing cost, (reducing peak demand offers load balancing, determining leakages/losses) as well as enabling new possibilities. Smart Electricity meters provide the City with a better understanding of the customers, while the customers obtain better insight in their own energy consumption patterns.

The goal of the smart water meters project is to replace for certain categories of customers their conventional meters with smart water meters. These smart meters will allow remote monitoring and reading by the Water utility provider. Smart water meters have clear benefits for the water utility provider and the city, increasing revenue and saving cost (determining leakages/losses) as well as enabling new possibilities.

Other parts of the programme focus on the Utilities including:

- Energy (infrastructure for production and distribution), increased installation of new public lighting in the City with working public lights for every pavement. Decreased public lighting downtime and to have public lights repaired or replaced quickly.
- Water and waste water (infrastructure for collection, distribution, use, reuse, recycling) and
- Waste management (collection, distribution, reuse and recycling of waste materials)

There numerous initiatives around green energy and sustainability, posited around climate change, the national government is now allowing municipalities to build their own renewable energy plants and the city has expressed its desire to become less dependent on the national electricity supplier (Eskom) and start to self-generate electricity for its own needs. There has also been projects that focussed on the circular economy and zero-waste projects that were initiated in the city, one of those projects which was trialled utilised waste material in developing road tar, which was then used to construct a road in the city.

8) Digital Joburg & Smart Governance: (24/7 City, Digital Government, Smart Governance, Data Driven & AI Enabled & Smart Services)

The Smart Institution/Governance program involves the creation of real-time platform that ensures business process integration related to data governance, ICT architecture, skills development and change management across all departments and provincial and Municipality Entities are well coordinated. This involves the following:-

- Interoperable ICT architecture & platform adopted across the city
- Common data governance implemented: overview of available data; data access; data sharing & re-use; data interoperability
- Citywide ICT enablement of interoperable infrastructure
- On-boarding & integration of multiple domains & entities into the IOC .
- The fast-tracking of the smart citizen service delivery app to reduce pressure upon customer care facilities

- The effective launch of the smart citizen service delivery app.

Part of the Programme focused on creating a responsive administration focused on delivering service with pride to the City's residents which focussed on the fast-tracking of the SAP rollout plan throughout the City.

9) Smart Integrated Nodal Economies, Services and Spaces

Key Areas of this Program was focussed on:

- Providing Digital Advantage to the Citizens.
- Provision of internet access in places of learning
- Online access to education enhances changes for (self) learning and employability for the youth.
- The expansion of extended hour libraries and clinics within the City. All of Identified City libraries and clinics operating with extended operating hours.
- Implementation of the City's Substance Abuse Strategy. All of Identified City clinics providing care to substance abuse victims.
- The significant improvement in the ease and experience of doing business in the City which meant an achievement of targets of all Business-Friendly Service Standards
- Implementation of investment facilitation programme and the establishment of a One-stop-shop for Investors red-carpet service.
- Expanding the reach and rollout of the basket of services offered to SMMEs via the City's Opportunity Centres with a target of two Operational Opportunity Centres per region offering a full basket of services.

10) Smart Mobility

The City has focussed on a number of projects in this space, such as a pilot Smart technology enabled transport through an Intelligent Traffic Management System (ITS) to address the current issues and envisaged future problems relating to traffic flow. The benefits to travellers and freight users will need to been given priority during the process. As both the population of city and the number of households with access to private cars will continue to increase over time, the pressure on the available road network will increase. Using ITS (including road side systems and Traffic Management Centre (TMC)) is needed to optimize traffic flows by operational traffic management.

The smart technology enabled transport will improve the throughput and flow in the city avoiding congestions, improve reliability and uptime traffic management systems (and traffic lights) and improved information provisioning to citizens (traffic conditions, real time BRT bus schedules) and other stakeholders.

Another project is The "Corridors of Freedom" which will transform entrenched settlement patterns which have shunted the majority of residents to the outskirts of the City, away from economic opportunities and access to jobs and growth. In this way the city will be re-defining and re-stitching the City together to create a new future. Having pioneered the first Bus Rapid Transit system in Rea Vaya, the City is now taking transit-orientated development a step forward, with a view to forever changing the urban landscape of Johannesburg and eradicating the legacy of apartheid spatial planning.

There are also plans to increase the rail network of the high-speed train (Gautrain) that will see it expand further east, west and south of the City.

11) Bigdata Analytics in the City

There is a dedicated Data analytics unit within the Monitoring & Evaluation (M&E) unit in the CoJ that develops and maintains departmental and entity related performance database sets, (through collecting relevant data per department, municipal entity, region and ward performance data). The aim is to analyse data on M&E across all city functions and entities to develop a holistic data view of the city's progress towards its strategic goals.

These data sets enable up-to-date performance and data profiling and presented using visualization tools. In addition, data analytics is applied to derive insights allowing well-informed decision making by internal and external stakeholders. For example, from the analysed data, insights are derived to identify trends based on CAPEX for monitoring and evaluation of projects allowing to easily identify project performance and to conduct site visits closely monitor service delivery.

Appendix 2 Smart City of Cape Town Case Study

2.1 Smart City of Cape Town

The City of Cape Town (CoCT) has a well-established digital economy and hosts many South African start-ups and venture capital companies resulting in a highly skilled workforce in tech-related fields and a concentration of investment into tech-related business providing an environment where tech-innovations can take root.

In the early 2000s, the CoCT initiated its first 'Smart City Strategy' with the aim of achieving City objectives such as job creation, economic growth, improving resident's engagement as well as building a system of high-quality public services that could be made accessible to a wide range of citizens. Since then, the "Broadband" project and the "SmartCape" initiative have addressed the digital divide and providing access to internet connectivity and technology.

Figure 19 Panorama of the City of Cape Town with Table Mountain in the background

2.2 Objectives, Aims and Priority areas of the Smart City Programme

Although there is no official policy document in the public domain that outlines the CoCT's digital strategy, there is an internal / draft Digital City Strategy CoCT that has the following four pillars:

- Digital government: driving transparency, enhancing service delivery, and promoting citizen engagement through ICT. The City is looking into modernizing the government utilising innovative technology like Artificial Intelligence, Data analytics and block chain technology that will raise the city's government to the next maturity level.
- Digital inclusion: closing the digital divide by promoting digital access, improving digital skills and promoting digital initiatives that enhances quality of life. By providing free WiFi access in public spaces like libraries and in busses and running digital skills and literacy programs through

tours and encouragement of the youth, the City is helping to bridge the digital divide by enhancing the digital literacy.

- Digital economy: creating an enabling environment for the growth of tech-based enabled enterprises and maximizing its job creation potential. The city is investing in the digital economy through incubating, nurturing and growing digital and technology companies within. As a result, many incubators have grown significantly providing services inside as well as outside the city. Central to successful smart city transformation in any global context is partnerships with other spheres of government, private sector, academia, and civil society organisations.
- Digital infrastructure: ICT infrastructure roll-out and using digital solutions to enhance the effectiveness of critical city infrastructure. Core is the putting more broadband fibre across the city with investments based on a positive business case, especially for IoT enhancing existing and new physical infrastructures, public WiFi as well as in safety and security space (using CCTV camera) all contributing towards a smart city infrastructure.

These pillars support the vision of Cape Town to:

- Be a prosperous city that creates an enabling environment for shared equitable economic growth and development.
- Achieve effective and equitable service delivery.
- Serve the citizens of Cape Town as a well-governed and effectively run administration.
- Shrink the digital divide by creating partnerships with outside actors, focusing investment in areas of low demand, and driving skills development.

2.3 Examples of smart City Projects

1) ERP Platform

The City of Cape Town established a digital backbone at an early stage, they have been able to build up the skills and experience around the ERP platform. The (award winning) ERP platform is now the single-most important database within the City has propelled the city really helped in terms of basic service delivery by bringing people, process, and technology together in a very well done way. The City has the digital structures in place to effectively manage its business processes. This provides a base from which to launch more externally focused platforms that facilitate an open exchange with various non- state urban actors such as NGOs, businesses, academic institutions, or individual citizens.

2) Broadband / WiFi

Broadband Project where the City has used its procurement muscle to connect public buildings with high capacity fibre in an attempt to partner with Internet Service Providers (ISPs) to bring affordable connectivity to impoverished parts of the city. This 'smart' practices focus on creating coalitions with private sector to provide the environment to enable the delivery of digital infrastructure.

Recognising the vital role that connectivity will play in the future development of Cape Town, the City developed an innovative way of catalysing connectivity in poorer areas whilst also advancing their own operational aspirations. They achieved this by building their own connectivity. Essentially, what this means is that the City linked all of its municipal buildings with digital infrastructure that it owns. Meaning that they did not need to procure the services of an Internet Services Provider (ISP) and plug into an existing network that did not service poor communities where it is not economically feasible for ISPs to

do so. Over 900km of fibre has been laid down and over 200 municipal buildings are connected to this network.

The City has attempted to address issues of access to digital skills and technology through projects like the Smart Cape programme. This initiative provides free access to Wi-Fi in public buildings and free use of computers in City libraries. The programme also offers a range of skills development and digital literacy courses, free of charge. In addition, there is Free Wi-Fi on other public places as on "MyCity" busses.

3) Open Data Portal / citizen application

Data is central to smart city development. Exploiting data for sharing and analytics is a key opportunity for The City. Having reliable and up- to-date data improves efficiencies in various urban systems. Not only is this important for improving service provision and decision- making but it is also important for creating market efficiencies as it opens up opportunities for economic growth and development in cities.

In terms of smart city development, data provides opportunities for Cape Town for two main reasons: firstly, open data is central to the notion of an open platform for innovation as it empowers citizens by providing them with the resources and information to assist in developing solutions to a particular issue. Secondly, it provides facilities for The City to make better, more informed decisions about where to allocate resources and improve their service delivery.

Cities sit on vast pools of data which, if correctly managed and analysed, can convey incredibly valuable insights into how to improve, identify weaknesses, and better inform decisions around service delivery and managing a city. They also provide valuable inputs for goods and services outside of government.

Permitting public access to city data can unleash opportunities for non-state actors to use their particular knowledge and skillsets to offer solutions to service delivery and other issues. Additionally, open data allows opportunities for citizens, governments, academic institutions and businesses to build onto the data to improve it, fill in gaps in datasets or provide useful insights and analysis into the data. This is the essence of an open innovation platform described in the previous section; a two-way exchange of information between The City and citizens. However, before this can be in place the data needs to be reliable and in a format that enables collaboration with a variety of different actors. Interoperability is absolutely key to realizing the main practical benefit of "openness" which is the ability to combine different datasets together and develop more and better products and services

The City has identified the potential benefits of conducting in-depth analysis on their data to improve service delivery and decision-making. The City has recently established a citywide data science team with the massive task of embedding the principles of data collection and analysis across the entire organisation. the unit has also begun experimenting with advanced data analytical methods such as machine learning, though it is argued that right now the focus should be on developing ways in which to organise and consolidate existing datasets. The city's own data analytics team is busy with predictive analytics and data modelling in many different domain. In addition the city is working closely with the universities (UCT and Stellenbosch) sharing the available data in the areas of predictive modelling e.g. to overcome droughts and other disaster and crisis management.

An external company that is using the open data portal, has developed an application for citizens, called "Smart City app", to be able to log any request service needs from the side, you know for potholders and road that they want to log that for it to get fixed. The application is integrated through the open data portal and links back into the city. This is an successful example of the open market space that's come through the usage of the open data portal.

4) Emergency Policing and Incident Command (EPIC)

The Emergency Policing and Incident Command (EPIC) system provides an integrated and multi-disciplinary real-time response system to matters relating to public safety across the city. The city was not able to find a suitable vendor driven platform that was flexible enough to adapt to disaster management, fire and policing, so they built their own for a fraction of the initial and cumulative subscription fees. The platform has been a great success so far. The EPIC system links into the City's ERP platform. The Emergency Policing and Incident Command (EPIC) system provides an integrated and multi- disciplinary real-time response system to matters relating to public safety across the city. The EPIC system shows promise by integrating privately owned CCTV cameras and neighbourhood watch applications into the City's central database.

5) Core Application Refresh program

The Core Application Refresh program is looking to the next 5 to 7 years. It's a multi-year program, where the City will engage with market in terms to full their (future) needs to ensure that the City's basic service delivery is taken to the next level of maturity and improving operational efficiencies by adopting novel technologies, such as Artificial Intelligence, Machine Learning, Data analytics. This covers also the city's internal processes like customer relationship management, HR processes using new ways of learning e.g. using and virtual learning technologies. Also strengthening the skills and knowledge of the City's IT departments on new emerging technologies such as blockchain. For each of these future investments and public private partnerships it is important that the city has a sound underlying business case, in terms of financial, economic or other clear benefits to the city. To validate new opportunities both bottom up (via proof of concepts and pilots) and top down (city wide) approaches (with clear proven benefits/business cases) especially for infrastructure projects (which require significant financial investments, are applied.

2.4 Opportunity for collaboration

In addition to the long term objective, the city is prioritizing economic programs to recover from the COVID-19 pandemic as fast as possible. It emphasises the importance for the city to become more resilient and be able to better cope with future (natural or other) disasters and absorb these shocks, which given the climate change is likely to have more impact.

The city is seeking international assistance and innovative solutions to utilise the potential of renewable energy to become the first load shedding free city in South Africa.

2.5 References for the case study

This case study is informed by four reports developed by the Urban Real Estate Research Unit at the University of Cape Town as part of the Ureru Smart City Series (Boyle, 2020b; Boyle, 2019a; Boyle, 2019b; Boyle and Staines, 2019) as well as a discussion with Ms Omeshnee Naidoo, CIO of city of Cape Town.

Appendix 3 Stakeholder Interaction

Some of the stakeholder interactions conducted during the project are summarised below.

- On the 11th of November 2021, the team assisted with arrangements and participated in a *Building Smart Cities through AI, blockchain and bigdata analytics* at the #CocreateMyCity event.
- RebelGroup and Maraxis are currently pursuing and following up on key stakeholders involved and (South African and Dutch) organisations who have shown interest in identifying partnering opportunities within the AI, Blockchain and Bigdata space.
- Wits University wants to get in touch with universities in the Netherlands that have AI in their curriculum. A good match would be the Dutch JADS (Jheroniums Academy of Data Science, see https://www.jads.nl/ in Den Bosch in the Netherlands.
- Unido has an upcoming project: Umnothoganix and the site is Khayelihle Agri-Estate on a 43ha plot that is being subdivided and rezoned to a township with residential/agricultural, commercial/industrial and a centre of excellence as well as recreational and hospitality amenities. The entire initiative is funded from private investment, and the principal funding is yet to be secured, and want to see if there is a possibility for collaboration on AI and Blockchain with Dutch partners.
- Marilyn White Radebe from Soma Solutions is interested if AI could be used in their training/education programs.
- The City of Johannesburg (department of community development) wants to start a project on smart farming, i.e. precision farming, together with Dutch organizations that have expertise and that have technology available.
- Several Dutch companies including Microsoft, Achmea, and several start/scaleups including Ledger Leopard, Sphereon, Gimly are interested in offering blockchain solutions to SA companies.
- Dr Nick Bradshaw of AI Media Group has shown interest in pursuing collaboration opportunities with Dutch AI companies.
- The InnovationQuarter, a regional development agency for Zuid Holland Province, has shown interest in possible collaboration with SA organizations, especially on Artificial Intelligence for energy (grid management), and sustainable buildings (maintenance, energy).
- Merryl Ford from the CSIR and SANBA has shared information regarding the Blockchain ecosystem in South Africa
- A meeting was held with the CoCT CIO Ms Omeshnee Naidoo whjere the City's Digital City Strategy was discussed.

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