RESEARCH SUMMARY 2025

Resilience of container-based sanitation:
evidence and insights

Photo: SOIL

Cranfield University

CBSA
Container Based Sanitation Alliance

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Introduction

In today's rapidly changing world, resilience has become a critical priority for infrastructure and services, as societies face increasingly frequent and severe shocks – including climate-related shocks as well as social, economic, and health crises. Rapid urbanisation is pushing human settlements into flood-prone areas, wetlands, and other hazard zones, often faster than planning and infrastructure can keep up (Rentschler et al., 2023). This growing overlap between urban expansion and climate risk makes it essential to strengthen resilience across all urban systems, including sanitation.

Climate-resilience in sanitation is gaining particular attention as the links between the climate crisis and sanitation systems become more widely recognised. Sanitation infrastructure and services are highly vulnerable to climate-related shocks – such as flooding, drought, and other extreme weather – which can damage infrastructure, interrupt service provision, and displace communities. These disruptions increase health risks and environmental pollution – particularly in low-income and marginalised communities, who are most at risk. In addition, poorly managed sanitation contributes to climate change, particularly through methane emissions from pit latrines and septic tanks.

CBS is a sanitation service that uses portable, sealable containers to collect human waste. These containers are regularly collected and safely treated, reused, or disposed of off-site. CBS has been recognised as a safe sanitation solution for achieving SDG 6.2 by the JMP (UNICEF & WHO, 2018) and is recommended by the World Bank as part of citywide inclusive sanitation strategies (World Bank, 2019). As CBS does not require digging, it has found a niche in many hard-to-reach or underserved contexts, where few safe options exist. This includes densely populated informal settlements, refugee or transitional settlements, areas with rocky ground, unstable soil conditions, high water tables, hills, limited water, or frequent floods.

In 2022, the Climate Resilient Sanitation Coalition was established to build momentum in the sector, strengthen policy and practice, and unlock climate investment for sanitation. In 2024, it developed new guidance (GCF, 2024) on climate-resilient sanitation, which has been included as an annex to the Green Climate Fund's Water Project Guidelines, helping to clarify what types of sanitation solutions are eligible for climate funding.

The GCF guidelines highlight Container-Based Sanitation (CBS) as a robust and adaptable sanitation solution that aligns well with climate resilience principles. CBS systems are water-efficient, rely on sealed containers for safe waste containment, and use flexible transport and frequent collection mechanisms – features that enable continued service delivery during floods, droughts, and other climate-related disruptions. The guidelines also emphasise the role of active service management and circular economy approaches in reducing emissions. These are core features of the CBS model: all providers actively manage their services and the majority convert waste into valuable reuse products such as fertilisers, biogas, and soil conditioners. This positions CBS as a strong candidate for climate funding, offering a pathway to simultaneously build resilience, cut emissions, and advance sustainable development.

Current evidence demonstrates that CBS offers strengths for mitigation – most notably through its potential to reduce methane emissions relative to on-site systems such as pit latrines or septic tanks. However, evidence on CBS as a climate adaptation strategy is

limited, and little is known about how services are adapting to the climate crisis. Strengthening this is critical to inform effective planning, support policy decisions, and unlock access to urgently needed climate funding. This project synthesises evidence on the resilience of CBS through literature review, interviews with CBS providers and longitudinal data analysis:

Literature review: An initial search identified 138 English-language academic articles from CBSA sources and independent research. Articles were found through databases such as Google Scholar, Scopus, and Science Direct, using search terms including container-based sanitation, on-site sanitation, and non-sewered sanitation, alongside terms related to disasters, emergencies, and climate resilience. Following the application of relevance and rejection criteria, a smaller number of high-quality studies were reviewed and cited in depth.

Interviews: Cranfield researchers conducted an online focus group discussion with CBSA members to gather evidence of their experiences of preparing and managing shocks. This process was complemented with five online interviews with representatives from various CBS enterprises.[1]

Data analysis: Data analysis was undertaken of data gathered from a large longitudinal ESRC-funded project data set on CBS in Kenya, South Africa and Peru. Data was collected on shocks experienced by individuals (including floods and civil unrest) and on problems with CBS services. This stage involved a comparative analysis of CBS users and non-users, and to identify the differences in their experiences during periods of shocks.

Through this work, the study examines how CBS systems have performed under climate stress – not only in theory, but in practice. Existing literature highlights the potential resilience of CBS, grounded in design features such as sealed waste containment and active service management. Interviews with CBS providers surface real-world examples illustrating how these features have supported service continuity during climate shocks, particularly flooding and heavy rainfall. They also gathered evidence of how providers are actively investing in and adapting their services to further enhance resilience. Complementing these insights, analysis from three informal settlements – in Nairobi, Lima, and Cape Town – suggests that CBS users experienced fewer sanitation-related problems during extreme weather events compared to users of other systems, except during droughts. While the experience during droughts is unexpected and warrants further investigation, these findings provide additional indications that CBS can support both climate adaptation and mitigation.

While the major focus of this paper is on climate resilience, it also highlights the broader dimensions of CBS resilience.

[1] Consent was sought from each interviewee, and interviews were recorded and auto transcribed. Ethical approval was received from Cranfield University, CURES/24539/2025. Interviews were analysed to identify emerging themes, and to compile specific examples of how CBS systems and organisations were resilient.

Rapid literature review

This review examined existing literature on the resilience of CBS services and their capacity to cope with social, operational and climate-related shocks. Organisational resilience is an organisation's strategic capability to anticipate, prepare for, respond to, and adapt to both incremental changes and sudden disruptions to ensure it survives and prospers (British Standards Institution (BSI), 2022). In a similar vein, climate-resilient sanitation is defined as services that anticipate, respond to, cope with, recover from, adapt to or transform based on climate-related events, trends and disturbances, all while striving to achieve and maintain universal and equitable access to safely managed services, where possible and appropriate, minimising emissions, and paying special attention to the most exposed vulnerable groups (SWA, 2024).

Studies highlight features such as modular, portable, and above-ground designs, along with low water requirements, that enable CBS to function in hard-to-reach or emergency settings, and during floods and water scarcity:

- **Rapid deployability and modular design:** CBS systems are highly deployable in post-shock, hard-to-reach, and emergency settings, including natural disasters and temporary refugee sites (Nyoka et al., 2017; World Bank, 2019a; Larson, 2018). They do not require digging or constructing superstructures, which enables faster setup. Modular and standardised designs allow flexibility in deployment: some providers import stand-alone toilets or kits for local assembly, while others manufacture structures locally and source containers through established markets (Nyoka et al., 2017; World Bank, 2019a).
- **Above-ground design and flood-resistant facilities:** CBS systems are positioned above ground, either at household elevation (SOIL, Sanima, Clean Team, Mosan, Sanivation) or in elevated superstructures (Fresh Life/Sanergy, Loowatt). Above-ground positioning limits water entry during rainfall and some flooding (VanRiper et al., 2022). In Haiti, EkoLakay toilet cartridges' elevation helps prevent water intrusion during minor flood events, and cartridges can be sealed during extreme flooding (VanRiper, 2021, p. 41). Some providers have also engineered flood-resistant treatment facilities, such as SOIL's elevated windrows for composting collected waste, demonstrating how CBS infrastructure can be designed to withstand extreme weather (World Bank, 2019d).
- **Low water requirements and flexible resource sourcing:** CBS systems function effectively under water scarcity, unlike traditional sanitation systems such as septic tanks or pour-flush latrines (Sherpa et al., 2014; Willetts et al., 2022). CBS relies on cover materials – most commonly sawdust – rather than water, providing a reliable and affordable option in water-stressed contexts (World Bank, 2019c, pp. 28 & 34). For example, during the 2017 Nairobi drought, potable water prices rose by 67%, making pour-flush toilets increasingly expensive, while CBS users could source sawdust locally at little or no cost (World Bank, 2019c). Providers have also developed adaptive strategies to maintain cover material supply: Sanergy obtains sawdust for free from carpentry workshops, Sanima mixes finished compost with cover material, and SOIL sometimes uses compost exclusively. These approaches strengthen resilience by ensuring supplies are locally available even during civil unrest or political upheaval (Ferguson et al., 2022; Hyde-Smith et al., 2022).

- **Operational resilience under systemic shocks:**
  CBS has also demonstrated resilience to social, economic, and health-related disruptions. During the COVID-19 pandemic, CBS providers maintained operations despite travel restrictions and social distancing requirements by expanding workforces, shifting to remote working, implementing staff bubbles, separating shifts, enforcing hygiene protocols, and deploying mobile payment systems and GPS-based routing to reduce dependence on individual staff knowledge. For instance, SOIL accelerated rollout of a GPS routing app to optimize collector routes, while Fresh Life deployed a cloud-based system for contracts, financing, and reporting. CBS ventures were often recognized as essential services, allowing continued operations even when revenue-generating activities like compost sales were curtailed. In contrast, conventional sanitation systems such as vacuum tankers faced restrictions that limited service delivery in countries including Uganda, Kenya, and Ghana (Mikhael et al., 2021).

The studies described above highlight CBS design and operational features that enable service continuity under diverse shocks – ranging from rapid deployability in emergencies, to flood-resistant and low-water designs, to adaptive workforce and supply chain strategies during systemic crises. These features demonstrate the capacity of CBS to anticipate and prepare for disruptions, respond to and cope with immediate shocks, and in some cases recover from and adapt to changing conditions. However, not all claims are supported by empirical evidence; several are based on theoretical reasoning or common-sense assumptions about CBS design. While these insights are not without merit, more real-world examples and systematic evaluations are needed to confirm how CBS systems function in practice. There is also limited evidence on how CBS systems transform post-shock to sustain service delivery and meet user needs over time. Further research is needed to understand recovery trajectories, user experiences during service restoration, and the extent to which CBS contributes to longer-term resilience and transformative adaptation in urban sanitation.

Findings

1. Interviews

Interviews with six CBSA member organisations explored how CBS systems respond to shocks and the ways providers are building resilience into service delivery. The discussions covered experiences across a range of stressors, including climate-related shocks (such as floods, heatwaves, and water shortages) and social disruptions (such as protests and insecurity). Providers shared their perceptions of what made their systems resilient, the adaptations they had implemented, the value of complementary approaches and cost implications.

Flooding emerged as the most common shock, reported by five out of the six providers interviewed. Several CBS characteristics highlighted in the literature proved valuable in practice. For example, sealed containers have been safely stored or moved during floods and CBS's inherent water efficiency – requiring minimal water for toilet use and container cleaning – has been a major asset during water shortages.

In addition, the interviews highlighted how their close relationships with communities supports resilience. For example, during the COVID-19 pandemic, CBS providers leveraged their trusted presence in informal settlements to disseminate health messaging and counter misinformation. In Haiti, CBS collectors were able to navigate protests and road barricades due to strong local trust and recognition.

Beyond these elements, providers described a wide range of adaptations – technical modifications, proactive management, and system flexibility – all embedded within a broader approach that treats adaptation as an ongoing process rather than a one-off exercise.

The following sections explore this in greater depth, focusing on:

- **Enterprise perspectives on adaptation planning** – how providers conceptualise resilience and adapt approaches to different local contexts;
- **Adaptive management practices** – how providers adjust and strengthen operations through ongoing experience and iterative learning;
- **Complementary approaches and planning implications** – how CBS interacts with other sanitation systems during shocks and the implications for citywide planning; and
- **Costs and investment** – the resources required to sustain resilient CBS services at scale.

Enterprise perspectives on adaptation planning

Understanding of adaptation planning varies across enterprises. Providers interpret resilience in terms of both system performance under climatic or operational shocks and the robustness of organisational processes. Beyond features that make CBS inherently resilient, organisational resilience has been critical to sustaining service delivery under stress.

Most respondents echoed one participant's definition of resilience as define resilience as "making gradual adaptation in the system to ensure it fits within the context in which we are working," reflecting attention to local hazards and aligning with established principles of adaptive planning. However, even enterprises in lower-risk areas have documented experiences from minor floods and slippery roads, enabling them to adjust more rapidly if confronted with severe events. These initiatives demonstrate that CBS adaptation planning involves not only gradual, context-specific adjustments but also proactive organisational strategies to anticipate, prepare for, and maintain service delivery under stress.

Adaptive management practices

Interviews revealed that CBS resilience is not a fixed attribute or a one-off effort, but evolves through a continuous, iterative process of "trial and error." These efforts are also context-specific: enterprises in semi-arid or low-flood-risk areas, such as Sanivation, Sanima, and Clean Team, face different challenges than providers in flood-prone locations like SOIL and Sanergy, where resilience often requires more proactive operational adjustments (see Table 1). Long-established enterprises such as Sanergy in Mukuru, Nairobi, have particularly learned to anticipate recurring challenges and embed proactive measures into their operations. The most common response strategies among providers included rescheduling collections and rerouting staff, complemented in some cases by secure storage of containers until transfer was possible. When necessary, providers paused collections until conditions improved, ensuring clients were informed and equipped to manage during the disruption.

"Our challenges are repetitive, *so we have invented ways to deal with the challenges we face within the community and organisation. We also encourage pragmatic innovation, so people are encouraged to come up with creative ways and solutions to challenges*." – Sanergy staff, 2025

Providers also draw on external information and strong customer communication systems. Access to weather alerts or security warnings, combined with WhatsApp groups, phone calls, or apps, allows them to advise households, reassure users, or mobilise collectors ahead of shocks. Stronger institutional linkages also support resilience: Sanergy benefits from access to information from the MET office, while Clean Team in Kumasi and Sanima in Lima are building closer ties with municipal authorities. Such proactive measures remain relatively uncommon across the sanitation sector. Yet, despite these efforts, forecasts are not always reliable - SOIL, for example, has at times had to adjust when weather updates underestimated rainfall intensity – underscoring the iterative, trial-and-error nature of adaptation.

These practices reflect the principles of adaptive management, which emphasise continual planning, implementation, monitoring, evaluation, and adjustment – a critical framework given the growing frequency and intensity of climate risks. The following table gives and overview of adaptations that CBS providers have undertaken:

CBS ADAPTATIONS

SHOCK	ADAPTATION TYPE	ADAPTATION
	Technical modifications	- Superstructures raised in flood prone areas. - Drainage installed at treatment plant to avoid flooding. - Toilets constructed with concrete to prevent displacement. - New transfer station sites selected to avoid riparian areas.
	Proactive management	- At least one-month stock of cover material kept in protected storage to ensure availability regardless of rainfall or supply chain interruptions. - Containers collected before forecasted rain event, with extra staff and vehicles deployed when needed. - Users advised to seal and move containers ahead of rain event. - Extra containers provided before flood events. - Users trained to empty urine jerry cans into pit latrines if collections are missed. - Collectors equipped with waders or wellies and raincoats.
	System flexibility	- Three wheelers switched for trucks when the roads are affected by heavy rains. - Household collection replaced with collection points during flooding. - Hygiene kits distributed during flood events. - Toilets cleaned after submersion in floodwaters rather than replaced. - Waste stored at transfer site or middle site if road to treatment site is impassible. - Waste is moved from flooded transfer stations to alternative stations. - Handcarts pulled by two or three people during flooding - Households are visited on foot by collectors if roads are impassable. - Collection resumed after floodwater recedes. - Toilets replaced free of charge if lost in flooding and free collection is provided for a few months after flood. - Loans and grants are provided to staff whose homes are affected.
Water shortages	Technical modifications	- Storage tank are installed at processing centres in case of piped water failure.
	System flexibility	- Customers advised that cleaning can be done with a damp cloth.
Heatwaves	System flexibility	- Hats, suncream and water provided to collection and sales teams. - Activities completed early in the morning, including windrow turning.
	Proactive management	- Wind resistant roofs constructed for superstructures.
		- Roofs repaired within 24 hours if damaged.
Subsidence	System flexibility	- Toilets returned to provider if subsidence becomes a problem after a home has been constructed.
Mud	System flexibility	- Collection points moved to accessible areas during muddy conditions.
Protests	System flexibility	- Cash payrolls conducted at employee homes during times of insecurity. - Collections completed early in the day before protests start.
Organised crime	System flexibility	- Security briefings provided to collection and sales teams.

Complementary approaches and planning implications

Respondents noted the complementarity between CBS and conventional sanitation systems during shocks. Some respondents mentioned instances where conventional systems have provided backup when CBS services are disrupted, while CBS has often served users during water shortages or infrastructure failures. This flexibility reduces user vulnerability and highlights the practical benefits of maintaining a mix of sanitation options to ensure continuity of service under a range of stressors.

Understanding how and where to deploy different sanitation options requires comparative evidence. The context-sensitive adaptations highlighted above show that providers adjust strategies according to local conditions. In Naivasha, where flooding occurs but drains quickly, CBS systems might appear to be resilient, but this is mainly due to the local geography. However, conventional systems such as pit latrines in the same context may still experience issues such as leakage or contamination. Comparing different systems experiencing the same shocks would enable planners and policymakers to evaluate resilience more reliably and inform decisions about which systems are most suitable in specific locations.

Costs and investment

Ultimately, adaptation is costly, and while the exact breakdown is unknown, it is evident that resilience carries a price tag – raising the critical question of who should bear the costs of adaptation and long-term resilience to ensure no one is left behind. CBS enterprises currently rely on internal budgeting, forecasting, and external support – including grants or public contracts – to sustain resilience. For example, SOIL grants have funded emergency hygiene kits, staff assistance, client support, and road maintenance, while Sanergy has replaced lost toilets and adjusted service arrangements after flash floods. In some of these areas, providers are evolving beyond standard sanitation operations toward roles more akin to humanitarian organisations to safeguard clients during crises.

Conclusion

CBS providers implement a wide range of adaptations to deliver more resilient sanitation services. A key strength of CBS is the flexibility of collection rounds, which can be adjusted in space and time to avoid disruptions from floods, protests, or other shocks. The containers themselves are another asset: they can be sealed or relocated ahead of flooding, a capability that becomes more effective as early warning systems improve. Most CBS systems require no water for flushing and only minimal water for cleaning, which have made them well-suited to serving areas suffering from water shortages caused by climate events or infrastructure failures. Providers also take active steps to protect and support their staff during shocks, including providing PPE, adjusting shift patterns, and offering grants or loans to employees whose homes are affected.

2. Secondary data

As part of a study on off-grid sanitation practices, focusing on how different user groups access and use sanitation facilities, high-frequency longitudinal smartphone surveys were conducted over a one-year period in Kenya, Peru, and South Africa. Approximately 100 participants were recruited from three informal settlements: Mukuru Kwa Reuben in Nairobi; Pamplona Alta in Lima; and BM Section of Khayelitsha in Cape Town. The sample was evenly split between CBS and non-CBS users, and between adult men and women. Survey data was systematically gathered, anonymised, and extensively cleaned process to ensure accuracy and reliability. A full description of the wider survey is available in Lewis et al. (2024).

Each week, participants recorded whether they experienced problems with their toilet, rating severity as minor, moderate, or serious. These categories were grouped as “problem,” while “none” was recorded as “no problem.” Participants were also asked whether any “bad things” (henceforth referred to as “shocks”) occurred that week. Response options included flooding, rainfall, storm, heat, drought, landslide, and protest, with an additional “other” category. Not all respondents completed every weekly survey.

For this analysis of resilience, only the listed shocks were considered. Where a shock was reported, responses were matched with the same week’s toilet problem data. Differences between CBS and non-CBS users were tested for statistical significance using Chi-squared tests. A p-value < 0.05 was considered significant. The test could not be conducted for storms due to small sample sizes (see Table 1).

All data are self-reported, meaning “problems” and “shocks” reflect participants own interpretations. For example, interviews suggest that “landslide” may refer to the collapse of the retaining walls. While this could be viewed as a limitation, it also captures the strength of capturing lived experience rather than externally defined categories. Participant engagement rates varied between countries, and missing data were excluded through complete case analysis. This approach may introduce bias if non-response was correlated with toilet experiences or satisfaction. A further limitation is the possibility of misreporting, including participants fabricating responses to secure survey payments.

The data indicate that CBS users were generally less likely to report toilet problems than non-users during weeks when shocks occurred – except during drought (see Figure 1).

Overall, the secondary data provide rare comparative evidence on the resilience of sanitation, showing that CBS users generally experienced fewer toilet problems than non-users during climate- and event-related shocks. The exception of drought, where CBS users reported similar problem levels to non-users, is unexpected and warrants further investigation. These findings offer important insights into how CBS performs relative to other sanitation systems in real-world conditions.

Table 1: Number of times users and non-users of CBS reported experiencing problems with their toilets while also reporting a shock.

Shock type	Flooding	Rainfall	Storm	Heat	Drought	Landslide	Protest
Number of times people reported experiencing the shock	83	455	21	129	120	76	81
CBS user, problems with toilet	13	50	10	19	24	11	8
CBS user, no problems with toilet	11	147	3	26	15	15	13
CBS non-user, problems with toilet	36	127	5	39	39	33	42
CBS non-user, no problems with toilet	23	131	3	45	42	17	18
p-value (Chi squared)	0.0017	1.6E-07	n/a	0.0074	0.00096	0.011	2.6E-05

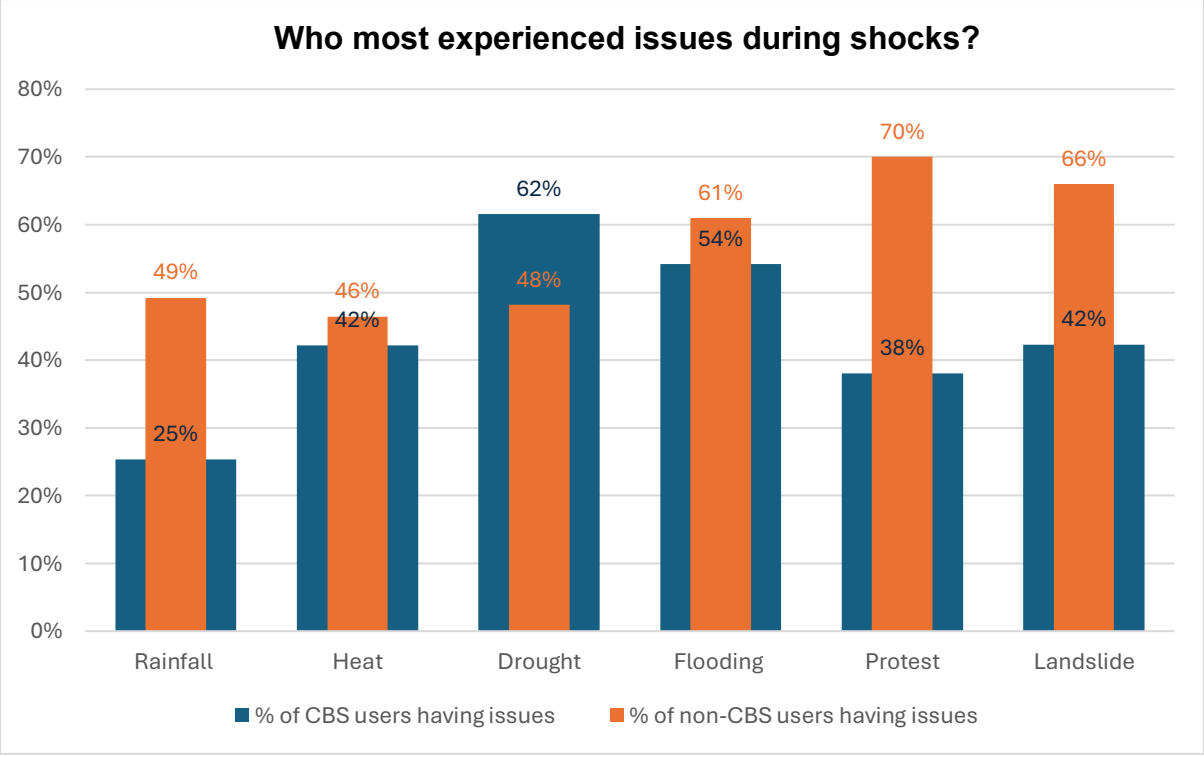

Figure 1: For each shock, percentage of the CBS users versus non-CBS users that reported a problem with their toilet.

Discussion

Evidence from literature, CBS provider interviews, and secondary data indicates that CBS systems offer meaningful resilience advantages over conventional sanitation approaches, while highlighting opportunities to strengthen the evidence and sector-wide adaptation.

Literature highlights CBS design and operational features – rapid deployability, flood-resistant and low-water designs, and adaptive workforce strategies – that enable service continuity under diverse shocks. These features suggest CBS can anticipate, respond to, and recover from disruptions, potentially contributing to longer-term resilience. However, empirical support is limited, with some claims based on theoretically grounded insights rather than evaluation of systems in the field. Much of the literature examines CBS in isolation rather than in comparison with other sanitation approaches, limiting understanding of its relative performance and contribution to resilience. Knowledge gaps remain around post-shock recovery trajectories, user experiences during service restoration, and the extent to which CBS contributes to transformative climate adaptation.

Insights from provider interviews complement and extend the literature. Minimal water requirements for cleaning or operation make CBS particularly robust in drought conditions or where water infrastructure is compromised. CBS enterprises actively implement a range of adaptations that enhance resilience in practice. Close customer relations with regular contact and communications allow providers to respond dynamically to floods, protests, or other disruptions, while containers themselves can be sealed or relocated ahead of flooding. Providers also take deliberate measures to protect staff, such as adjusting shifts, providing PPE, and supporting employees affected by shocks. These operational strategies demonstrate how that CBS provides some inherent resilience in its design but can be further enhanced through adaptive management.

Secondary data provide rare comparative evidence: across three informal settlements, CBS users reported fewer service disruptions than non-users during climate- and event-related shocks, though drought presented an exception, highlighting an area for further investigation. Key opportunities to strengthen CBS resilience include:

- **Clarifying and standardising adaptation planning**: Enterprises vary in how resilience is defined and documented. Structured frameworks would improve learning and consistency.
- **Generating further evidence**: Systematic analyses comparing CBS with other sanitation options under similar shocks, including post-shock recovery trajectories, user experiences, and longer-term service sustainability, would help fill critical knowledge gaps and guide context-appropriate planning.
- **Sustaining resources for resilience**: Adaptations currently rely on internal budgets or grants. Dedicated climate funding will be critical as shocks become more frequent and severe.

In summary, CBS demonstrates tangible resilience potential through design and actively managed operations. Strengthening evidence, planning frameworks, and dedicated resources will help translate this potential into durable, climate-resilient sanitation services that reliably serve vulnerable populations.

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