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Co-Designing Waste Governance in Informal Settlements: A Participatory Framework for Cape Town Grounded in 4IR Theory and Community Practice

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Abstract: Objectives: To explain why conventional waste governance fails in dense informal settlements and to propose a replicable participatory model for Cape Town. **Prior Work:** The paper builds on doctoral research into Fourth Industrial Revolution technologies in South African metropolitan waste management, and on the literature on governance failure, technology adoption and community participation. **Approach:** A theory-informed case analysis of a municipal co-design and prototyping project in Dunoon North, drawing on a household survey of 1,135 dwellings, six sequential co-design workshops, weighted multi-criteria analysis and a three-month operational pilot covering 390 households. **Results:** The pilot achieved organics and recyclables participation rates of 36 and 51 per cent, diverted more than 843 kilograms of waste in five days and measurably reduced illegal dumping. Community-elected ambassadors and cross-departmental coordination were the decisive variables. **Implications:** Municipal administrators should institutionalise co-design as a standard operating procedure rather than a once-off innovation pilot, formalise the ambassador role, and sequence digital investment after community systems. **Value:** The paper contributes the PIDA Co-Design Framework, comprising Prepare, Investigate, Design and Activate phases, as a four-phase, theoretically grounded model for waste governance reform across informal settlements.

Keywords: Circular economy; Waste ambassadors; Design-led thinking; Dunoon; Smart technologies

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1. Introduction

South African metropolitan municipalities face what might fairly be called a structural paradox in urban waste management. The legislative framework is in place. The policy intent is clear — the National Waste Management Strategy mandates waste diversion from landfill and community participation in service design (Department of Environmental Affairs, 2011). The fiscal investment is substantial. And yet, in the 850 informal settlements that are home to an estimated 174,000 dwellings in Cape Town alone (The Housing Development Agency, 2023; Mabiletsa, 2026), illegal dumping remains endemic, collection is inconsistent, and resident trust in municipal waste services is low. The problem, as Mabiletsa (2026) demonstrates across two metropolitan municipalities including Cape Town, is not simply one of resource deficiency — it is one of systematic misalignment between service design logic and settlement reality.

Mabiletsa's (2026) doctoral research, which examined the application of Fourth Industrial Revolution (4IR) technologies in urban waste management across two South African metropolitan municipalities, identified five critical moderating variables for effective solid waste management: technological integration, data management, sustainability focus, human capital development, and public participation. His regression analysis further established that waste efficiency is significantly influenced by ICT adoption, staff training in Industry 4.0 applications, and investment in smart waste management infrastructure. These findings are theoretically grounded in four complementary frameworks — the Diffusion of Innovation Theory (Rogers, 1962, as cited in Mabiletsa, 2026), the Technology-Organisation-Environment (TOE) Framework (Tornatzky & Fleischer, 1990, as cited in Mabiletsa, 2026), Actor-Network Theory (Bencherki, 2017, as cited in Mabiletsa, 2026), and Institutional Theory (Guth, 2016, as cited in Mabiletsa, 2026) — all of which point to the same conclusion: technology adoption in municipal waste management cannot succeed without simultaneously addressing the social, organisational, and institutional dimensions of service delivery.

The Bloomberg Philanthropies Mayors Challenge — Dunoon Waste Management Project, piloted from October to December 2025 in the Dunoon North informal settlement in Cape Town, offers a rare empirical test of what happens when these

dimensions are addressed together. The project combined a structured community co-design process (six sequential workshops with 65–80 participants each), a large-scale household survey (1,135 households), multi-criteria analysis, industry partnerships with Producer Responsibility Organisations (PROs), and a three-month operational pilot covering 390 households. The results were compelling: a 36 per cent organics participation rate, a 51 per cent recyclables participation rate, over 843 kg of waste diverted in the first five days of operation, and a measurable reduction in illegal dumping (City of Cape Town, 2025, 2026).

This paper makes three interrelated contributions. First, it situates the Dunoon pilot within the theoretical architecture established by Mabiletsa (2026), demonstrating that the project's success can be theoretically explained — and its replicability theoretically justified — by the same frameworks that his doctoral research applied to 4IR technology adoption. Second, it analyses the process, outcomes, and lessons of the Dunoon initiative across four analytical dimensions: design methodology, community dynamics, institutional coordination, and waste infrastructure. Third, and most originally, it proposes the PIDA Co-Design Framework — a four-phase participatory model comprising Prepare, Investigate, Design, and Activate — as a structured, replicable, and theoretically grounded approach to waste governance reform in Cape Town's informal settlements. The paper concludes with policy implications and recommendations for embedding co-design as a standard municipal operating procedure rather than a time-limited innovation experiment.

2. Theoretical Framework

2.1. Why Conventional Waste Governance Fails in Informal Settlements

The failure of top-down waste governance in informal settlements is not a recent discovery. Kubanza and Simatele (2018), as cited by Mabiletsa (2026), established that inadequate waste management in South African municipalities is fundamentally linked to governance failures: the exclusion of private sector actors, the absence of community participation in urban development planning, and the misapplication of urban waste policies to spatial contexts for which they were never designed. What Mabiletsa's (2026) research adds is a technology dimension to this diagnosis: not only are governance structures misaligned, but the technological infrastructure that could enable adaptive, data-driven, community-responsive waste management is either absent or inaccessible to the municipalities that need it most.

The TOE Framework (Tornatzky & Fleischer, 1990, as cited in Mabiletsa, 2026) provides a useful diagnostic lens. In the technological dimension, informal settlements lack the IoT sensors, real-time data dashboards, and mobile data capture tools that would generate the granular waste flow data necessary for evidence-based collection optimisation. In the organisational dimension, municipal departments operate in silos, with waste management, water and sanitation, and spatial planning rarely collaborating on integrated informal settlement responses. In the environmental dimension, regulatory frameworks — including the Municipal Finance Management Act and Supply Chain Management policies — create procurement and contracting structures premised on formal, vehicle-accessible service environments, not the dense, irregular spatial fabric of informal settlements (City of Cape Town, 2026; Mabiletsa, 2026).

Actor-Network Theory (Bencherki, 2017, as cited in Mabiletsa, 2026) offers an additional explanatory layer. ANT insists that technology adoption is not simply a matter of technical deployment but of building stable networks between human actors (residents, municipal officials, waste ambassadors, PROs) and non-human actors (collection bins, trolleys, mobile data tools, recycling infrastructure). Mabiletsa (2026) applies ANT to demonstrate that municipal technology adoption fails when these networks are incomplete — when, for example, a smart collection system is deployed without the community relationships that would generate the behavioural compliance the system requires. The Dunoon pilot's success, viewed through an ANT lens, lies precisely in its systematic attention to building both the human and non-human networks before deploying any infrastructure.

Institutional Theory (Guth, 2016, as cited in Mabiletsa, 2026) completes the theoretical picture by explaining why change is so difficult even when its necessity is acknowledged. Mabiletsa (2026) identifies three institutional pressures that shape municipal waste management behaviour: coercive pressures from national legislation and the South African National Development Plan (Fourie, 2018, as cited in Mabiletsa, 2026), normative pressures from professional standards and sustainability goals, and mimetic pressures — the tendency of municipalities to replicate approaches used elsewhere without adapting them to local contexts. The challenge for informal settlement waste governance is to harness coercive and normative pressures as enablers of change while resisting the mimetic temptation to import solutions designed for formal urban environments.

2.2. The 4IR Opportunity in Informal Settlement Waste Governance

Mabiletsa's (2026) regression analysis identified a statistically meaningful relationship between ICT adoption, staff training in Industry 4.0 applications, and investment in smart waste management on one side, and waste efficiency performance on the other. This finding has direct implications for informal settlement waste governance. The five moderating variables Mabiletsa (2026) identifies — technological integration, data management, sustainability focus, human capital development, and public participation — function as necessary conditions for 4IR adoption to translate into efficiency gains. If any of these conditions is absent, the technology investment yields limited returns.

The Dunoon project operationalises several of these moderating variables in an informal settlement context. Public participation was addressed through the six-workshop co-design process. Human capital development was addressed through the training of 17 Waste Ambassadors by PROs, the City's Smart Living team, and the Small Enterprise Development Agency. Data management was addressed through the household survey and the M&E framework tracking waste weights, participation rates, and hotspot reduction (City of Cape Town, 2026). Technological integration, while still at an early stage — the project used manual registers, photo documentation, and weighing scales rather than IoT systems — was explicitly flagged as a next-phase priority, with mobile-based data tools identified as essential for scaling (City of Cape Town, 2025, 2026). This trajectory aligns precisely with Mabiletsa's (2026) argument that 4IR adoption must be sequenced: community and human systems first, digital infrastructure second.

The Diffusion of Innovation Theory (Rogers, 1962, as cited in Mabiletsa, 2026) explains how the Dunoon pilot generates the early-adopter momentum that can catalyse broader diffusion. The election of 17 Waste Ambassadors — community members who voluntarily took on leadership roles and visibly championed the new waste practices — creates exactly the kind of trusted peer network that Rogers' DOI theory identifies as the primary driver of innovation diffusion in communities. When neighbours see their elected representatives actively participating in a new system, compliance barriers lower and adoption accelerates. The 51 per cent recyclables participation rate achieved in the first five days of the pilot is a concrete expression of this diffusion dynamic (City of Cape Town, 2026).

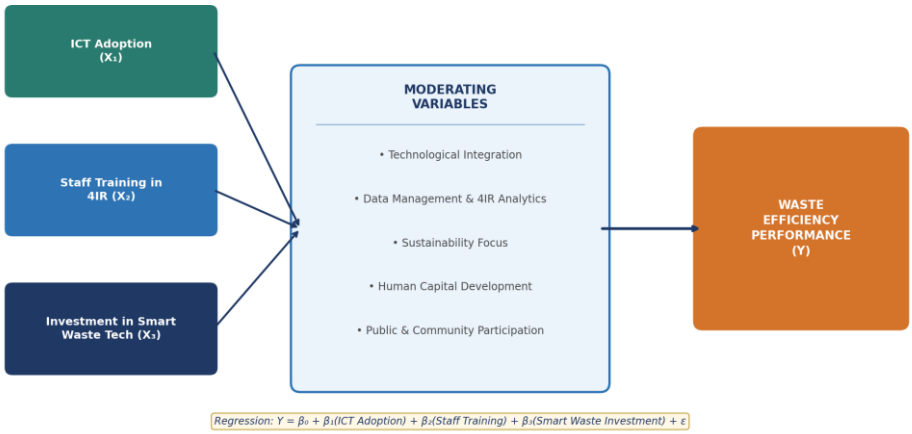

Figure 1. Moderating Variables for 4IR Adoption in Solid Waste Management — Thesis Conceptual Model

Source: Mabiletsa (2026, pp. 160–161)

3. The Dunoon Initiative: Process, Outcomes, and Lessons

3.1. Context and Challenge

Dunoon is not an atypical case — it is an acute expression of a systemic pattern. Originally designed for 3,000 households, Dunoon now accommodates over 31,000 people, with the study area alone (Dunoon North, comprising five sub-settlements: Ekuphumleni, New Rest, Small Farmers, Siyabangena, and Oaklands) containing more than 3,000 households (City of Cape Town, 2026). This density creates an environment in which conventional waste collection — premised on accessible roads, predictable generation rates, and individual household bin placement — fails structurally. The results are predictable: pervasive illegal dumping, unhygienic living conditions, blocked stormwater drains, and a chronically inadequate service that generates community disengagement rather than compliance (City of Cape Town, 2025; Mabiletsa, 2026).

The Bloomberg Philanthropies Mayors Challenge offered an opportunity to test a different approach. In May 2025, Cape Town was selected as one of 25 global cities to receive a $50,000 prototyping grant (City of Cape Town, 2025). The project was managed by ARG Design through UNDP, with a transversal City team spanning Urban Waste Management, Water and Sanitation, Spatial Planning and

Environment, and the Organisational Effectiveness and Innovation (OEI) directorate. The vision articulated from the outset was both modest and ambitious: 'A cleaner and healthier Cape Town for all: Community and authorities co-design a waste management system that delivers' (City of Cape Town, 2025, 2026). With Cape Town's informal population projected to reach 50 per cent by 2040 (City of Cape Town, 2026), the pressure to develop a scalable model for this vision has never been greater.

3.2. The Co-Design Process

The pre-piloting phase comprised a community survey and six sequential workshops held at Dunoon North Community Hall and Library in September and October 2025. The household survey, conducted by the City's Water and Sanitation team across 1,135 households using a 22-question instrument, generated the baseline data that grounded the co-design workshops in evidence rather than assumption (City of Cape Town, 2025). This sequence — evidence gathering before ideation — reflects the data management imperative that Mabiletsa (2026) identifies as a critical moderating variable for effective waste management.

Workshop 1 (15 September, approximately 65 participants) established the spatial and relational landscape through participatory mapping, stakeholder identification, and waste hotspot documentation. Workshop 2 (17 September, approximately 80 participants) applied problem tree methodology, dot voting, 'How Might We' reframing, and World Café cross-pollination to generate six priority root causes and 26 community-generated potential solutions. Workshop 3 (19 September) served as a reflection and expectation-setting session, resulting in the election of 17 Waste Ambassadors from six informal neighbourhoods — a figure the close-out report notes was 88.5 per cent women (City of Cape Town, 2025, 2026). Workshop 4 (26 September) applied Multi-Criteria Analysis (MCA) to the 26 solutions, using four weighted criteria: addressing illegal dumping (30%), deliverability in the prototyping timeframe (25%), scalability (25%), and resource feasibility (20%) (City of Cape Town, 2025). Workshops 5 and 6 finalised pilot locations and onboarded the Waste Ambassadors and eight EPWP workers for implementation.

The MCA process is worth particular analytical attention, as it represents the bridge between community voice and technical feasibility — a bridge that is often missing in both purely community-led and purely technically-driven waste management

initiatives. As Figure 2 illustrates, the four highest-scoring solutions (each achieving a weighted score of 4.0 out of 4.0) were voluntary community clean-ups, designated disposal spots for bulky waste, improved container servicing frequency, and reliable collection schedules — precisely the interventions that residents could see, touch, and immediately attribute to the co-design process. This early-win logic is consistent with Rogers' (1962, as cited in Mabiletsa, 2026) DOI framework, which emphasises that innovation adoption accelerates when early adopters can observe concrete, attributable improvements in their immediate environment.

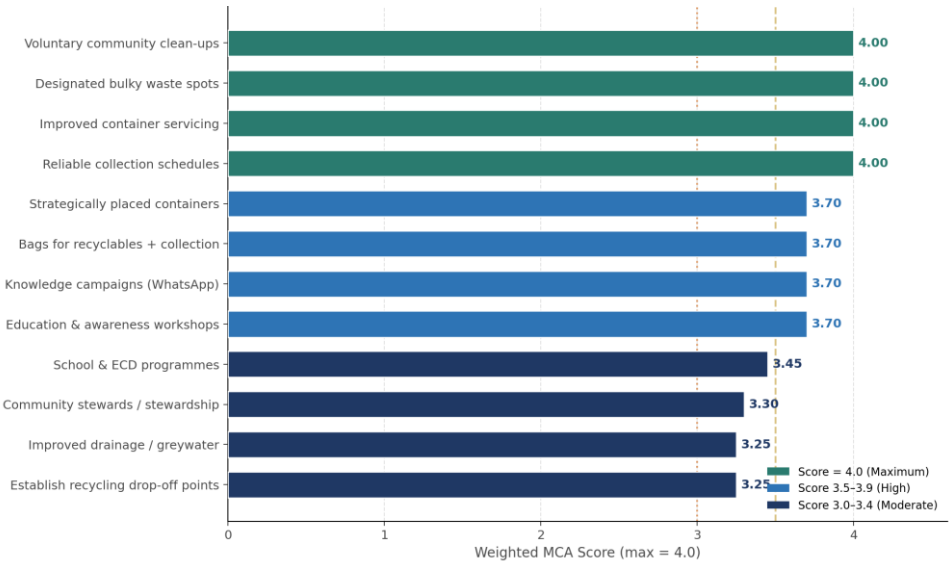

Figure 2. Multi-Criteria Analysis Results — Top 12 Prioritised Interventions, Dunoon North

Source: City of Cape Town (2025, 2026)

3.3. Pilot Implementation and Results

The operational pilot ran from October to December 2025, covering 390 households across four collection zones in Dunoon North. The pilot tested a community-led waste management model comprising separation at source (organics in five-litre buckets and recyclables in clear bags), door-to-door awareness raising by Waste Ambassadors, inclusive relay collection systems using trolleys for areas inaccessible to vehicles, and mini sorting stations at the community centre and Library Square. Recyclables were transported to the community centre precinct for storage and

sorting; organics were directed to pig farmers and then to Potsdam Campus. Ten of twelve PROs invited to an industry engagement session on 1 October committed to supporting the project through equipment, training, and market access (City of Cape Town, 2026). This 83 per cent commitment rate reflects the circular economy integration that Mabiletsa (2026) identifies as a sustainability imperative for effective waste governance.

The initial five-day pilot results, summarised in Figure 3, were striking. The organics participation rate was 36 per cent; the recyclables participation rate was 51 per cent. Over five days, 443 kg of organics and 400 kg of recyclables were collected, totalling over 843 kg of waste diverted from the illegal dumping stream (City of Cape Town, 2026). The close-out report notes that these figures were subsequently revised upward following the full October collection cycle, with actual tonnage suggesting that the scalability projections should almost double the initial estimates: extrapolating to 10,000 households projects 93.3 tonnes of organics and 183.3 tonnes of recyclables diverted, a ratio of approximately 1.96:1 (recyclables to organics), indicating that recyclable waste dominates the informal settlement waste stream more heavily than initial pilot data suggested (City of Cape Town, 2026).

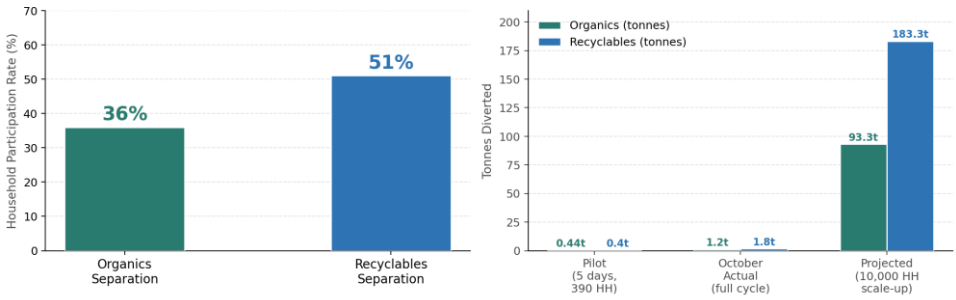

Figure 3: Bloomberg Dunoon Pilot — Results and Scalability Projections
Source: City of Cape Town (2026)

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Source: City of Cape Town (2026)

3.4. Key Lessons

The close-out report identifies lessons across four domains (City of Cape Town, 2026), each of which maps directly onto one or more of Mabiletsa's (2026) theoretical frameworks. In terms of *process*, design-led thinking proved transformative: structured tools such as problem trees, dot voting, and World Café

sessions enabled residents to co-create solutions grounded in lived experience, fostering creativity, ownership, and practical innovation in ways that conventional community consultations could not. The phased implementation model — Prototype, Iteration, Expansion, Institutionalisation — allowed for real-time learning and adaptation, a feature that the TOE framework (Tornatzky & Fleischer, 1990, as cited in Mabiletsa, 2026) identifies as essential for technology adoption in resource-constrained municipal environments.

In terms of *community dynamics*, the embeddedness of the elected Waste Ambassadors was identified as the single most important operational variable. Their grassroots legitimacy — derived from community election rather than institutional appointment — created trust networks that enabled both behavioural compliance and rapid problem resolution. The 88.5 per cent female composition of the Ambassador cohort, and the evidence that women's leadership consistently produces stronger community compliance and sustained behaviour change in waste management interventions (City of Cape Town, 2025, 2026), is a finding that carries significant implications for the design of future replication programmes.

In terms of *management*, adaptive management proved essential. Early logistical challenges — damaged trolleys, misaligned collection zones, inadequate bag distribution — were resolved through rapid feedback loops rather than formal escalation processes. The M&E framework, though primarily manual at this stage, tracked household engagement rates, waste volumes, and hotspot reduction, providing the data management function that Mabiletsa (2026) identifies as a critical moderating variable. The explicit identification of mobile-based digital tools as a next-phase priority represents the 4IR transition pathway — from people-led data gathering to technology-enabled real-time monitoring — that the thesis anticipates.

In terms of *coordination*, cross-departmental collaboration was both the project's most significant institutional achievement and its most precarious asset. The Dunoon transversal team — spanning Urban Waste Management, Water and Sanitation, the City Manager's Office, and Future Planning and Resilience — maintained meaningful collaboration across a six-month design-and-implementation process, a feat that Mabiletsa (2026) identifies as genuinely unusual in South African municipal governance, where departmental silos and competing performance frameworks typically create structural incentives for isolation. The recommendation in the close-out report to embed this collaboration in a formal Project Steering Committee with Mayoral Programme reporting accountability (City of Cape Town, 2026) reflects a

sophisticated understanding of the institutional conditions required for this kind of cross-departmental integration to survive beyond the lifespan of an externally funded innovation project.

4. The PIDA Co-Design Framework for Informal Settlement Waste Governance

4.1. Framework Overview and Rationale

The PIDA Framework — Prepare, Investigate, Design, Activate — is proposed as a structured, theoretically grounded, and empirically validated model for community co-design of waste management systems in Cape Town's informal settlements. It is both an adaptation and an extension of the Dunoon process: an adaptation in that it codifies the sequential logic of the six Dunoon workshops into a replicable four-phase structure, and an extension in that it explicitly incorporates Mabiletsa's (2026) theoretical frameworks and moderating variables as structural requirements rather than background assumptions. Figure 4 presents the full framework, including its cross-cutting enablers.

The framework rests on a foundational premise that is both theoretically established and empirically demonstrated: that community co-design is not a supplementary activity to waste service delivery but a prerequisite for it. In informal settlements where spatial constraints, irregular tenure, and high densities defeat conventional collection models, community knowledge and community labour are the most critical inputs into effective service design. This premise is supported across all four theoretical frameworks applied by Mabiletsa (2026): DOI theory demonstrates that trusted community adopters accelerate innovation diffusion; the TOE framework identifies public participation as a critical environmental driver of technology adoption; ANT reveals that sustainable waste systems require stable human-non-human networks built around community engagement; and Institutional Theory shows that institutional resistance to change is overcome when community participation generates visible early results that demonstrate legitimacy.

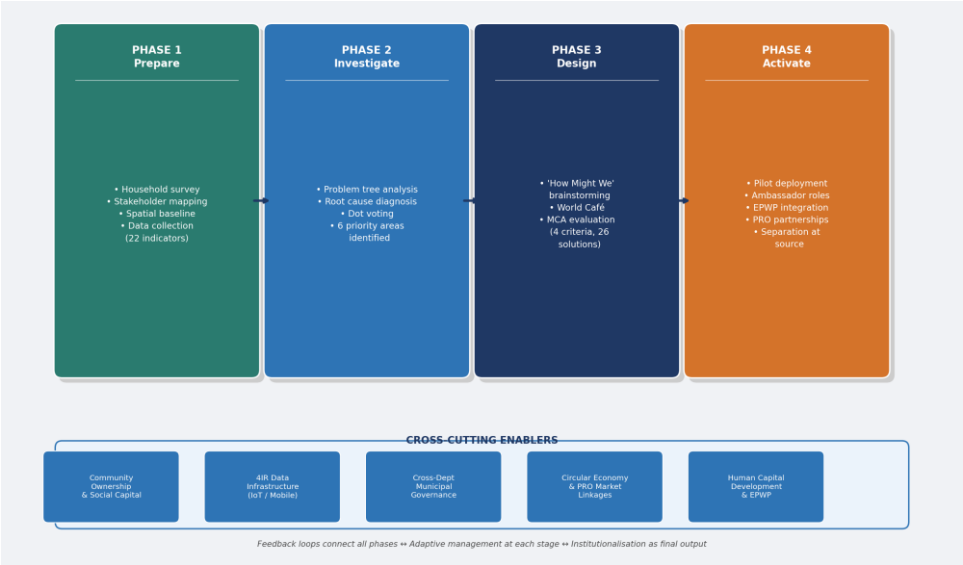

Figure 4. The PIDA Community Co-Design Framework for Informal Settlements

Source: Adapted from Mabiletsa (2026); City of Cape Town (2025, 2026)

4.2. Phase 1: Prepare — Building the Evidence and Relationship Foundation

The Prepare phase establishes the empirical and relational conditions without which co-design cannot be genuinely participatory. It comprises four activities: a structured household survey using a minimum of 20 validated indicators covering waste practices, service perceptions, willingness to engage, health impacts, and existing community initiatives; stakeholder mapping to identify all formal and informal actors in the waste system; spatial baseline documentation using participatory mapping to locate waste hotspots, collection points, drainage systems, and access constraints; and initial relationship-building with community structures, ward committees, and informal recyclers.

The theoretical grounding for this phase comes from Mabiletsa's (2026) data management moderating variable: evidence-based waste governance requires reliable baseline data, which in informal settlements can only be generated through community-mediated, face-to-face data gathering. The Dunoon survey's 22-question instrument, administered to 1,135 households by the City's Water and Sanitation team, created the first systematic, granular baseline of waste practices and perceptions in the area, directly enabling the precision of subsequent co-design work

(City of Cape Town, 2025). Without this foundation, the workshop outputs would have been generic; with it, they were spatially specific, behaviourally grounded, and operationally actionable.

The Prepare phase also serves a function that goes beyond data collection: it signals institutional intent. When a municipality invests in listening before it proposes, it shifts the power relationship between institution and community from directive to collaborative, creating the trust environment that the Dunoon experience demonstrated is essential for community ownership of waste solutions (City of Cape Town, 2026). This is the mechanism through which Institutional Theory's normative pressures (Guth, 2016, as cited in Mabiletsa, 2026) can be converted into positive drivers of change: when communities see that their lived knowledge is taken seriously, they bring it — fully and without the self-censorship that characterises purely consultative engagement.

4.3. Phase 2: Investigate — Diagnosing Root Causes Through Community Analysis

The Investigate phase applies structured design-thinking tools to transform the data gathered in Phase 1 into a shared, community-owned diagnosis of the root causes of waste management failure. The core tools are the problem tree, used to map causal chains from immediate symptoms (illegal dumping) to underlying causes (inadequate infrastructure, behavioural norms, service inaccessibility) to structural roots (governance misalignment, contractual inflexibility, data absence); dot voting, used to prioritise the root causes on which interventions should focus, based on community judgements about impact and tractability; and the 'Five Whys' analytical technique, which deepens root cause analysis by tracing causal chains to their systemic origins.

The Dunoon Investigate phase (primarily Workshop 2) generated six thematic priority areas from a community of 80 participants, producing insights about the spatial dynamics of illegal dumping, the role of container accessibility and servicing frequency, the barriers to recycling engagement, and the connection between greywater management and waste accumulation that technical assessments by municipal engineers had not surfaced (City of Cape Town, 2025). This is the core epistemological contribution of community co-design: it generates actionable knowledge that cannot be generated any other way. As Mabiletsa (2026) notes in

discussing the data gaps identified in South African waste management research, the absence of reliable, granular, community-level waste data is one of the primary barriers to effective governance reform — and participatory root cause analysis is among the most powerful tools for generating it.

The Investigate phase culminates in a community-validated problem hierarchy — a ranked map of the root causes that the community and the municipality agree to address — which becomes the specification for the Design phase. This hierarchy serves a dual function: it grounds the subsequent ideation in a shared understanding of what actually needs to change, and it creates the accountability structure that the close-out report identifies as essential for community ownership of implementation (City of Cape Town, 2026).

4.4. Phase 3: Design — Co-Creating and Evaluating Solutions

The Design phase moves from diagnosis to solution generation using three primary tools: 'How Might We' brainstorming, which reframes root causes as design opportunities and generates a broad solution space through colour-coded team ideation; the World Café format, which rotates participants across solution stations to enable cross-pollination and refinement; and Multi-Criteria Analysis, which applies a structured, weighted evaluation matrix to prioritise solutions based on feasibility, impact, scalability, and resource availability.

The MCA instrument developed for Dunoon — using four weighted criteria (illegal dumping reduction 30%, deliverability 25%, scalability 25%, resource feasibility 20%) to evaluate 26 community-generated solutions — represents a significant methodological contribution that should be institutionalised in all future co-design processes (City of Cape Town, 2025, 2026). It converts community creativity into municipal operationalisability: it does not override community priorities, but it applies technical rigour to the question of which community priorities can actually be implemented, at what cost, and with what likelihood of success. This is the integration of Mabiletsa's (2026) technological integration and sustainability focus moderating variables into the design process itself: solutions are not selected on the basis of community enthusiasm alone but on the basis of a structured assessment of their long-term viability.

The Design phase also includes industry engagement, as the Dunoon process demonstrated through the PRO session of 1 October 2025, which secured

commitments from 10 of 12 invited industry bodies for equipment, training, and market access. This engagement translates the circular economy aspiration — treating waste as a resource rather than a disposal problem — into concrete market linkages that make household waste separation economically meaningful for residents. Mabiletsa (2026) identifies sustainability focus as a critical moderating variable for effective waste management; the PRO engagement model is the mechanism through which this sustainability focus is operationalised in an informal settlement context.

4.5. Phase 4: Activate — Deploying, Monitoring, and Learning

The Activate phase comprises the operational pilot deployment, the M&E framework, the ambassador training and onboarding, and the feedback loops that enable adaptive management. The Dunoon experience demonstrated that a 325+ household pilot, divided into four collection zones each served by a dedicated team of Waste Ambassadors, can generate meaningful waste diversion data within five days of operation (City of Cape Town, 2026). The key design principles for this phase are: starting small and evidence-rich (generating data that can justify scale-up); deploying inclusive collection infrastructure (trolleys, relay systems) that can serve the full spatial range of the settlement; integrating EPWP mechanisms to formalise Ambassador roles with fair compensation; and building feedback loops that are fast enough to enable real-time operational adjustment.

Mabiletsa's (2026) regression findings establish that ICT adoption and investment in smart waste management significantly influence waste efficiency performance. The Activate phase is where this finding is most directly actionable: the transition from manual data capture (registers, weighing scales, photo documentation) to mobile-based digital tools represents the 4IR entry point for the informal settlement waste governance system. The close-out report explicitly identifies this transition as a next-phase priority (City of Cape Town, 2026), and the PIDA Framework formalises it as a built-in Activate phase requirement: every pilot deployment must include a digital data capture component, even if initial data capture remains primarily manual, so that the baseline for the 4IR transition is systematically established from the first day of operation.

4.6. Cross-Cutting Enablers

Five cross-cutting enablers are essential to all four phases of the PIDA Framework. *Community ownership and social capital* — activated through the election of legitimate community leaders and the systematic recognition of community knowledge as a primary design input — is not simply a desirable outcome but an operational prerequisite. The Dunoon evidence shows that elected Waste Ambassadors achieved compliance rates that externally appointed community workers consistently fail to achieve (City of Cape Town, 2026). *4IR data infrastructure*, including mobile data capture, IoT-enabled waste monitoring, and digital dashboards, enables the transition from reactive to predictive waste management and from manual to automated performance tracking (Mabiletsa, 2026). *Cross-departmental municipal governance*, formalised through a Project Steering Committee with Mayoral Programme accountability, ensures that the integration of waste, water, sanitation, and spatial planning that informal settlements require is structurally mandated rather than dependent on individual relationship. *Circular economy and PRO market linkages* convert waste separation from a civic obligation into an economic opportunity, aligning the sustainability focus moderating variable with household-level incentives. *Human capital development and EPWP integration* formalise the Waste Ambassador role and ensure that the social capital generated by co-design is converted into durable, compensated, institutional capacity.

5. Policy Implications and Recommendations

The convergence of Mabiletsa's (2026) doctoral findings and the Dunoon pilot evidence generates a set of policy implications that are both theoretically grounded and empirically supported. They are organised here around the five moderating variables Mabiletsa (2026) identifies as prerequisites for effective 4IR-enabled waste management in South African metropolitan municipalities.

On *technological integration*, the City of Cape Town should invest in a phased digital infrastructure programme for informal settlement waste monitoring, beginning with mobile-based data capture tools deployable by Waste Ambassadors and progressing to IoT-enabled bin sensors and real-time collection route optimisation. Mabiletsa (2026) recommends establishing dedicated SWM technology funds at the municipal level and developing regulatory sandboxes for

SWM innovation — both of which would facilitate this transition without requiring simultaneous city-wide deployment.

On *data management*, the household survey instrument developed for Dunoon should be standardised, digitised, and deployed as a baseline tool in all informal settlements where co-design processes are initiated. The target of 22 validated indicators covering waste practices, service perceptions, and health impacts (City of Cape Town, 2025) provides a replicable template. Mabiletsa (2026) identifies the absence of reliable waste data as one of the primary barriers to evidence-based governance reform; systematic baseline surveying before every co-design process directly addresses this gap.

On *sustainability focus*, the PRO engagement model tested in Dunoon — which secured commitments from 10 of 12 industry bodies contacted — should be formally institutionalised as a standard component of all informal settlement waste management initiatives. Mabiletsa (2026) recommends aligning municipal strategies with national waste management goals, including the Extended Producer Responsibility Regulations introduced under the Waste Act Amendment; the PRO model provides the operational mechanism for this alignment in informal settlement contexts.

On *human capital development*, the Waste Ambassador model should be formalised in municipal contracts with fair compensation, clear performance incentives, and structured career pathways. Mabiletsa (2026) recommends investing in human capital development for smart waste management as a standalone policy priority. The Dunoon evidence demonstrates that community-elected ambassadors, properly trained and compensated through EPWP mechanisms, are among the most cost-effective human capital investments available in the informal settlement waste management space (City of Cape Town, 2026).

On *public participation*, the PIDA Framework's co-design process should be embedded in the City of Cape Town's standard operating procedures for informal settlement waste management, replacing the current practice of periodic community consultation with a structured, six-phase engagement process applied systematically before any service delivery redesign. Mabiletsa (2026) explicitly recommends mandating public and stakeholder participation in smart SWM as a policy requirement; the PIDA Framework provides the operational architecture through which this mandate can be implemented.

6. Conclusion

The persistent failure of waste management in Cape Town's informal settlements is not a mystery. It is the predictable result of applying service models designed for formal urban environments to spatial and social contexts that those models were never designed to serve. What the Dunoon Bloomberg Philanthropies Mayors Challenge pilot demonstrates — with striking empirical clarity — is that when this design assumption is abandoned, and when residents are treated as the primary experts on their own settlement's waste dynamics, the results can be both immediate and significant.

This paper has situated the Dunoon evidence within the theoretical architecture established by Mabiletsa (2026), demonstrating that the pilot's success is theoretically explicable and its methodology replicable. The five moderating variables Mabiletsa (2026) identifies — technological integration, data management, sustainability focus, human capital development, and public participation — were each operationalised in the Dunoon process, and each contributed to its outcomes. The Diffusion of Innovation Theory explains the rapid adoption trajectories generated by trusted community ambassadors. The TOE Framework explains why cross-departmental municipal collaboration and community co-design address the organisational and environmental barriers that have historically defeated technology adoption in this context. ANT explains why the careful assembly of human and non-human waste management networks — residents, ambassadors, trolleys, sorting stations, PRO market linkages — generated a system more durable than any of its individual components. Institutional Theory explains why embedding the process in formal municipal governance structures, with Mayoral Programme accountability, is necessary to ensure that what began as an innovation pilot becomes standard practice.

The PIDA Framework proposed in this paper — Prepare, Investigate, Design, Activate — provides a structured, four-phase model for replicating this approach systematically across Cape Town's 850 informal settlements and, potentially, across the informal settlement landscapes of South African and Global South metropolitan municipalities more broadly. The framework's five cross-cutting enablers — community ownership, 4IR data infrastructure, cross-departmental governance, circular economy integration, and human capital development — are not optional enhancements but structural requirements. Remove any one of them, and the

framework loses the integrative coherence that the Dunoon pilot demonstrated is the source of its effectiveness.

The City of Cape Town recently secured one million US dollars in Bloomberg Philanthropies Mayors Challenge funding to scale the Dunoon model to four additional informal settlements over 24 months (City of Cape Town, 2026). That scale-up will be the test of the PIDA Framework's replicability claim. The theoretical prediction, grounded in Mabiletsa's (2026) research and the empirical evidence from Dunoon, is that the framework will hold — provided that the institutional conditions for genuine community co-design are created and sustained at each new site, and provided that the digital data infrastructure that enables adaptive management is built systematically from the first day of each new engagement. The ambition, as the Dunoon initiative expressed it from the outset, is not modest: 'A cleaner and healthier Cape Town for all.' The PIDA Framework is a step toward making that vision governable.

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