



Taking Container-Based Sanitation to Scale: Opportunities and Challenges

Kory C. Russel^{1*}, Kelvin Hughes², Mary Roach³, David Auerbach⁴, Andrew Foote⁵, Sasha Kramer⁶ and Raúl Briceño⁷

¹ Department of Landscape Architecture and Environmental Studies Program, University of Oregon, Eugene, OR, United States, ² Clean Team Ghana Ltd, Kumasi, Ghana, ³ Loowatt Ltd, London, United Kingdom, ⁴ Sanergy, Nairobi, Kenya, ⁵ Sanivation, Naivasha, Kenya, ⁶ SOIL, Cap-Haitien, Haiti, ⁷ X-Runner, Lima, Peru

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*Correspondence:

Kory C. Russel
krussel@uoregon.edu

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Container-Based Sanitation (CBS) has rapidly progressed from its inception less than a decade ago to its recent classification as a type of improved sanitation facility by the Joint Monitoring Programme. CBS in many ways represents a sustainable service, as it addresses the entire sanitation service chain; offers a variety of service-based business models; and is affordable to people living in marginalized and informal urban settlements. At the same time, CBS services which have been operating for a number of years have grown relatively slowly. Taking CBS to scale will require solving several diverse challenges, particularly the need for government mandates; regulation; and innovative financing. This paper presents the collective views of some of the world's leading CBS practitioners in an effort to summarize the potential, research gaps, and major challenges to scaling CBS.

Keywords: container-based sanitation, sustainable sanitation system, scale-up, safely managed sanitation, urban sanitation, innovative financing, government regulation, improved sanitation services

INTRODUCTION

Sustainable Development Goal (SDG) target 6.2 aims to provide “access to adequate and equie sanitation and hygiene for all and an end to open defecation.” The objective's indicator is based on the proportion of the population using safely managed sanitation, rather than obtaining access to a basic toilet. Thus, government agencies and municipalities need to upgrade ~4.5 billion people globally to safely managed sanitation services by 2030 (JMP)¹. This monumental task falls primarily upon low-income countries and rapidly growing informal urban settlements, which often have large populations coupled with small implementation budgets. Choosing the most sustainable methods and infrastructure for providing sanitation services to all remains a vexing challenge (Whittington et al., 2008, 2012; Jeuland et al., 2013).

SDG target 6.2 is more demanding than the Millennium Development Goal targets. Nevertheless, it provides an impetus to pursue more effective approaches that can serve the entire sanitation value chain. One such example has been the rapid development of container-based sanitation (CBS). CBS consists of an end-to-end service in which toilets collect excreta in sealable, removable containers (also called cartridges). The containers are regularly collected and transported to treatment facilities when full. Since 2010, modern CBS iterations have rapidly evolved into a viable, low-cost sanitation option, particularly in low-income urban settlements where demand for sanitation services is high and on-site sanitation and sewerage are not feasible or cost-effective (O'Keefe et al., 2015; Russel et al., 2015; Tilmans et al., 2015; Nyoka et al., 2017). While transporting waste in containers is not a new concept, doing so in a cost effective, safe and

¹JMP. (2017). “Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines.”

desirable manor has been a significant improvement over previous systems (Nilsson, 2006; Letema et al., 2014).

CBS services have been provided by social enterprises or NGOs, and several city utilities (such as Cape Town and Manila) are adopting CBS as part of their approach to citywide inclusive sanitation (CWIS). Revenues come from customer service fees and the sale of waste treatment by-products, including compost; protein (for animal feed); and energy (Preneta et al., 2013; Foote et al., 2017). It is important to note that CBS service are not cost recovering currently and some amount of philanthropic or public financing is still necessary.

In 2018, the JMP formally recognized CBS as a type of improved sanitation facility². The CBS full value chain approach follows the SDG definition for “safely managed” household sanitation (6.2), even in disaster and humanitarian emergency conditions.

However, as noted in a 2019 World Bank report, despite having been operational for a number of years, most CBS services are still operating in relatively early stage development³. This slow growth can primarily be attributed to the serious challenges of operating a utility service focused on the urban poor in the absence of an enabling environment supported by government mandates and regulation.

DISCUSSION OF CBS SERVICE POTENTIAL

CBS has several attributes that enable it to complement the existing suite of sanitation solutions to provide a robust citywide sanitation portfolio.

Flexible, Adaptable, and Modular

CBS has typically been used where it is infeasible or inappropriate to install sewerage systems, such as in densely populated urban neighborhoods, informal settlements, displaced person camps, or areas with high water tables or risk of frequent flooding (O’Keefe et al., 2015; Russel et al., 2015; Greenland et al., 2016; Nyoka et al., 2017).

Traditional sewerage systems require significant up-front capital investment and reliable water and energy supplies to function (Haller et al., 2007; Hutton, 2008; Massoud et al., 2009). Simplified sewers which have been successfully implemented for lower costs than traditional sewers in Brazil and Pakistan also need reliable water supplies (Mara and Alabaster, 2008). Highly professionalized, well-resourced utilities are also required to operate and maintain traditional sewers. Installing sewers may additionally be politically challenging, and can confer legitimacy on squatter settlements, disrupting the integrity of property laws (McFarlane, 2008; Scott et al., 2013; Meeks, 2018). Waterborne sewerage alone is thus unlikely to achieve SDG target 6.2, and calls are increasing for the use of more non-networked options (Mara and Evans, 2018).

In contrast, CBS toilets have a lower capital burden, require less water and energy to operate, and require limited infrastructure or installation, allowing users continuous service even after a move (Figure 1). In addition, CBS has the potential to be deployed in new areas and quickly scaled to match refugee, emergency, or disaster response needs (Nyoka et al., 2017).

Due to the relatively nascent nature of CBS, operators have typically had to act as designers, developers and builders, all while trying to meet health and safety standards for the entire sanitation value chain. However, the individual modules of the CBS value chain could be plugged into existing CWIS systems to strengthen overall sanitation service delivery. For example, Sanivation treatment plants accept both CBS and pit latrine waste, Sanergy integrates organic solid waste into its treatment process, and Clean Team disposes of waste at government treatment facilities.

Reducing Water Usage

The use of water to convey waste creates interdependency between the SDG sanitation target (6.2) the SDG water target (6.1). However, it is impractical in many regions to expect water availability and infrastructure to be able to support the implementation of sanitation in addition to providing basic water access. Instead of water, CBS uses dry cover material (sawdust, charcoal powder or unused by-products of agricultural production) or polymer film (e.g., Loowatt) for “flushing⁴”. Water savings using dry or minimal-water systems like CBS as compared to water-flush systems can vary from 6 m³/person to 25 m³/person annually, depending on waste separating techniques (Andersson, 2016). Such water saving solutions are becoming more crucial as global cities struggle with the increasing likelihood of water shortages (Muller, 2018).

Combating Climate Change

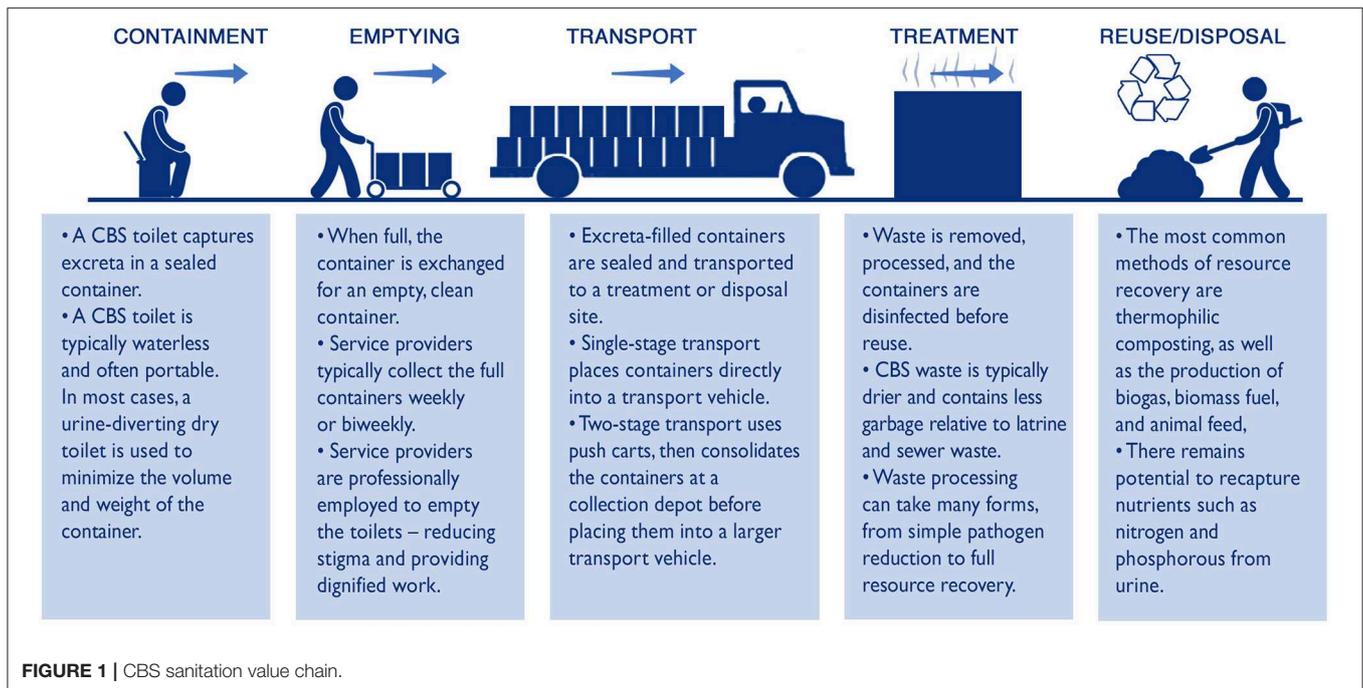
Sanitation is a significant contributor of greenhouse gas emissions (GHG), producing ~2–6% of global anthropogenic methane (Saunois et al., 2016). As urban populations grow, the use of rudimentary sanitation systems like pit latrines, septic tanks, and waste settling ponds will increase sanitation-related GHG emissions, potentially undermining efforts to slow climate change (Reid et al., 2014; Ryals et al., 2019). Thus, increased access to sanitation could be linked to increased GHG emissions, unless the prevailing sanitation paradigm shifts to climate-positive sanitation solutions.

A recent study in Haiti found the CBS system there produced less net GHG emissions compared to both waste stabilization ponds and illegal dumping (Ryals et al., 2019). Furthermore, depending on the resource recapture and reuse technology employed during treatment, CBS, unlike other sanitation systems, could contribute to carbon sequestration (Ryals and Silver, 2013; Paustian et al., 2016). CBS toilets produce less diluted or decomposed waste, which is ideal for reuse because it has not been mixed with graywater in sewers or stored in a pit for extended periods of time. As a result, fecal waste from CBS systems often produces higher quality reuse

²JMP. (2018). “Core questions on drinking water, sanitation and hygiene for household surveys: 2018 update.”

³WB. (2019). “Evaluating the Potential of Container-Based Sanitation.”

⁴Dry cover material acts as a visual barrier, smell reducer, and desiccant.



products like biomass and biogas fuels, fertilizer, or animal feed. Hence, CBS could allow for simultaneous progress toward increasing global sanitation access and reducing sanitation-related GHG emissions.

Hygienically Safe

CBS services encompass the full sanitation value chain, and therefore meets the requirement for safely managed sanitation according to the WHO. Assuming feces are properly handled throughout the service chain, including treatment and safe disposal/reuse, CBS is likely to be an effective solution for limiting the spread of fecal contamination within household and community environments (Preneta et al., 2013; Russel et al., 2015; Foote et al., 2017; Mackinnon et al., 2018; Bischel et al., 2019).

Protecting Women and Girls

Two recent reports from the Bill and Melinda Gates Foundation on gender and sanitation noted that in-home CBS services provide women and girls with a private, safe space to use the toilet and manage menstruation and pregnancy⁵. By contrast, open defecation and public sanitation options expose women and girls to high risks of violence and harassment as they travel to defecation locations, often at night (Pommells et al., 2018; Sclar et al., 2018). CBS could contribute to multi-sector approaches to eradicate this type of violence and harassment.

Affordable and Cost Effective

There has been widespread optimism around the potential for CBS providers to be financially self-sustaining given their

⁵BMGF. (2018). "Gender and the Sanitation Value Chain: A Review of the Evidence" and "Case Studies in Gender Integration: Sanitation Product and Service Delivery in Kenya."

business-focused approach⁶. A 2018 EY report found that Clean Team in Ghana was able to achieve positive gross margins, a significant step toward self-sufficiency⁷. However, whilst positive gross margins are possible, this could come at the expense of affordable user fees, thus defeating the goal of universal coverage at the city level⁸. Currently, CBS provider user fees in Ghana, Haiti, and Peru range from 3.21 to 12.00 USD per household per month (these fees are between 1.2 and 2.5% of a household income, assuming one adult in the household is earning the annual gross national income). Both a 2017 Copenhagen Consensus Center report and the 2019 World Bank report note that CBS is an affordable and likely cost-effective method of expanding services to marginalized communities⁹. However, the principal pathway to achieving scale is likely to be through government-backed contracts which guarantee service providers revenue and reduce risk.

DISCUSSION OF KEY CHALLENGES FOR CBS

Enabling Environment

Gaining government buy-in at national and local/district levels is essential to extending CBS into unserved areas. However, challenges remain in persuading governments and the wider sanitation sector that CBS is a viable alternative to sewerage.

While CBS has gained official recognition in the 2016 Kenya Environmental Sanitation and Hygiene Strategic Framework as a

⁶EY and WSUP. (2017). "The World Can't Wait for Sewers."

⁷EY. (2018). "Global Leaders in Household Container-Based Sanitation Services."

⁸Combined WASH expenditures below 5% of household income are generally considered affordable.

⁹Sklar and Faustin. (2017). "Pit Latrines or Container Based Toilets?"

safe and cost-effective alternative to sewers and on-site sanitation systems, most countries have yet to take any official stance (van Welie et al., 2019). This is often due to a lack of regulation or restrictive regulation based on outdated definitions of what comprises “safe” sanitation (Peal et al., 2014; O’Keefe et al., 2015).

In an effort to improve the enabling environment, the Container-Based Sanitation Alliance (CBSA) was formed in 2016 and became a legal entity in 2019¹⁰. The CBSA seeks to standardize CBS through research and advocacy. Each CBSA member seeks to build a policy environment in their respective countries that is conducive to the provision of CBS services. For example, CBSA members are working together with local government partners to conduct World Health Organization (WHO) Sanitation Safety Planning (SSP)¹¹, which is a modular risk assessment process used to understand and mitigate health-related hazards for each link of the sanitation chain. There is a need to foster conducive policy frameworks and regulation for waste reuse, as well as the development of markets for reuse byproducts.

Financial

There is a significant investment hurdle to ensure a CBS service can start and grow. The unit economics of sanitation and, in particular, the fees that customers can pay (assuming ~2-3% of household budgets) means the economics are difficult. Additionally, there are few examples of full value chain sanitation services in low-income markets and thus few examples of how to pay for such services. More research is therefore needed to compare the costs and benefits of CBS to traditional options and to understand the magnitude of cost savings gained through increasing service densities and economies of scale.

A new CBS service requires capital expenditures on treatment systems, conveyance equipment (i.e. trucks and carts), and toilets. These expenditures can be very expensive and difficult for any single organization to cover on their own. Additionally, by committing to addressing the full sanitation value chain, CBS providers may have higher operational cost as compared to pit emptying services. However, CBS providers are demonstrating that the use of novel treatment technologies which are safe, efficient, and can facilitate resource recovery ultimately make CBS more cost effective. Thus, leveraging public, philanthropic, and private funds to get CBS services running at scale can lead to greater return on investment in terms of public goods (public health and environmental quality) as well as private goods (privacy, cleanliness, and social status) than traditional options in dense urban settlements.

At an operational level, access to capital and longer-term financing mechanisms to scale up CBS services is often lacking (O’Keefe et al., 2015). CBS implementers are working to develop blended finance models for ensuring that there is sustainable financing in place from a mixture of earned revenues and

public sector funding. Like all sanitation options, ongoing public support will be required. This may be through public-private partnership models or other government support such as land leases, tax reductions, access to lower-cost capital, carbon credits, or electricity supply.

Management and Staffing

Some CBS service providers have faced challenges to hire, train and manage their workforces. In some contexts, local recruitment, and retention of high capacity staff can be challenging, as team members must be interested in working in a low-margin and historically stigmatized sector. Similarly, there can be a lack of fecal sludge experts as education typically focuses on traditional sewerage and wastewater treatment plant operations. Thus, incentivizing the creation of university programs that include training in a variety of sanitation technologies, in similar ways to the Gates Foundation-funded MSc at IHE Delft would be very helpful. Furthermore, governments could provide incentives to encourage qualified professionals to continuing working in nascent sanitation services that currently do not provide the economic security of more established sanitation jobs.

Building a More Complete Solution

A toilet must be attractive and aspirational to customers, easy to use, durable, and simple to install. It also needs to be attractive to governments and utilities, and meet the needs of their constituents (i.e., politically and culturally acceptable). The toilet user interface can largely be classified by defecation position and anal cleansing preferences (Figure 2). Currently, the majority of CBS toilets are designed for sitters and wipers. Wash water is a particularly important challenge in a dry CBS system, thus more research and design work are needed in washer dominated locations.

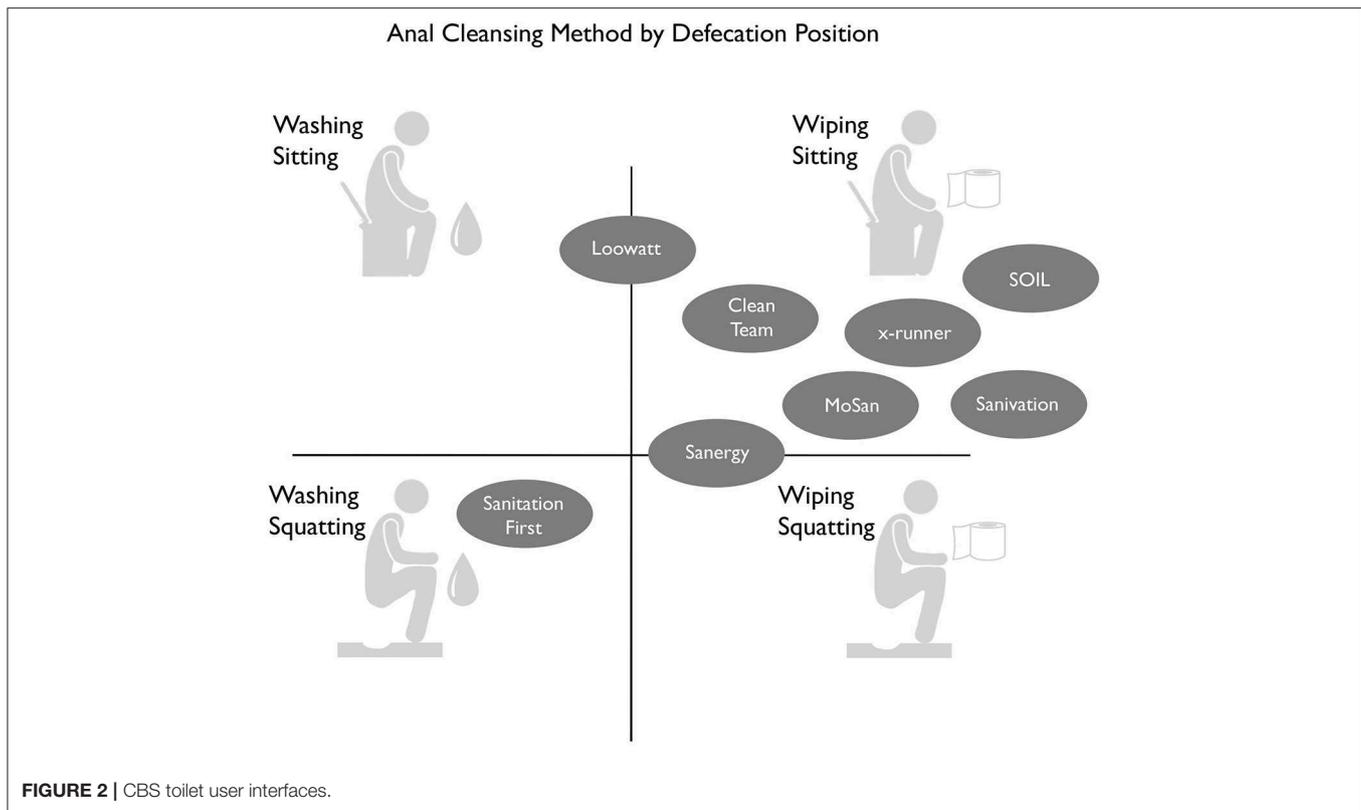
Currently, not all CBS services collect urine, as it represents a high added cost due to its weight and volume. While infiltration or urine and graywater may be an acceptable short-term solution, large scale infiltration of urine could lead to elevated nitrate and nitrite levels, as well as pharmaceutical contamination in groundwater (Templeton et al., 2015; Larsen et al., 2016). In places where water tables are high or infiltration is slow, there could be significant standing water and contamination issues. There has been substantial research by the VUNA project among others on urine resource recovery, but these technologies have not been integrated into CBS services (Simha and Ganesapillai, 2017; Hyun et al., 2019; Nagy et al., 2019)¹². Applied research that achieves a value-add proposition for integrating urine and graywater solutions in CBS services is an area of great interest.

Additionally, more research is need into the impacts CBS services have on access equality and inclusion. Given the potential to positively impact the lives of women and girls, their needs should be at the forefront of future research and design work.

¹⁰Founder members of the CBSA include Clean Team (Ghana), Loowatt (Madagascar), Sanergy and Sanivation (Kenya), SOIL (Haiti) and X-Runner (Peru). Additional CBSA members and affiliates: Sanitation First (India) and Mosan (Guatemala). Additional CBS organizations: Fundación Sumaj Huasi (Bolivia) and Non-Water Sanitation (India).

¹¹WHO. (2016). “Sanitation Safety Planning.”

¹²The VUNA project was a collaboration of EAWAG and municipality of eThekweni in South Africa (<https://www.eawag.ch/en/departement/eng/projects/vuna/>).



Logistics

CBS providers have been developing digital systems to support and strengthen service delivery as well as improve the customer experience through better logistics management (Saul and Gebauer, 2018). To aid in this digital transformation, CBSA members have been collaborating on a shared IT platform (VeriSan) for the management of service provision, but continued innovation will be an ongoing necessity.

Transportation needs to be developed in context, especially where there may be poor road infrastructure, high housing density or difficult topography. Several CBS providers use a two-stage model: door-to-door collection of containers with push carts or small motorized vehicles; use of transfer stations for temporary storage; and employing larger trucks for secondary delivery of containers to waste treatment facilities. Transport distance between households and treatment facilities is a key cost driver, and exploring innovative methods for route optimization is an ongoing and needed area of research.

Finally, maintaining hygienic safety throughout the sanitation value chain is essential. Future work that monitors potential contamination failure points and the magnitude of the associated risk in comparison to traditional sanitation options is important for improving the safety of CBS.

CONCLUSION

CBS has the potential to reach un- and under-served urban communities with sustainable, high quality, cost-effective

services that can yield multiple economic, health and environmental returns. However, wider sector buy-in and financing is required—this will help shift the prevailing paradigm to a broader understanding of the suite of sanitation options necessary for achieving inclusive citywide sanitation. There is a need to encourage sanitation and public health ministries and policy makers to include CBS among their sanitation policy options and to structure financing (e.g., targeted investment and tariffs, payment by results mechanisms, etc.) and public-private partnerships to support the expansion of CBS services.

With cities expanding at unprecedented rates and the number of people living in informal urban settlements expected to double by 2030, it is critical that new sanitation technologies and services like CBS be studied and made available to governments and unserved communities¹³.

AUTHOR CONTRIBUTIONS

KR, KH, MR, DA, AF, SK, and RB contributed the concept and identification of the perspectives presented. KR wrote the first draft of the manuscript. All authors contributed to manuscript revision and have both read and approved of the submitted version.

¹³UN-Habitat. (2010). "The Challenge of Slums."

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Conflict of Interest: KR serves as the Chair of the CBS Alliance. KH, MR, DA, AF, SK, and RB are all members on the steering committee of the CBS Alliance and individually represent organizations providing CBS services in different locations around the world. The CBSA is an alliance of CBS providers (www.cbsa.global). The CBS Alliance's stated goal is to deliver greater quality and availability of CBS services through the formalization of CBS as a widely accepted and endorsed approach among municipalities and regulators.

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