PAPER 7

ENGINEERING SERVICE RESPONSE TO FUTURE DENSIFICATION THROUGH BACKYARD DWELLERS, INFORMAL SETTLEMENTS AND SMALL-SCALE RENTAL UNITS

Johan Basson
Pr.Eng.; B.Eng.; B.Com.; Honorary Fellow IMESA

ABSTRACT

Urbanisation has become a global phenomenon leading to an increased demand for housing in urban areas. Densification often happens through the emergence of backyard dwellers, where people construct informal housing structures in the backyards of formal houses, or informal settlements on undeveloped land. Planning for this is a social and physical challenge to engineers in the field of urban development. It has a direct impact on the demand management and maintenance of services. Densification raises sustainability concerns, as informal settlements often lack access to basic services such as clean water, sanitation and electricity. Existing services are often unable to cope with the increased demand, causing breakdowns and service failures. Additionally, the increased pressure on already limited resources may lead to unsustainable development.

Current civil engineering guidelines have served the industry well, but questions are increasingly being raised regarding their application in rapidly densifying environments and their ability to address higher population densities. Current minimum service standards may require ongoing review in rapidly densifying environments to account for higher demands on the infrastructure services.

To address these challenges, civil engineering infrastructure design plays a crucial role in supporting sustainable urban development. In the design process, engineers should consider, best practices, current guidelines, engineering principles, measured and expected demand, capital and life-cycle costing, maintenance and affordability, amongst other factors. Appropriate designs can provide infrastructure that supports the integration of informal settlements into the formal urban fabric, such as by providing basic services and improving access to transportation.

By adopting a holistic approach, civil engineers can contribute to building more resilient and equitable urban areas. Civil engineers have a key role to play in designing infrastructure that supports sustainable urban development and the integration of informal settlements. By doing so, they can contribute to building more equitable and resilient cities that are able to meet the needs of all residents.

Municipal engineers are required to investigate and propose adjusted engineering guidelines as a response to meet these challenges. This paper

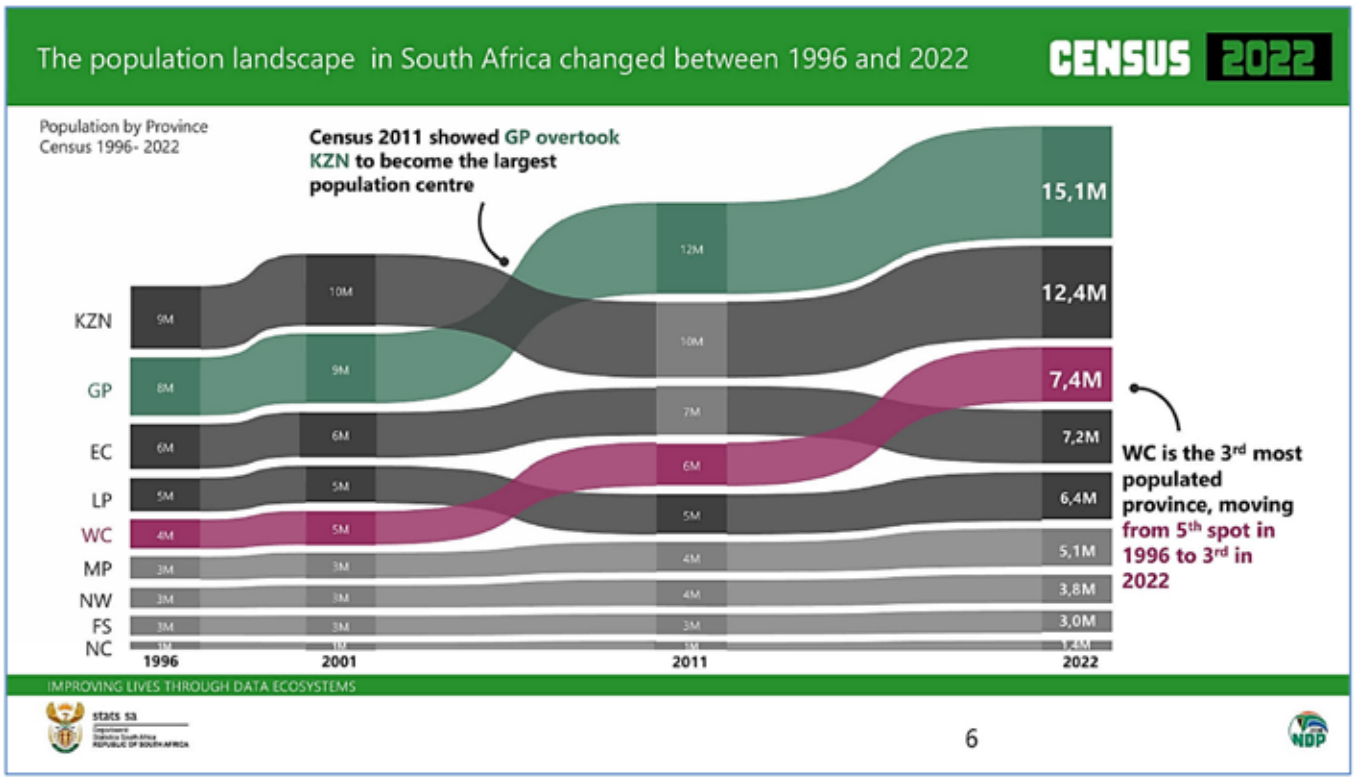


FIGURE 1: *Population Growth by Province (1996–2022); Source: Statistics South Africa Census*

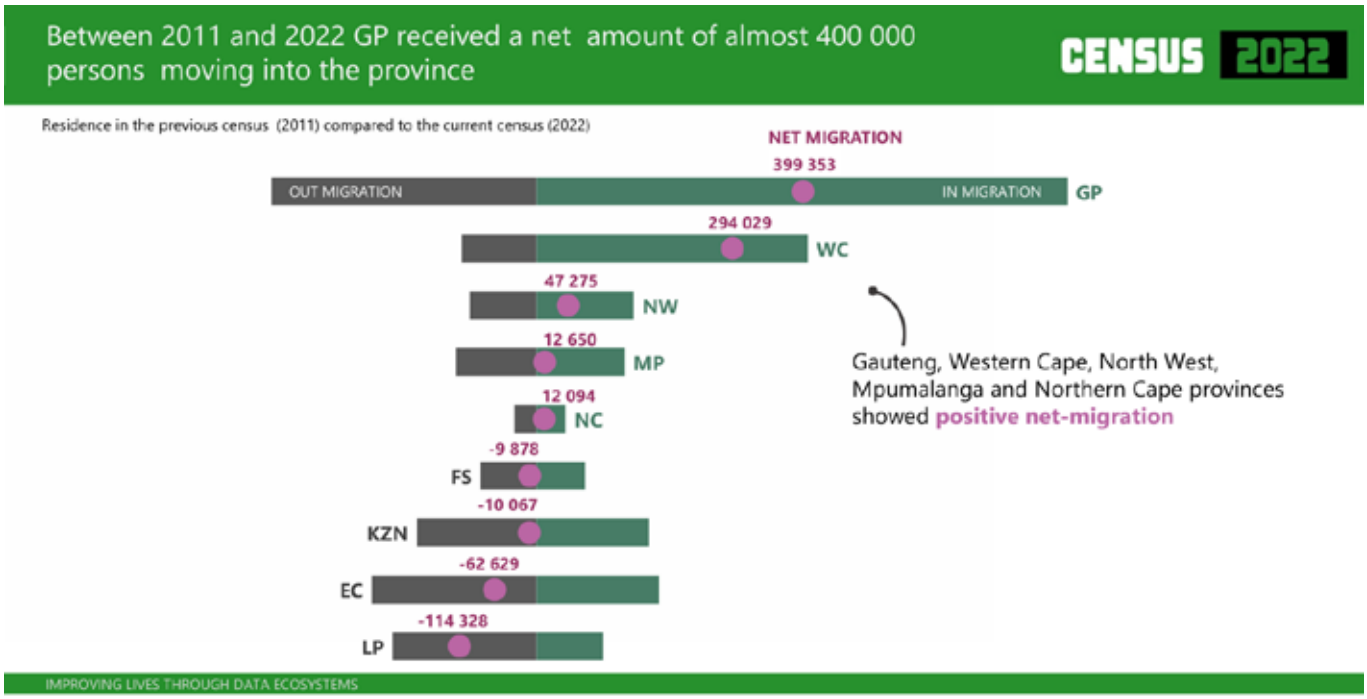


FIGURE 2: *Net Migration by Province (2011–2022); Source: Statistics South Africa Census*

reviews current planning frameworks, engineering guidelines, emerging research and municipal operational experience relating to densification. The paper highlights the uncertainty currently faced by engineers when planning infrastructure for rapidly evolving urban environments and discusses the need for improved monitoring, empirical data collection and industry collaboration. It concludes that existing engineering standards remain an appropriate basis for planning and design, but that additional evidence is required to support future refinements to planning assumptions and infrastructure investment decisions. This could provide critical input to more Sustainable Cities delivering services to their communities.

1. INTRODUCTION

1.1 Urbanisation and Housing Demand

Urbanisation continues to reshape South African cities. Population growth, migration to economic centres and ongoing housing shortages have resulted in increasing pressure on urban land, housing delivery and municipal infrastructure systems. Statistics South Africa data indicates significant growth in both population and household numbers over the past three decades.

The Western Cape, in particular, continues to experience sustained inward migration and population growth. Figure 1 indicates the population in the

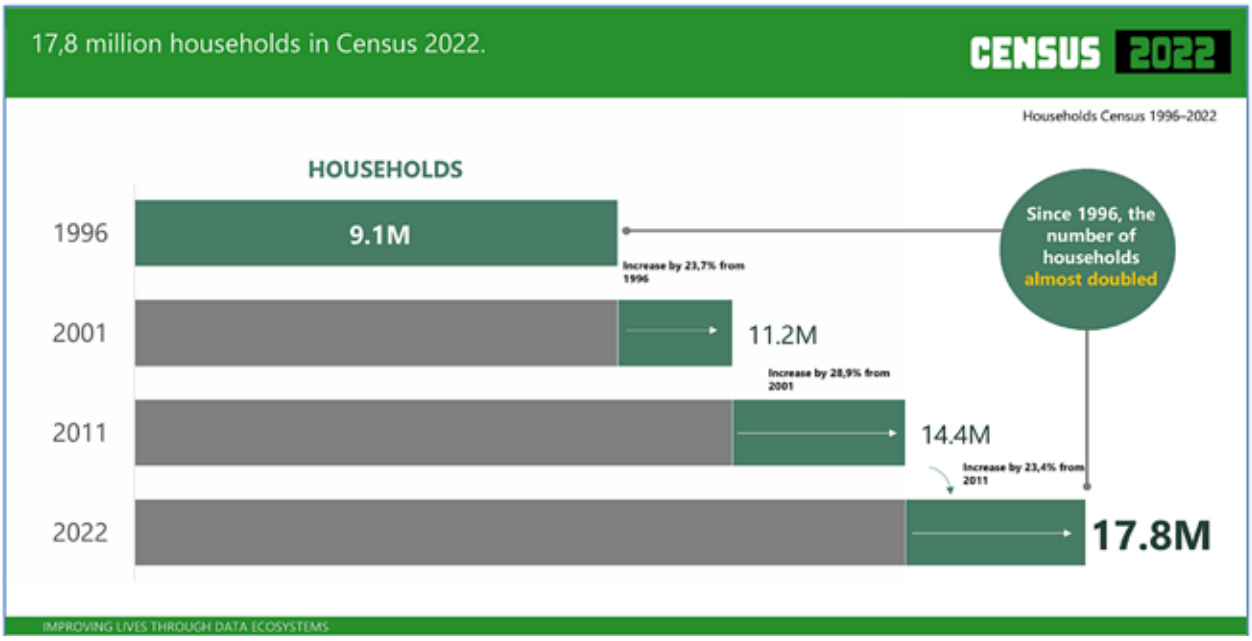


FIGURE 3: *Growth in South African Households (1996–2022); Source: Statistics South Africa Census*

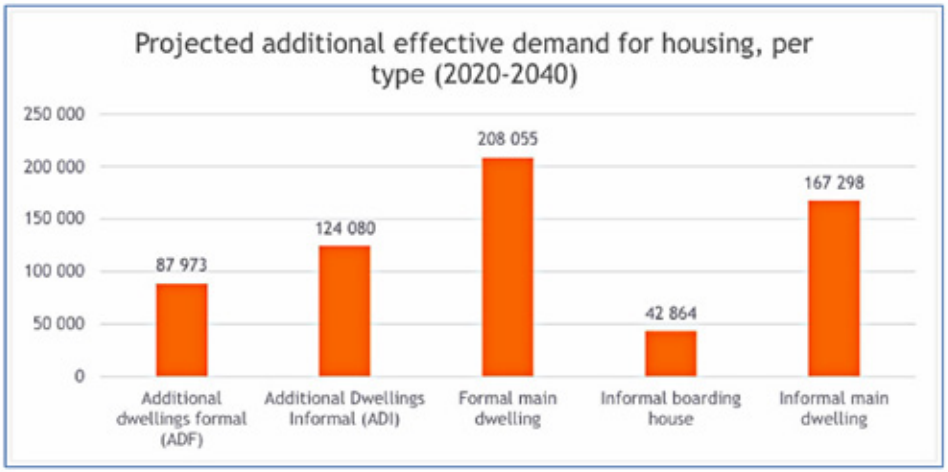


FIGURE 4: *Total projected additional units, 2020-2040 by dwelling type; Source City of Cape Town*

Western Cape jumping from the fifth largest populated province in 1996 to the third largest in 2022 according to the Census 2022 report by Statistics South Africa.

Urbanisation and population growth resulted in the provinces of Gauteng, Western Cape, North-West, Mpumalanga and Northern Cape showing positive net-migration between 2011 and 2022. Figures 1 to 3 indicate national household numbers increased significantly faster than population growth, indicating changing household formation patterns and increasing housing demand even where population growth rates are relatively moderate.

Consequently, a variety of housing responses have emerged, in addition to more conventional housing subsidised and GAP housing. In addition to the more conventional formal growth of cities and towns, greater focus is needed on addressing other housing options, including:

- Backyard dwellers;
- Informal settlements;
- Small-Scale Rental Units (SSRUs);
- Affordable rental accommodation;
- Incremental housing extensions;
- Informal subdivision of occupation;
- Backyarder service programme;
- Emergency housing;
- Micro-developments.

These forms of development have become important components of the urban housing response and increasingly contribute to urban densification.

TABLE 1: *Number of informal areas and structure count within the City of Cape Town December 2023; Source City of Cape Town*

TYPES - AREAS OF INFORMALITY	# SETTLEMENTS	# RESIDENTIAL STRUCTURES
Backyarder Settlement	57	3975
IDA/TRA/Reblocked	45	14085
Informal Settlement	654	244587
Rental Stock Settlements	72	10392
Settlements to be investigated	4	1768
Small Farmers/Rural Settlement	16	3182
Upgraded Settlement	1	55
Grand Total	**849**	**278044**

The Integrated Human Settlements Five-year Sector Plan 2022/23-2026/27: 2025/26 Review provides strategic guidance and a roadmap for implementing interventions at resolving human settlements within the City of Cape Town. Figure 4 indicates the projected demand on various housing provisions required in the City of Cape Town.

The provision of basic interim services to informal settlements is essential to alleviate the urgent/emergency needs of services to access to potable water and sanitation and preventative measures to curtail the risks of disasters.

1.2 Purpose of the Paper

Much of the current discussion regarding densification focuses on infrastructure capacity and whether existing planning assumptions remain appropriate. Discussions with municipal engineers further highlight these emerging concerns, which are also reinforced by communities' demands for better services. This paper focuses on these concerns, not particularly on urban growth in general, but rather on densification options and their effect on the provision of municipal engineering services.

Operational departments increasingly report sewer blockages, sewer overflows, stormwater pollution, greywater disposal challenges, illegal service connections, refuse accumulation, maintenance difficulties, and reduced emergency and service access.

These observations are frequently associated with densifying communities, yet limited verified empirical information exists regarding the relationship between these operational challenges and their underlying causes. These causes may include densification, informality, infrastructure condition, maintenance practices, user behaviour or combinations thereof.

To address the urbanisation and densification challenges facing our towns and cities, planning and design guidelines have provided the municipal engineering industry with valuable guidance that remains applicable today. However, it is important to question and verify whether these guidelines continue to effectively reflect current conditions.

This paper therefore does not advocate an immediate blanket change to engineering standards or planning methodologies. Existing planning frameworks remain the accepted basis for infrastructure planning and design. Rather, the paper seeks to highlight the uncertainty currently faced by engineers, discuss selected servicing challenges through practical project examples, identify areas requiring additional research and encourage industry discussion regarding future planning approaches.

Although many examples presented originate from City of Cape Town investigations and projects, the issues discussed are not unique to Cape Town. Similar challenges are increasingly evident across South African municipalities and should therefore be viewed as a national engineering concern.

2. POLICY AND ENGINEERING PLANNING CONTEXT

2.1 Current Planning and Design Guides

The concept of densification is not new within planning policy. Strategic planning documents guiding the City of Cape Town on densification include, amongst others:

The Integrated Urban Development Framework (IUDF), CSIR Red Book, City of Cape Town Human Settlements Directives, Water and Sanitation



FIGURE 5: *Conceptual diagrams illustrating how generic house types can be added to and extended over time; Source: City of Cape Town,*

Guidelines and Roads and Stormwater Standards, the Integrated Human Settlements Five-year Sector Plan and various internal Council reports.

All recognise the need for compact development, more efficient use of infrastructure and increasing residential densities. The Red Book provides planning guidance for evolving urban environments and remains one of the primary references for settlement planning and engineering service provision in South Africa.

Municipal Water and Sanitation Guidelines and Roads and Stormwater Standards continue to provide the accepted basis for infrastructure design and service planning. These standards have evolved through decades of practical experience and remain essential planning tools.

The Human Settlements Directives explicitly make provision for future densification and settlement intensification, including significantly higher residential densities than historically associated with low-income housing developments. This document placed a renewed requirement on municipal engineers to evaluate current design practice.

2.2 Densification Options

2.2.1 Formal subsidised residential blocks and plots

The Human Settlements Directives indicate in Section 10.8 that formal residential plot sizes should be a minimum of 75m^2 ranging up to 100m^2. This is inter alia to promote incremental densification and the development of second or more dwellings on the plot. These plots can take the form of formal dwellings with future extensions and backyard dwellings, or serviced sites only where the dwellings can be more informal or formal. Although the plots' engineering services are normally planned and designed according to existing standards, the future connections and servicing of the additional units, whether formal or informal, in the backyard require further attention and consideration in relation to services.

2.2.2 Flats and Group housing

Flats are designed to discourage illegal extensions and second or more dwellings on the plot during the design and construction phases. Affordable rental developments can also be included in this option. The engineering services are normally planned and designed according to existing standards, but when rezoning or densification occurs, the impacts on available services should be considered.

2.2.3 Small Scale Rental Units (SSRU)

is an emerging form of land use not necessarily catered for in existing conventional land use planning practices. These can be individual properties to be used for multiple rental units. It is estimated in the Mayor's 2025 Infrastructure Report by the City of Cape Town that thousands of informal SSRU units already exist, often built outside formal approval systems. These rental units can cater for between 3 and 12 units per erf, depending on the size of the property. Similar to the above-mentioned options, the impacts on available services should be considered.

2.2.4 Emergency Housing and Servicing Informal Settlements

These options can also include the formalisation of non-conventional housing options. Traditionally, services are not available or cannot be provided to the same standard as formal plots and can include temporary or alternative engineering services. Often, formalising existing informal settlements provides the opportunity to improve the existing lack of services and reduce pollution of stormwater systems. The additional load to existing services and the experience that temporary housing options become more "permanent" again require attention from municipal engineers.

3. OPERATIONAL IMPACTS OF DENSIFICATION AND INFORMALITY

3.1 Beyond Capacity-Based Planning

Traditional civil infrastructure planning focuses on water demand, wastewater generation; traffic generation, parking requirements, stormwater runoff, and solid waste generation.

These remain essential engineering planning parameters. However, municipal operational experience increasingly suggests that many challenges associated with densification may emerge through operational performance rather than capacity limitations alone.

3.2 Sewer Systems

In several Cape Town service areas, operational teams have reported recurring sewer blockages in areas experiencing backyard densification and informal occupation, although the exact causal relationship remains uncertain. Reports include sewer blockages; sewer overflows; foreign objects entering sewer systems; illegal connections; and difficulties in accessing and maintaining infrastructure in densely occupied environments.

While these problems are frequently associated with densification, the extent to which they are caused by increased loading, settlement form, behavioural practices or maintenance limitations remains uncertain. The relationship remains largely unquantified despite being routinely encountered by practitioners.



FIGURE 6: *Small Scale Rental Units in Cape Town; Source: City of Cape Town,*

3.3 Stormwater and Environmental Systems

Traditional stormwater planning focuses on runoff generation and flood management.

Operational staff increasingly identify different concerns: greywater entering stormwater systems; sewer contamination of canals and waterways; litter accumulation; illegal discharges; and environmental degradation of rivers and wetlands. Consequently, a drainage system may be hydraulically adequate while simultaneously performing poorly from an environmental perspective.

3.4 Solid Waste

Municipal practitioners increasingly raise concerns regarding: illegal dumping; refuse entering drainage systems; access and collection service pressures; and environmental impacts associated with waste accumulation. The relationship between occupation density and operational waste management costs remains poorly quantified.

3.5 Access, Parking, Transport and Serviceability

Current Transport, Roads and Stormwater Standards place considerable emphasis on access and maintainability.

In densifying communities, engineers frequently report: illegal parking and pedestrian access deterioration and illegal structures in road reserves; reduced refuse collection and constrained emergency vehicle access and movement; restricted maintenance access; and encroachment into service corridors.

These impacts rarely appear within traditional demand calculations despite significantly influencing long-term operating costs and service reliability.

4. THE ENGINEERING UNCERTAINTY GAP

Municipal infrastructure planning has traditionally relied upon recognised engineering methodologies, planning standards, empirical observations and professional judgement. These approaches have generally performed well and remain the foundation of infrastructure planning in South Africa. However, the urban environment within which these standards were developed continues to change. Densification also affects municipal services, both existing and planned, including planning and design, construction costs, and operation and maintenance considerations.

Despite the frequency with which these concerns are raised, relatively little verified empirical information exists regarding cause-and-effect relationships, particularly given the changing land use environment.

This creates an Engineering Uncertainty Gap.

Engineers observe operational impacts but often lack sufficient data to confidently determine whether these impacts result primarily from increased density, informality, settlement morphology, user behaviour, infrastructure deterioration, lack of maintenance, inadequate future-proofing, or a combination of these factors.

The uncertainty does not imply that current standards are incorrect. Rather, it highlights the need for a stronger evidence base to support long-term planning decisions and the appropriate application of standards and guidelines.

4.1 Why the Uncertainty Matters

The significance of the uncertainty identified in this paper extends beyond hydraulic design, infrastructure capacity and engineering calculations. Municipal engineering infrastructure provides the platform upon which communities function and develop. The availability, reliability and affordability of water, sanitation, roads, stormwater management and waste services directly influence public health, economic activity, environmental performance and overall quality of life.



FIGURE 7: *Du Noon informal settlement*

Unlike researchers, practising municipal engineers cannot wait for perfect information. Infrastructure decisions must be made continuously as developments are planned, services upgraded and communities expanded. Consequently, engineers are required to exercise professional judgement while simultaneously recognising the limitations of currently available information. The challenge is therefore not the absence of decision-making, but rather making responsible decisions in the presence of uncertainty.

The challenge facing engineers is therefore not whether densification should occur. Rather, the challenge is whether sufficient empirical evidence exists to understand how changing settlement forms influence infrastructure performance, maintenance requirements and long-term serviceability. Dealing with densification in existing developed areas requires consideration of the availability of "spare" capacity, constraints, the potential for retrofitting existing municipal engineering infrastructure to accommodate changes in land use and densification, and how to plan and design future developments to be robust and able to respond to future challenges. These considerations are critical tools in the municipal engineer's toolbox.

5. LESSONS FROM EXISTING DENSIFICATION AREAS

Examples such as Delft, Khayelitsha and Du Noon demonstrate that densification frequently occurs incrementally over time. The Mayor's 2025 Infrastructure Report by the City of Cape Town, reports that without structured support, service failure and unsafe conditions could escalate.

These areas have become important examples because they reveal the practical realities encountered by municipalities when settlement patterns evolve beyond their original planning assumptions.

Common observations include increasing occupation densities; backyard development; affordable rental accommodation; informal extensions; environmental management challenges; and maintenance pressures. Figure 7 indicates the overflow of toilets and greywater into the road and subsequent stormwater system.

Improving access to basic services for informal households may include additional taps and toilets; raising platforms to prevent flooding; integrated environmental health services; communal ablutions and wash facilities; stormwater channels; greywater drainage; electrification infills; access roads; and appropriate buffers or firebreaks to reduce fire risks.

TABLE 2: *Impact of SSRUs on Municipal Infrastructure; Source City of Cape Town*

INFRASTRUCTURE SECTOR	DU NOON CURRENT	DU NOON FUTURE	LANGA CURRENT	LANGA FUTURE	PHILLIPPI CURRENT	PHILLIPPI FUTURE
Water	Moderate	High pressure	Adequate	Severe constraints	Low pressure	Major upgrades needed
Sanitation	Blockages	Major upgrades	Spare capacity	At risk	Partial capacity	Severe overload
Energy	Stable	Reinforcements	Adequate	Expansion needed	Spare capacity	New substation required
Stormwater	Undersized pipes	Flooding risk	Limited capacity	High flood risk	Overwhelmed	Major attenuation upgrades
Urban mobility	Congested roads	Increased demand	Moderate congestion	Rank overcapacity	Over capacity	Severe congestion
Urban waste management	Under pressure	Increased pressure	Under pressure	Increased pressure	Under pressure	Increased pressure

Table 2 indicates the status on various service and maintenance components being put under pressure by densification actions in areas of the City of Cape Town. Lessons include that capacity is not always the primary constraint, access and maintainability often become limiting factors. Environmental impacts may emerge before hydraulic capacity is exceeded.

6. WELMOED ESTATE CASE STUDY

Welmoed Estate provides an example of how municipal engineers are increasingly required to consider future densification during the planning stage of new developments. The project was planned during 2016/17 within a policy environment that explicitly recognised future settlement intensification and increasing densities. The Directives for the Planning, Design and Implementation of Human Settlement Projects in Cape Town were published in 2016. Engineering teams were therefore required to consider not only immediate service requirements, but also the long-term evolution of the settlement and the associated implications for future municipal infrastructure demand.

Importantly, infrastructure planning proceeded using accepted design standards, engineering judgement and interdisciplinary engagement. Using the Directives and enumeration studies of the potential beneficiaries of the project, it was estimated and approved by the City of Cape Town that an average of three dwelling units per plot is plausible. Given the expected future water demand associated with an average of 3.5 persons per dwelling, a demand of 900 l/plot per day provided a basis to allow for the expected average of three dwelling units per plot under incremental densification. An average of 750 l/plot per day was used for estimating daily sewage generation.

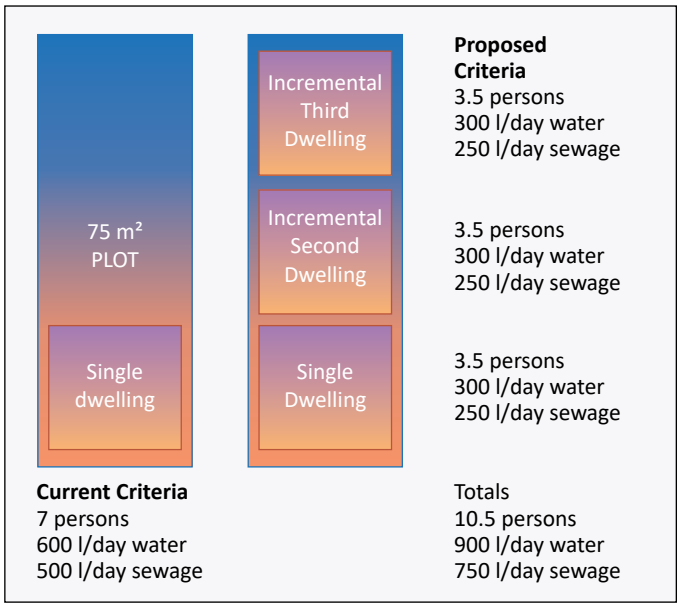


FIGURE 8: *Proposed Planning, Design Criteria for AADD Water and Sewage*

The significance of the Welmoed case study is not the specific demand figures ultimately adopted, but rather the planning process that occurred. The project highlighted several broader questions:

- How should future densification be accommodated?
- How should resilience be incorporated into infrastructure planning?
- How should uncertainty be managed?
- How should serviceability be maintained over the long term?

7. EMERGING EVIDENCE

A 2022 investigation into SSRUs and affordable rental accommodation provided useful insights into changing settlement patterns. The SSRU studies identified several emerging observations:

- Most units were occupied by one or two adults.
- Vehicle ownership was comparatively low and trip generation rates were similar to the rate of student apartments.
- Public transport usage was significant.
- Densified sites often displayed very high levels of impervious coverage for stormwater calculations.
- Water demand findings were inconclusive and additional monitoring was recommended.

In comparing this with the Welmoed assumptions, different plot sizes and uses will dictate the planning and design parameters, and geographic location could also influence the appropriate engineering solutions. The importance of these investigations lies not in the specific numerical findings but in demonstrating both the value and limitations of current datasets. The studies themselves concluded that additional monitoring and larger sample sizes would be required before definitive conclusions could be drawn.

8. REDUCING THE UNCERTAINTY

The most effective response to uncertainty is the collection of reliable evidence. Municipalities should consider service provision capacity assessments in their focused development zones and across the total municipal area. In providing input into the uncertainty of densification, measuring existing units will provide more certainty to guide future decisions. As the saying goes: "measure, measure, measure".

This can take the form of:

Water monitoring: Smart water metering; district metered areas; residential demand studies; occupancy versus consumption assessments.

Sewer Monitoring: Flow monitoring in selected catchments; blockage databases; overflow tracking; maintenance event analysis.

Stormwater Monitoring: Water quality monitoring; pollution studies; greywater investigations; imperviousness mapping.

Serviceability Monitoring: Maintenance accessibility assessments; emergency response evaluations; refuse collection performance reviews.

Long-term monitoring of existing neighbourhoods and selected new developments could provide valuable information regarding occupancy; water, sewage, solid waste, parking and transport demand; service performance; maintenance requirements; and environmental impacts. Local municipalities can also implement measurement of their water use by making use of the existing bulk and erf meters, and by analysing this data alongside densification data they can retrieve from census statistics. Analysis of existing data will provide a basis to make decisions and can be verified with further measurements and analysis.

Industry collaboration through IMESA could facilitate the development and comparison of larger, nationally relevant datasets.

9. RECOMMENDATIONS

1. Recognise informality and densification and enable the formalisation of appropriate municipal infrastructure and service delivery to these communities.
2. Existing standards should remain the primary basis for engineering decision-making until sufficient verified evidence exists to justify alternative approaches. However, continued application of existing standards should not prevent interim refinements, pilot studies, engineering innovation or local design responses where supported by sound engineering judgement and appropriate monitoring.
3. Expand municipal monitoring programmes for water, wastewater, stormwater and operational performance, as well as infrastructure capacity analysis.
4. Establish infrastructure performance databases tracking blockages, overflows, pollution incidents and maintenance interventions.
5. Encourage pilot projects and innovation where local circumstances warrant alternative approaches.
6. Document and evaluate interim design responses implemented by municipalities.
7. Promote collaboration between municipalities, universities, consultants and professional institutions.
8. Develop nationally coordinated datasets through IMESA and other professional forums.
9. Continue reviewing planning assumptions as additional evidence becomes available.
10. Update master and sector plans to align with real densification patterns and mitigate infrastructure strain.

10. CONCLUSIONS

Urbanisation, housing demand and densification will continue to shape South African cities for the foreseeable future. Existing planning frameworks, including the CSIR Red Book, Human Settlements Directives and municipal engineering standards, already recognise these realities and provide an appropriate basis for infrastructure planning and service delivery.

Municipal engineers nevertheless increasingly encounter uncertainty regarding the relationship between densification, informality and infrastructure performance. Operational concerns relating to sewer blockages, pollution, maintenance requirements, accessibility and serviceability are widely reported, yet limited verified empirical information exists regarding the causes of these challenges.

The paper does not conclude that current standards should be replaced, nor does it advocate immediate revisions to established planning methodologies. Rather, it highlights an Engineering Uncertainty Gap within which long-term infrastructure decisions are currently being made in the context of current and future planning and settlement trends. Densification requires good design, and "one size does not fit all". Engineers will continue to make decisions based on best practice, professional judgement and experience.

The appropriate response is therefore not the abandonment of existing standards, but the systematic collection of evidence capable of supporting future, evidence-based refinement of planning assumptions and infrastructure investment decisions. Existing standards remain the foundation of municipal engineering practice. Improved monitoring, professional collaboration, applied research and industry engagement provide the pathway toward reducing uncertainty and enhancing sustainable service delivery in increasingly densified urban environments.

Municipal engineers have successfully adapted to changing urban environments for decades, and addressing future densification challenges will similarly require a combination of sound engineering judgement, appropriate standards and improved evidence-based planning.

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