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Container-Based Sanitation Services and Attrition: An Examination of Drivers and Implications

Froggi VanRiper[1], Kory C. Russel[2], Lori A. Cramer[3], Daniel Tillias[4], Jessica Laporte[5], Erica Lloyd[5] and Sasha Kramer[5]*

[1]Environmental Sciences Graduate Program, Oregon State University, Corvallis, OR, United States, [2]Department of Landscape Architecture and Environmental Studies Program, University of Oregon, Eugene, OR, United States, [3]School of Public Policy, Oregon State University, Corvallis, OR, United States, [4]FatraKa, Cite Soleil, Haiti, [5]SOIL, Cap Haïtien, Haiti

Haiti is far from achieving the UN goal of sanitation access for all; 20% of the population has no sanitation access, and less than 0.1% of the country's excreta is safely managed. Container-Based Sanitation (CBS) may be key to achieving timely and equitable sanitation coverage in Haiti's cities. CBS can provide immediate sanitation access without preexisting infrastructure, and where permanent infrastructure is impractical. Investor caution and policy barriers, however, presently limit the growth of CBS solutions. Globally, most CBS services are provided by private organizations like EkoLakay, which provides a portable toilet and weekly excreta collection for a monthly fee. While the EkoLakay service is popular, attrition is high. This study examines the relationship between users and the service, and its role in improved sanitation accessibility. For this study, 633 active and former EkoLakay subscribers in Cap Haïtien were interviewed to reveal causes and implications of attrition. Households with active EkoLakay subscriptions are more likely than former subscribers to live in unauthorized informal residences and to lack energy or water infrastructure. A quarter of users unsubscribe voluntarily, after investing in permanent sanitation infrastructure. Over 30% of former users, however, reported unsubscribing due to economic challenges. Many involuntary terminations resulted in households losing access to private improved sanitation or reverting to open defecation, reducing progress toward global sustainability goals. Insights obtained contextualize the relationship between users and CBS services to inform public strategies for mitigating barriers to achieving universal safe sanitation.

Keywords: container-based sanitation, urban sanitation, non-sewered sanitation, citywide inclusive sanitation, safely managed sanitation, SDG6, sustainable sanitation, on-site sanitation

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****Correspondence:***
Froggi VanRiper
vanriper@oregonstate.edu
sustainablesanitationresearch@gmail.com

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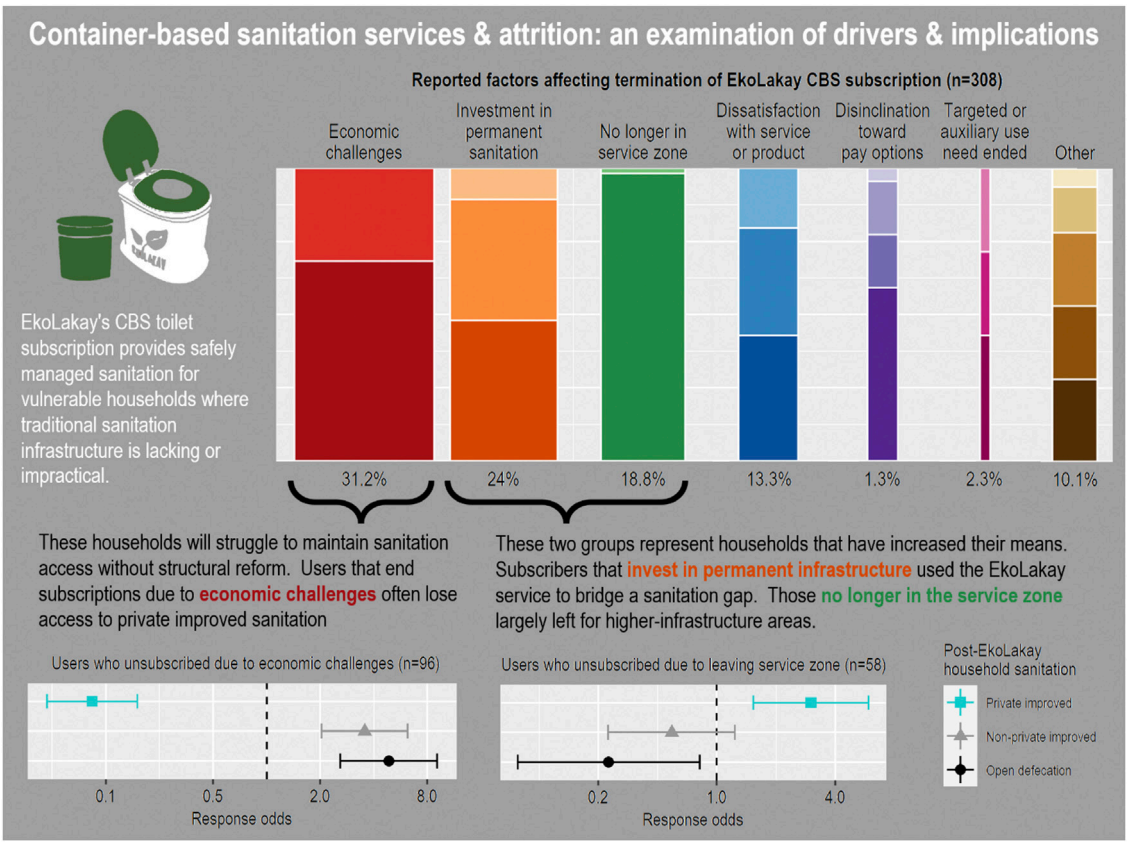
1 INTRODUCTION

In 2015, 10.4% of global citizens lacked access to basic sanitation, a daunting number given the United Nations' Sustainable Development Goal 6 (SDG 6) strives to eliminate open defecation and halve untreated wastewater by 2030 (WHO/UNICEF, 2017). The picture is especially grim in Haiti, where open defecation rates stood at 19.8% (World Bank, World Development Indicators, 2018a), and over 99% of the country's wastewater remained untreated as of 2017 (WHO Joint Monitoring Programme, 2017). A potential solution for making rapid progress on these goals exists in Container-Based Sanitation (CBS). CBS is a non-sewered sanitation strategy, through which excreta is captured



GRAPHICAL ABSTRACT |

in sealable containers and transported to semi-centralized[1] facilities for treatment, requiring limited in-home infrastructure. Since 2017, CBS technology has been recognized by the Joint Monitoring Programme as "improved sanitation" (WHO/UNICEF, 2017). To assess its future viability in Haiti and potentially other regions of the world facing similar sanitation needs, and to optimize service delivery, it is vital to better understand the factors affecting use of CBS services, the relationship between users and the service, and its role in improved sanitation accessibility. To address this critical need, this study utilizes interviews with 633 active and former CBS service users in Haiti.

As of 2018, two-thirds of Haiti's urban population lived in impoverished unplanned communities (World Bank, World Development Indicators, 2018b). Haiti ranks among the lowest twenty countries globally for urban sanitation coverage; except for a small number of local projects, all other forms of improved sanitation in the country only meet "basic" standards; from latrines to piped, water-based sanitation, excreta is ultimately released untreated into the environment (World Bank, World Development Indicators, 2012). In 2017, diarrhoeal disease was the fifth leading contributor to loss of life in Haiti, at a rate of 20.5 years of life lost (YLL) for every 1,000 people in the country (Fene et al., 2020). About half of the diarrhoeal disease burden in Haiti is attributable to inadequate excreta management (WHO, 2018).

One of Haiti's only safely managed sanitation options is EkoLakay, a privately run CBS service (Russel et al., 2019). The CBS model is uniquely suited to provide sanitation access in rapidly urbanizing informal settlements like those found in Haiti. In such environments, disputed land rights, low-income levels, inadequate infrastructure, and/or vulnerable environmental conditions combine to make forms of sanitation such as traditional sewage or latrines unattainable and risky, from environmental and economic perspectives (Tilmans et al., 2015). CBS allows users to seal excreta in containers during flooding; it is waterless, and the toilet itself is space-efficient and portable (Russel et al., 2019). CBS can be quickly deployed as an immediate intervention to the sanitation crisis, and can serve as either a transitional or long-term solution for urban households.

While CBS has identifiable advantages over traditional sanitation systems, it also has unique vulnerabilities. CBS service delivery can be interrupted by disruptions in transportation infrastructure, worker strikes, or pandemics (Saul and Gebauer, 2018; Mackinnon et al., 2019; Russel et al.,

[1]Semi-centralized facilities treat the products of sub-city populations; they are defined by scale, and definitions vary from tens to thousands of households.

2019; World Bank, 2019; Ferguson et al., 2021). CBS technologies also require greater user engagement than more traditional sanitation technologies. Perhaps the most significant barrier to CBS expansion, however, is policy and/or regulatory environments established without consideration of the characteristics, abilities, and needs of this unique sanitation service model (Mara, 2018; UNICEF and WHO, 2020). Examples range from direct obstacles to excreta reuse, to ambiguity caused by policy language based on the assumption of centralized infrastructure. Furthermore, while CBS has lower life-cycle costs than traditional sanitation infrastructure (EY, 2020), it does not yet benefit from public subsidization (Remington et al., 2018).

The EkoLakay CBS service, operated by Haitian non-governmental organization SOIL (Sustainable Organic Integrated Livelihoods), provides subscribers with a urine-diverting toilet and weekly container collection. The monthly service fee is 200–300 HTG (Haitian gourdes); the equivalent of 2.11–3.15 USD as of August 2019 (details of pricing structure in **Supplementary Table S1**). The EkoLakay toilet (**Supplementary Figure S1**) houses a sealable five-gallon container that receives solid excreta and a one-gallon jug that receives liquid waste through a urine diverter. During the weekly exchange of full excreta containers for sanitized containers, EkoLakay provides dry carbon-based cover material for covering the fecal matter after each defecation. Users manually dispose of urine (which has a minimal pathogen load in comparison to feces) (Bischel et al., 2019) primarily through infiltration into the ground, reducing the volume and weight of excreta to be transported and treated. EkoLakay transports the sealed excreta containers to a treatment site where trained staff, equipped with personal protective equipment, thermophilically compost the material for local sale (Preneta et al., 2013).

Despite their many advantages, CBS services can be subject to high attrition rates. Such patterns can lead to hesitantancy among decision-makers to subsidize or fund widespread adoption of CBS services. EkoLakay provides CBS service to twelve neighborhoods around Cap Haïtien, all of which are flood-prone, dense, urban or peri-urban, and generally have comparably low sanitation coverage and income levels. Between August 2014 and August 2019, EkoLakay customers in this service area opened 2,331 contracts, 1,323 of which were eventually closed. Subscription durations ranged from 1 week to 5 years[2]. For the economically vulnerable households[3] that represent the bulk of the EkoLakay subscriber base (Russel et al., 2019), financial shocks, resource constraints, and housing instability may disrupt continuity of subscription (Alwang et al., 2001; Briguglio et al., 2009).

CBS is likely one of, if not the lowest-cost, most readily deployable means of extending sanitation coverage to resource-insecure and low-infrastructure communities (Sklar and Faustin, 2017; EY, 2020; Delaire et al., 2021), but among such households, even the subsidized cost of service may be prohibitive. The newly emerging Citywide Inclusive Sanitation (CWIS) framework is a response to such a challenge. CWIS posits that *all* urban residents suffer when *some* lack sanitation access; therefore, this framework prioritizes sanitation coverage for vulnerable residents as a tool for protecting community health. Through the lens of CWIS, urban sanitation coverage is best achieved through adaptive approaches, employing varied and context-appropriate technologies, incremental infrastructure development, and responsive pricing models. This framework proposes that the public health objectives of urban sanitation can only be achieved through a public service approach to the sanitation delivery (Schrecongost et al., 2020).

Analyzing the challenges and opportunities in achieving sustainable sanitation access requires a system-wide approach. In this study, problems are viewed in the context of a large, complex system involving multiple interconnected subsystems (Clayton and Radcliffe, 1996). For this research, we identify how household-level factors affect the ability of CBS to close the sanitation gap an urban Haitian community, allowing for the emergence of systemic-level variables to describe the larger context. .

Building on the study of a 2012 pilot project (Russel et al., 2015) and subsequent expansion of SOIL into Northern Haiti, this study seeks to gain insight into the causes of attrition from the EkoLakay CBS service and the implications of attrition for reaching 100% safely managed sanitation coverage. Toward this end, we ask four key research questions:

- What characteristics differentiate active and former EkoLakay subscriber households?
- Why do subscribers terminate their EkoLakay subscription?
- What household characteristics are associated with various reasons for terminating an EkoLakay subscription?
- Do household-level responses reflect larger systemic-level relationships, (e.g.,relationships between economic, social, ecological, governance, and technical systems)?
- How do former subscribers feel about their EkoLakay CBS experience?

The answers to these questions will provide insight into the challenge of access to safe and reliable sanitation in low-income urban contexts, and generate important knowledge for decisionmakers in the public sector. By contextualizing the relationship between users and CBS services, as well as potential systemic-level relationships, including those affected by the systems listed above, we can expand our understanding of the potential role of CBS as a component of an urban sanitation portfolio, as low-income countries strive for universal safe sanitation access.

2 METHODOLOGY

This study used a mixed methodology approach (Greene, 2007), deriving qualitative and quantitative data from EkoLakay subscriber records and structured interviews with active and

[2]Subscriptions were terminated either by the subscriber voluntarily, or by the service provider after incurring 3 months of cumulative debt.

[3]The concept of economic vulnerability takes into account more than the static concept of poverty level by also looking forward at potential economic shocks and risks that could plunge a household into poverty.

TABLE 1 | Reported sanitation options available in metro Cap Haïtien, and correlative study response categorizations.

WHO Joint Monitoring Programme Categories			Options available in Cap Haïtien, Haiti	Study categories and responses
Improved sanitation	Private improved sanitation	Safely managed facilities	• EkoLakay CBS service	• Private flush toilet • Private latrine • Private dry toilet
		Basic facilities	• Private latrine, flush, or dry toilet (no treatment after discharge)	
	Non-private improved sanitation	Limited facilities	• Shared or public latrine, flush, or dry toilet (no treatment after discharge)	• Public or shared flush toilet, latrine, or dry toilet • Improved sanitation at home of neighbor or family member • Improved sanitation at church, school, or work
Unimproved sanitation		Unimproved facilities	• Shallow pit • Pit with no slab	• No access to a toilet • "In a hole" • "In a bag" • "By the river"
Open defecation		No facilities	• In a bag • In a field • By the river	

Detailed WHO sanitation category definitions provided in ***Supplementary Table S2.***

former subscribers of the EkoLakay CBS service in Cap Haïtien, Haiti. Interview questions addressed respondents' experiences with EkoLakay, motivations for terminating their subscription, and post-EkoLakay household sanitation, where relevant. In addition, self-reported data on household demographics, household income, infrastructure, expenses, and property were collected (details in supplemental materials).

2.1 Research Team and Research Instrument Development

Fourteen field team staff were hired from the Cap Haïtien region, reflecting a range of neighborhoods and socioeconomic backgrounds. The field team participated in an intensive 4-week training period facilitated by an investigator, project manager, and local translator/guide. The field team trained in research ethics and survey/interview best-practices while collaboratively refining and validating the survey instrument. Interview questions were structured around self-reported results whether by telephone or in-person, to ensure consistency regardless of interview format. Field team members then recruited respondents and served as interviewers. The result of this process was an optimized research tool, deeply informed by local cultural expertise, as well as skilled interviewers with an intimate understanding of the response coding protocols for our interview guide. All training and tool-development was conducted in Haitian Kreyol.

2.2 Sample Selection, Response Rate, Confidence

SOIL provided lists of former and active EkoLakay subscribers for whom telephone contact information was available. To ensure that active subscribers would have sufficient experience with EkoLakay to describe their satisfaction (i.e., three financial transactions and twelve collection events), we filtered out newly enrolled subscribers with less than 3 months' exposure to the service. Households of SOIL employees were also eliminated. The total number of potential participants meeting the criteria was 1,199 former and 733 active subscriber households.

We anonymized and randomized the lists of households. Research team staff recruited participants by phone, requesting an in-person appointment for an interview. Respondents who had moved away from the Cap Haïtien area, or were unwilling to meet in-person, were offered the opportunity to be interviewed by phone. We recruited one respondent to represent each household who had decision-making input and was 18 years or older.[4]

Due to high rates of inactive phone numbers, it was necessary to attempt contact with all active and former subscribers to achieve an adequate sample size. Recruiters attempted to reach respondents up to five times.[5] Of 733 potential active subscriber households, we contacted 383; nine declined to participate, 49 failed to schedule an interview, and we were unable to reach 358. We achieved an active-subscriber completion rate of 84.5%, for a sample of 44.3% (n = 325), a 95% confidence level and 4% margin of error. Of 1,199 potential former subscribers, we successfully contacted 407; 30 declined to participate, and 68 failed to schedule or complete an interview. We achieved a former-subscriber completion rate of 75.9%, for a sample of 25.8% (n = 309), a 95% confidence level and 5% margin of error. Sample sizes vary by analysis because respondents could decline to answer any prompt.

2.3 Data Collection and Analysis

Interviewers visited households and collected survey responses using Qualtrics® (XM, 2019) on a handheld smartphone. For the first month, 347 household interviews were completed both in-person and

[4]SOIL's experience in these communities has found household structures rarely recognize a single "head of household"; they are more likely to have multiple adult members engage in financial decision-making.

[5]As answering services are uncommon, telephone numbers are often reassigned to new users, and returning calls would place the expense burden on the recipient, recruiters did not leave messages for respondents who did not answer the phone.

TABLE 2 | Subscriber status, by household characteristics.

	Sample odds ratio (95% CI); *p*-value	
By count of selected amenities in home (*n* = 626)		
	Former subscribers (*n* = 303)	Active subscribers (*n* = 323)
0 amenities (*n* = 333)	0.51 (0.37–0.70)‡ *p* = 3.85e-05***	1.97 (1.43–2.71)‡ *p* = 3.85e-05***
1 amenity (*n* = 155)	1.27 (0.88–1.83)‡ *p* = 0.230	0.79 (0.55–1.13)‡ *p* = 0.230
2 + amenities (*n* = 138)	2.07 (1.40–3.04)‡ *p* = 3.08e-04***	0.48 (0.33–0.71)‡ *p* = 3.08e-04***
By presence of children under 5 years in home (*n* = 624)		
	Former subscribers (*n* = 302)	Active subscribers (*n* = 322)
No children under 5 years in home (*n* = 170)	0.69 (0.48–0.99)‡ *p* = 0.053	1.44 (1.01–2.06)‡ *p* = 0.053
Children under 5 years in home (*n* = 454)	1.44 (1.01–2.06)‡ *p* = 0.053	0.69 (0.48–0.99)‡ *p* = 0.053

Dark gray field indicates a response occurring more frequently than would occur in a random distribution.
Light gray field indicates a response occurring less frequently than would occur in a random distribution.
*= *significant at 0.05 level.*
**= *significant at 0.01 level.*
***= *significant at 0.001 level.*
‡*p-value is the result of Pearson's chi-square test between the sample and all other respondent-response combinations (1 df).*
Selected amenities were self-reported by respondent, from list including: Drilled or Hand-dug well; Generator; Indoor shower; Inverter; Solar panels; Water cistern on house.

over the phone. Due to significant transportation and energy disruption countrywide, the second month of surveys was administered exclusively by telephone for a total of 633 interviews.[6] Interviews consisted of closed-ended questions regarding household demographics, home infrastructure, and subscription payment method; and open-ended questions regarding present household sanitation, perceptions of the EkoLakay service, and factors affecting subscription termination. These open ended questions focused on household-level factors, but allowed for potential systemic-level concerns to arise.

Former subscriber respondents were asked *What were your main reasons for leaving EkoLakay*? They were not prompted or offered potential responses or categories. Interviewers limited participant responses to three "reasons". Many respondents described more than one reason; therefore, total responses exceed total respondent count. Responses to open-ended questions were categorized in the field by the interviewer, using predefined codes. Interviewers summarized responses that did not fit the available codes, and investigators later categorized these summaries. In some cases, new categories were necessary to house these responses.

Interviewers coded respondents' descriptions of their household sanitation, using a detailed list. After all data had been collected, investigators further aggregated codes into qualitative categories. Reports of household sanitation were organized into categories associated with the WHO Sanitation Ladder (**Table 1**), and through an iterative process of team-based coding (Tolley et al., 2016), investigators created thematic categories to describe reported factors affecting an EkoLakay subscription termination (these themes are fully explored in **section 3.2**).

Additional closed-ended questions used a Likert-style scale to ascertain subscriber perspectives on the EkoLakay experience. These included, *Would you want to subscribe to the EkoLakay service again?*, and *Would you recommend EkoLakay to a friend or neighbor?*

Characteristics of active and former subscriber households were compared to identify parameters associated with retention or attrition. Household characteristics were also analyzed for associations with reported attrition factor themes. Comparisons were based on odds ratio analysis, performed using chi-square and Fisher's exact tests. Relevant contextual factors associated with systemic-level variables were identified through emergent themes in open-ended responses (**Supplementary Table S3**).

3 RESULTS

3.1 Household Characteristics Associated With Attrition and Retention

We examined multiple household variables for potential association with attrition and retention of the EkoLakay service and found associations between subscriber status (active vs. former) and two household characteristics: household amenities count, and presence of children under the age of five in the home.[7] Selected amenities were self-reported by the respondent from list including: Drilled well; Hand-dug well; Generator; Indoor shower; Inverter; Solar

[6]After data collection, responses to one open- and three closed-ended questions were analyzed to ensure that this transition did not skew the results (analyses available in supplemental materials). Results did not yield significant differences between groups; therefore, all data were included in analyses.

[7]Non-inferential findings are available in supplemental materials.

TABLE 3 | Reported factors affecting decision to terminate EkoLakay subscription (n = 308).

Themes; specific reasons	Respondent count	% within theme	% of all respondents
Economic challenges	**96**	—	**31.2**
Negative external factors	35	36.5	11.4
Affordability/economic accessibility	75	78.1	24.4
Investment in permanent infrastructure	**74**	—	**24.0**
Repaired existing sanitation option	8	10.8	2.6
Dug a latrine	31	41.9	10.1
Installed flush toilet	36	48.6	11.7
Access to service zone	**58**	—	**18.8**
EkoLakay left the neighborhood	1	1.7	0.3
Subscriber no longer in EkoLakay service zone	57	98.3	18.5
Dissatisfaction with aspects of service or product	**34**	—	**11.0**
Dissatisfaction with aspects of cover material	10	29.4	3.2
Dissatisfaction with aspects of service provision	11	32.4	3.6
Dissatisfaction with aspects of toilet	21	61.8	6.8
Disinclination toward/accessibility of payment options	**21**	—	**6.8**
Don't want to use mobile payment	1	4.8	0.3
Payment options	4	19.0	1.3
Unable to reach payment collector	4	19.0	1.3
Difficulty with monthly payment schedule	13	61.9	4.2
Targeted or auxiliary use need ended	**7**	—	**2.3**
Renters left	2	28.6	0.6
Semipublic use location (church, school, or business) moved or closed	2	28.6	0.6
Illness abated or accessibility need ended	3	42.9	1.0
Other	**31**	—	**10.1**
Negative sentiments about CBS or excreta reuse	2	6.5	0.6
Irresponsible users or inability to control other users	5	16.1	1.6
Moved to new location	8	25.8	2.6
Economic means changed positively	8	25.8	2.6
Traveling or rarely at home	9	29.0	2.9
All respondents	**308**	—	—

Cumulative column sums may exceed total respondent count, as respondents could offer up to three 'reasons' for terminating subscription.

panels; and Water cistern on house. Active subscribers were more likely to report none of the selected household amenities in their home (OR = 0.51, CI = 0.37–0.70, $p < 0.001$) and less likely to report two or more amenities (OR = 2.07, CI = 1.40-3.04, $p < 0.001$) (**Table 2**). Active subscriber households are more likely to have children under the age of five in the home (OR = 1.44, CI = 1.01–2.06, $p = 0.05$) [8] Household and respondent characteristics with no relationship to attrition or retention are listed in **Supplementary Table S4**.

3.2 Self-Reported Factors Affecting Termination of EkoLakay Subscriptions; Major Themes

From respondents' self-described reasons, seven major themes emerged to describe factors affecting the termination of an EkoLakay subscription. The two prevailing themes include *economic challenges* (n = 96; 31.2% of former-subscriber respondents), and *investments in permanent sanitation infrastructure* (n = 74; 24.0%). These are followed by: loss of *access to the service zone* (moving away from an EkoLakay service zone or EkoLakay ceasing service in the area[9]) (n = 58; 18.8%), *dissatisfaction with aspects of the EkoLakay service or technology* (n = 34; 11.0%), *disinclination toward or accessibility of payment options* (n = 21; 6.8%), *cessation of a targeted or auxiliary purpose for the toilet* (n = 7; 2.3%), and other factors (n = 31; 10.1%) (**Table 3**). Further breakdown of specific responses within each category is provided in **Supplementary Table S5**.

3.2.1 Economic Challenges

Within the dominant theme of economic challenges as a reason for terminating a household EkoLakay subscription, responses fell into two sub-themes: general affordability or

[8]Note that the number of children in each household was reported as of the time of interview; it is likely that former subscribers reporting no children under five did have young children in their household at the time of their subscription to EkoLakay.

[9]EkoLakay ceased service to one neighborhood (Milo), which was located far from the processing facility and had insufficient subscriber numbers.

TABLE 4 | Reported factors affecting termination of EkoLakay subscription, by selected household characteristics.

	Odds ratio (95% CI); *p*-value		
By count of selected amenities in home at time of interview (*n* = 248)			
	0 amenities (*n* = 117)	1 amenity (*n* = 66)	2 + amenities (*n* = 65)
Economic challenges (*n* = 77)	2.65 (1.52–4.62)‡ *p* = 8.18e-04***	0.57 (0.30–1.09)‡ *p* = 0.121	0.46 (0.24–0.92)‡ *p* = 0.037*
Investment in permanent infrastructure (*n* = 66)	0.77 (0.44–1.36)‡ *p* = 0.448	0.84 (0.44–1.62)‡ *p* = 0.729	1.62 (0.87–2.99)‡ *p* = 0.170
No longer in EkoLakay service zone (*n* = 40)	0.48 (0.24–0.98)‡ *p* = 0.063	1.06 (0.49–2.25)‡ *p* = 1.000	2.16 (1.06–2.16)‡ *p* = 0.049*
Dissatisfaction with aspects of service or product (*n* = 31)	0.78 (0.37–1.68)‡ *p* = 0.665	1.37 (0.61–3.08)‡ *p* = 0.587	0.98 (0.41–2.31)§ *p* = 1.000
Disinclination toward/accessibility of payment options (*n* = 20)	0.35 (0.12–0.98)§ *p* = 0.059	2.45 (0.97–6.22)§ *p* = 0.065	1.23 (0.45–3.34)§ *p* = 0.791
Targeted or auxiliary use need ended (*n* = 6)	1.12 (0.22–5.67)§ *p* = 1.000	0.54 (0.06–4.75)§ *p* = 1.000	1.42 (0.25–7.95)§ *p* = 0.654

Samples include only respondents reporting characteristics of the home associated with their EkoLakay subscription
Amenities considered for this analysis include: generator, indoor shower, inverter, solar panels, water cistern on house, well

By presence of household member(s) with a disability or chronic illness (*n* = 301)		
	No disability or chronic illness in home (*n* = 186)	1 + members with disability or chronic illness in home (*n* = 115)
Economic challenges (*n* = 95)	0.90 (0.54–1.47)‡ *p* = 0.759	1.12 (0.68–1.84)‡ *p* = 0.759
Investment in permanent infrastructure (*n* = 74)	1.94 (1.09–3.46)‡ *p* = 0.032*	0.51 (0.29–0.92)‡ *p* = 0.032*
No longer in EkoLakay service zone (*n* = 55)	0.83 (0.46–0.83)‡ *p* = 0.648	1.20 (0.66–2.18)‡ *p* = 0.648
Favorable comparison to existing/other options (*n* = 34)	1.56 (0.71–3.38)‡ *p* = 0.351	0.64 (0.30–1.40)‡ *p* = 0.351
Disinclination toward/accessibility of payment options (*n* = 21)	0.28 (0.11–0.72)§ *p* = 0.009**	3.54 (1.39–9.07)§ *p* = 0.009**
Targeted or auxiliary use need ended (*n* = 7)	0.45 (0.10–2.07)§ *p* = 0.434	2.20 (0.48–10.00)§ *p* = 0.434

Disabilities reported for this analysis include: Arthritis, Bad back, Blindness or visual impairment, Chronic medical condition, Cognitive or mental health issues, Deaf, Missing a leg or foot, Mobility issues, Mute

By reported payment method (*n* = 302)			
	Cash only (*n* = 219)	Mobile payment (*n* = 100)	Subsidy (*n* = 3)
Economic challenges (*n* = 93)	1.72 (0.96–3.08)‡ *p* = 0.091	1.01 (0.60–1.70)‡ *p* = 1.000	16.20 (0.83–316.94)§ *p* = 0.009**
Investment in permanent infrastructure (*n* = 74)	0.86 (0.48–1.54)‡ *p* = 0.728	1.04 (0.60–1.82)‡ *p* = 0.999	0.43 (0.02–8.47)§ *p* = 0.575
No longer in EkoLakay service zone (*n* = 57)	0.44 (0.24–0.44)‡ *p* = 0.010**	1.55 (0.85–2.82)‡ *p* = 0.201	0.60 (0.03–11.83)§ *p* = 1.000
Dissatisfaction with aspects of service or product (*n* = 34)	4.40 (1.31–14.80)§ *p* = 0.008**	0.81 (0.37–1.76)‡ *p* = 0.726	1.10 (0.06–21.74)[b] *p* = 1.000
Disinclination toward/accessibility of payment options (*n* = 21)	0.94 (0.35–2.52)§ *p* = 1.000	2.32 (0.95–5.67)§ *p* = 0.091	1.85 (0.09–37.00)§ *p* = 1.000
Targeted or auxiliary use need ended (*n* = 7)	2.31 (0.27–19.48)§ *p* = 0.678	0.79 (0.15–4.13)§ *p* = 1.000	5.57 (0.26–117.71)§ *p* = 1.000

Dark gray indicates response occurring significantly more frequently than would occur in a random distribution.
Light gray indicates response occurring significantly less frequently than would occur in a random distribution.
**= significant at 0.05 level.*
***= significant at 0.01 level.*
****= significant at 0.001 level.*
‡*p-value is the result of Pearson's chi-square test between the sample and all other respondent-response combinations (1 df).*
§*p-value is the result of Fisher's exact test between the sample and all other respondent-response combinations (1 df).*

economic accessibility (*n* = 75; 24.4% of former-subscriber respondents) and negative outside factors (*n* = 35; 11.4%) (**Table 3**).

Within the *affordability* sub-theme, common explanations included difficulty avoiding debt in the service (*n* = 37, 12.3%) or affording the cost (*n* = 35, 11.6%). Some respondents

TABLE 5 | Former subscribers' household sanitation upon leaving, by reported factors affecting subscription termination (n = 309).

	Odds ratio (95% CI); p-value		
	Open defecation (n = 56)	**Non-private improved sanitation (n = 75)**	**Private improved sanitation (n = 169)**
Economic challenges (n = 96)	4.66 (2.53–8.59)‡ p = 4.86e-07***	3.56 (2.06–6.15)‡ p = 6.00e-06***	0.11 (0.06–0.19)‡ p = 7.71e-16***
Investment in permanent infrastructure (n = 74)	0.26 (0.01–4.79)§ p = 0.343	0.09 (0.03–0.29)§ p = 1.42e-07***	46.76 (11.19–195.36)‡ p = 1.69e-15***
No longer in EkoLakay service zone (n = 61)	0.36 (0.14–0.36)§ p = 0.037*	0.57 (0.27–1.20)‡ p = 0.187	2.78 (1.44–5.35)‡ p = 0.003**
Dissatisfaction with aspects of service or product (n = 35)	1.65 (0.73–3.77)§ p = 0.245	2.32 (1.11–4.86)‡ p = 0.039*	0.32 (0.15–0.68)‡ p = 0.004**
Disinclination toward/accessibility of payment options (n = 22)	1.69 (0.63–4.53)§ p = 0.271	0.64 (0.21–1.95)§ p = 0.611	0.90 (0.38–2.16)‡ p = 0.993
Targeted or auxiliary use need ended (n = 7)	0.38 (0.02–6.98)§ p = 0.598	0.26 (0.01–4.79)§ p = 0.343	8.59 (0.47–156.83)§ p = 0.039*

Dark gray indicates response occurring significantly more frequently than would occur in a random distribution.
Light gray indicates response occurring significantly less frequently than would occur in a random distribution.
*= significant at 0.05 level.
**= significant at 0.01 level.
***= significant at 0.001 level.
‡p-value is the result of Pearson's chi-square test between the sample and all other respondent-response combinations (1 df).
§p-value is the result of Fisher's exact test between the sample and all other respondent-response combinations (1 df).

TABLE 6 | Former subscriber responses to "Would you want to join the EkoLakay service again?", by household sanitation status at time of interview (n = 299).

	Sample odds ratio (95% CI); p-value		
	Open defecation (n = 47)	**Non-private improved sanitation (n = 72)**	**Private improved sanitation (n = 184)**
Yes (n = 117)	3.00 (1.58–5.71)‡ p = 9.98e-04***	1.80 (1.05–3.08)‡ p = 0.042*	0.36 (0.22–0.59)‡ p = 5.85e-05***
I don't know (n = 59)	1.30 (0.62–1.30)‡ p = 0.625	1.09 (0.57–2.11)‡ p = 0.921	0.75 (0.42–1.33)‡ p = 0.402
No (n = 123)	0.21 (0.09–0.21)‡ p = 1.33e-04***	0.50 (0.28–0.89)‡ p = 0.026*	3.56 (2.12–5.98)‡ p = 1.71e-06***

Dark gray field indicates a response occurring more frequently than would occur in a random distribution.
Light gray field indicates a response occurring less frequently than would occur in a random distribution.
*= significant at 0.05 level.
**= significant at 0.01 level.
***= significant at 0.001 level.
‡p-values are the result of Pearson's chi-square test between the sample and all other respondent-response combinations (1 df).
Row and column counts may exceed respondent count, as respondents could report multiple household sanitation options.

expressed a perception that the service "costs too much" (n = 7; 2.3%).[10]

Negative outside factors described by respondents included a change in economic means; reports that cost of living had increased; and difficulty due to sudden or large expenses. Many respondents expressed multiple concerns within the "economic challenges" theme.

Respondents reporting none of the selected amenities in their home at the time of interview were more likely than the average household to report having terminated their subscription over economic challenges (OR = 2.65, CI = 1.52-4.62, p < 0.001), and those with two or more amenities were less likely to mention this theme (OR = 2.16, CI = 1.06–2.16, p = 0.049) (**Table 4**).

Respondents reporting that the cost of their EkoLakay subscription was covered by a subsidy were more likely than the average household to report ending their subscription due to economic challenges (OR = 16.20, CI = 0.83–316.94, p = 0.009) (**Table 4**). Every respondent representing a household formerly covered by subsidy indicated that withdrawal of the subsidy caused them to lose access to the EkoLakay CBS service.

Respondents who attributed their subscription termination to economic challenges were highly likely to transition to open defecation after losing access to EkoLakay (OR = 4.66, CI = 2.53–8.59, p < 0.001) (**Table 5**).

[10]Respondents were not asked to compare EkoLakay specifically to alternative services.

TABLE 7 | Interest in re-subscribing to EkoLakay, by factors affecting subscription termination.

	Odds ratio (95% CI); *p*-value		
	"Would you want to join the EkoLakay service again?"		
	Yes (*n* = 121)	**I don't know (*n* = 59)**	**No (*n* = 182)**
Economic challenges (*n* = 95)	2.44 (1.48–4.00)‡ *p* = 5.99e-04***	0.78 (0.41–1.46)‡ *p* = 0.532	0.41 (0.25–0.67)‡ *p* = 5.99e-04***
Investment in permanent infrastructure (*n* = 73)	0.33 (0.18–0.62)‡ *p* = 3.25e-04***	0.51 (0.24–1.09)‡ *p* = 0.090	2.99 (1.62–5.52)‡ *p* = 3.25e-04***
Access to service zone (*n* = 57)	0.64 (0.35–1.18)‡ *p* = 0.178	1.84 (0.95–3.58)‡ *p* = 0.093	1.56 (0.85–1.56)‡ *p* = 0.178
Dissatisfaction with aspects of service or product (*n* = 34)	1.06 (0.51–2.19)‡ *p* = 1.000	1.58 (0.69–3.59)e *p* = 0.260	0.94 (0.46–1.95)‡ *p* = 1.000
Disinclination toward/accessibility of payment options (*n* = 21)	1.40 (0.58–3.41)‡ *p* = 0.493	1.32 (0.46–3.76)e *p* = 0.573	0.71 (0.29–1.74)‡ *p* = 0.493
Targeted or auxiliary use need ended (*n* = 7)	3.88 (0.74–20.33)e *p* = 0.120	0.68 (0.08–5.79)e *p* = 1.000	0.26 (0.05–1.35)e *p* = 0.120

Dark gray indicates response occurring significantly more frequently than would occur in a random distribution.
Light gray indicates response occurring significantly less frequently than would occur in a random distribution.
**= significant at 0.05 level.*
***= significant at 0.01 level.*
****= significant at 0.001 level.*
‡p-value is the result of Pearson's chi-square test between the sample and all other respondent-response combinations (1 df).
[e]p-value is the result of Fisher's exact test between the sample and all other respondent-response combinations (1 df).

3.2.2 Investment in Permanent Sanitation Infrastructure

Among subscribers who reported that they left the EkoLakay service because they installed or repaired permanent sanitation infrastructure in their home, 36 (11.7%) reported installing a flush toilet, 31 (10.1%) installed a latrine, and 8 (2.6%) reported repairing or servicing their preexisting sanitation infrastructure (including emptying a full pit latrine) (**Table 3**).

3.2.3 No Longer in EkoLakay Service Zone

Most respondents who reported no longer living in an EkoLakay service zone reported having moved to a neighborhood outside of the EkoLakay service area (*n* = 57; 18.5%) (**Table 3**).

Respondents reporting two or more amenities in the home were more likely than the average respondent to mention losing access to an EkoLakay service zone (OR = 2.16, CI = 1.06-2.16, *p* = 0.049) (**Table 4**).

3.2.4 Dissatisfaction With Aspects of EkoLakay Service or Product

Former subscribers who cited dissatisfaction among their reasons for leaving EkoLakay offered critiques of the physical toilet technology (*n* = 21; 6.8%), customer service or service provision (*n* = 11; 3.6%), and characteristics of the cover material (*n* = 10; 3.2%) (**Table 3**). Some respondents expressed multiple themes within this category.

3.2.5 Disinclination Toward or Difficulty Accessing Payment Options

Among reports of disinclination toward or difficulty accessing payment options, most expressed difficulty with the monthly payment schedule (*n* = 13; 4.2%). Others reported difficulty reaching a payment collector, dissatisfaction with the payment options in general, and disinclination toward mobile payment specifically (**Table 3**).

Respondents indicating the presence of a household member with a disability or chronic illness were more likely than other household representatives to cite disinclination toward or accessibility of EkoLakay's payment options as a reason for leaving EkoLakay (OR = 3.54, CI = 1.39–9.07, *p* = 0.009) (**Table 4**).

3.2.6 Targeted or Auxiliary Use Need Ended

Six subscribers reported that they terminated their EkoLakay service because they had used it to meet a targeted or auxiliary purpose, and that need had ended. These reports included the abatement of an illness or cessation of an accessibility need (including the death of a mobility-challenged household member); departure of renters for whom they had supplied the EkoLakay toilet; and closing of a semipublic location (such as a church or business) at which they had used EkoLakay.

3.2.7 Other Reported Reasons for Terminating an EkoLakay Subscription

Other factors reported among respondents' reasons for leaving the service included travel or time away from the home; positive changes in economic means; moving to a home with preexisting sanitation infrastructure; inability to control other users of the toilet (from within and/or outside the home); and negative sentiments about transformation or treatment of excreta, or the use of CBS (**Table 3**).

3.2.8 Systemic-Level Contextual Factors

Consistent with the intent to consider relationships between interacting systems, we identified the presence of variables indicating the influence of systemic-level contextual factors on

the accessibility and suitability of the EkoLakay CBS system for respondents. Responses included reference to economic, social, governance, technical, and ecological systems, with multiple overlapping responses (**Supplementary Table S3**).

3.3 Subscriber Retention

3.3.1 Interest in Re-subscribing

Nearly 40% of former subscribers ($n = 118$) indicated that they would be interested in subscribing to EkoLakay again. Respondents whose households practiced open defecation at the time of interview were more likely than the average respondent to express interest in re-subscribing to EkoLakay (OR = 3.00, CI = 1.58–5.71, $p = 0.001$), as were those using non-private sanitation (OR = 1.80, CI = 1.05–3.08, $p = 0.042$). Households with private improved sanitation at the time of interview were more likely to express disinterest in re-subscribing (OR = 3.56, CI = 2.12–5.98, $p < 0.001$) (**Table 6**).

Respondents who reported economic challenges among the reasons for terminating their EkoLakay subscription were highly likely to be interested in re-subscribing to the service (OR = 2.44, CI = 1.48–4.00, $p < 0.001$). Households that left due to having installed permanent sanitation infrastructure were likely to be uninterested in re-subscribing (OR = 2.99, CI = 1.62–5.52, $p < 0.001$) (**Table 7**).

3.3.2 Willingness to Recommend EkoLakay

Over 94% of respondents reported that they would recommend EkoLakay to a friend or neighbor (**Supplementary Table S6**). Willingness to recommend was even expressed by some of the 16% of respondents who mentioned dissatisfaction with aspects of the EkoLakay service or technology among factors affecting their subscription termination. Willingness to recommend was not related to subscriber status or interest in re-subscribing (**Supplementary Table S7**).

4 DISCUSSION

Using selected household amenities as a proxy for household economic capacity, it appears that odds of having ended a household EkoLakay subscription increase as economic capacity increases. This relationship illustrates the important role EkoLakay serves in providing sanitation access for households experiencing extreme resource-insecurity; i.e., lacking basic water and electrical infrastructure.

While resource scarcity is associated with subscription retention, we can also see that many resource-strained households struggle to afford even the lowest price of the service, or to keep up with the monthly payment schedule. Inconsistent employment incomes, unexpected expenses, or withdrawal of subsidy can tip this balance, causing a household to lose access to the CBS service. Though the EkoLakay service model includes a buffer period for missed payments, [11] service is eventually terminated when subscribers have not paid down their debt within 3 months. Whether a subscription was terminated by EkoLakay due to debt, or preemptively by a subscriber experiencing economic challenges, many of these departures can be inferred to be involuntary. This inference is corroborated by the finding in **section 3.3.1**, that interest in re-subscribing to EkoLakay is strongly associated with having cited economic challenges among reasons for subscription termination. Furthermore, reports of difficulty affording EkoLakay's monthly fee were significantly more common than statements indicating that the cost of the service is too high. This differentiation is meaningful: the former responses frame the economic barrier as a lack of household means, while the latter suggests that the perceived value of the service is insufficient to warrant its price tag. The distribution of these responses illustrates broad recognition of EkoLakay's value regardless of ability to afford the service.

Households reverting to open defecation after losing access to EkoLakay represent the most vulnerable group in terms of sanitation access. The role of economic barriers in involuntary attrition suggests that realizing the potential public health gains of CBS may require economic assistance for resource-strained households. Subsidization of sanitation access for economically insecure households is a strategic component of the CWIS approach. Recent research indicates that the cost of supporting households with subsidized access to the EkoLakay CBS service would be comparably low relative to alternative public sanitation infrastructure investments (EY, 2020), and therefore well warranted from a public health perspective.

Collectively, respondents who reported having invested in permanent sanitation infrastructure or no longer living an EkoLakay service zone represent a quarter of all former subscribers. The association between higher household amenities count and likelihood of moving out of an EkoLakay-serviced neighborhood imply that such movement is associated with advancement in means rather than poverty-related instability. For these users, EkoLakay's CBS service met immediate sanitation needs while the household amassed the resources to obtain or repair permanent sanitation infrastructure. Together with the subscribers who attributed their departure to an improvement in economic means (**section 3.2.7**), it appears that while one third of attrition is attributable to economic vulnerability, another third is associated with advancement.

Some complaints about the EkoLakay toilet technology give insight into vulnerabilities of a CBS system like EkoLakay. Traditional improved sanitation technologies require little familiarity or user effort to function effectively. Container-based systems, however, require application of cover material, exchange of collection receptacles, and in the case of EkoLakay model, regular emptying of a urine collection jug. Only one respondent cited dissatisfaction with this effort as a reason for leaving. Multiple respondents, however, were driven to leave the service because they could not control the behavior of other toilet users. While regular users of the CBS system can be trained in the basic maintenance of these components, non-household users, or users less committed to stewarding the system, may misuse it,

[11] At the time of the study, container exchange would be suspended after two missed payments, but the toilet would not be reclaimed.

causing malfunction. As CBS service providers have refined their product, this unique challenge has shaped service models. User responsibility is a key challenge for management of public and multifamily CBS toilets in Haiti, and this is a main reason that SOIL transitioned to the EkoLakay household-level service model from previously providing public toilets. Providing CBS services at the household level reduces challenges associated with untrained users, which can occur in public settings; in low-resource environments, however, household structure and lack of property barriers limit control over potential users of the toilet.

Along a similar vein, some respondents ended their subscription for lack of a reasonable place to keep the toilet. A CBS toilet has the advantage of being small and mobile, but EkoLakay does not provide a superstructure to protect it from weather if users prefer to place it outdoors. Subscriber households must provide some form of protection for the toilet if they want to use or store it outside of the home. Some EkoLakay users have a household density of up to 11 persons per room; for such households, indoor space is particularly limited. Such a challenge is likely to characterize many CBS services, and may be a topic of focus for future service model research and development.

Reports of difficulty with payment methods imply that aspects of a CBS business model, other than price alone, may affect accessibility of the service. EkoLakay ceased offering door-to-door payment collection to incoming subscribers in 2018 (and raised the price of door-to-door payment for existing subscribers to incentivise the shift to a more efficient system) (Saul and Gebauer, 2018), so for many users, cash payment now requires a visit to an EkoLakay depot or office. Households reporting disabled members were the only respondents to cite unwillingness to use mobile payment or difficulty reaching a payment collector among reasons for ending their subscription. The use of mobile payment apps requires one to deposit cash at a payment agent, and these facilities are sparser in low-income, low-infrastructure neighborhoods, making mobile payment less accessible to EkoLakay customers in such neighborhoods. Furthermore, use of mobile cash apps requires basic literacy, and therefore this money management tool is not accessible to some highly vulnerable members of a community. Our findings imply that pricing differences favoring mobile payment may place a burden on mobility-challenged subscribers and households in the distant peri-urban environment with a limited transportation budget. This burden could be ameliorated through a context-responive payment model, either through the service provider or as part of public sector-supported service delivery.

Reported interest in re-subscribing to EkoLakay, as related to post-subscription household sanitation, paints a picture of a bimodal user base; with progress from open defecation to private improved sanitation, former subscribers express reduced interest in re-subscribing to EkoLakay. It appears most subscribers either used EkoLakay to meet their household needs while saving to access desired permanent sanitation infrastructure, or they exist in a state of extreme resource scarcity, with marginal resources and scant access to sanitation alternatives. The latter group will require public support in order for Haiti to achieve sanitation coverage in urban communities.

The EkoLakay service is perceived positively by most users, whether it be for its inherent value or its usefulness at a specific stage in a household's development, which fits with a growing body of literature (O'Keefe et al., 2015; Nyoka et al., 2017; Tidwell et al., 2020). Respondents who report willingness to recommend EkoLakay include many who left the service voluntarily. Former subscribers with private improved sanitation in their home express high likelihood of recommending EkoLakay, despite low interest in re-subscribing. This indicates that, while some may favor permanent infrastructure, former EkoLakay users are satisfied with the role that CBS played in a past period of their household history.

5 CONCLUSION

Given the low national sanitation coverage (62% improved access in 2017), and rapid urban population growth (3% annual increase), the Haitian public health sector will likely need to prioritize interventions that can increase urban sanitation coverage rapidly (The World BankWorld Development Indicators, 2019). Considering urban Haiti's land tenure ambiguities, household poverty, high risk of flooding, and other geologic vulnerabilities, the traditional large-infrastructure approach to achieving citywide sanitation coverage is untenable in the near-term and perhaps even inappropriate in the long-term (Spuhler and Lüthi, 2020; Öberg et al., 2020).

This research has generated insights into the potential of CBS to close the sanitation gap among resource-insecure households in environments like that of northern Haiti. Former subscribers from the 7 years of EkoLakay service provision, fall largely into two groups; those for whom the service met household needs until they amassed the resources to invest in desired permanent sanitation infrastructure, and those who gained private sanitation through the service but struggled to maintain access due to extreme economic insecurity. Both groups indicate a 94% willingness to recommend the service to others.

Widespread desire to re-subscribe among vulnerable households, and high willingness to recommend the EkoLakay service to others provide evidence that household-level CBS is a tool with positive recognition and great potential for meeting SDG six within the Cap Haïtien population. Our findings indicate, however, that the potential public health gains of the CBS service model cannot be realized without financial subsidies for many economically vulnerable target users. Citywide Inclusive Sanitation provides a framework including context-dependent elements, such as responsive pricing and public subsidies for extending services to the most vulnerable. Our findings provide evidence that for CBS to reach those who need it most, a public service approach may be essential (Schrecongost et al., 2020). Public-private partnerhips, as have become common in water supply and distribution, could begin to bridge this gap. The measurable outcomes of CBS services also make them a suitable candidate for results-based financing models (Howard and White, 2020).

In addition to measurable household characteristics, it is evident that multiple interacting systemic-level factors affect continuity of access to sanitation in urban Haiti. Governance structures define access to sanitation infrastructure across locales.

Public policy also interacts with technical resources, including transportation and communication infrastructures, which affect the quality and accessibility of CBS service. Social support networks affect backup options and resilience; social awareness drives desire to maintain sanitation access. Ecological and geological characteristics endanger users of sanitation technologies that cannot contain excreta. Further research is warranted to go beyond household level analysis to specifically ascertain information regarding systemic-level opportunities and barriers to CBS adoption.

The abovementioned interconnected sytems impact the appropriateness and accessibility of CBS for households. Integrating CBS into community-wide sanitation delivery models may be key to ensuring that all aspects of the social, cultural, and technological systems can interact effectively, thus allowing the benefits of this innovation to reach those who need it most. Furthermore, increasing the CBS user base in Haiti could further contribute to cost-effectiveness; a recent study of resource-oriented CBS services including EkoLakay suggests that increasing the scale of such operations would optimize efficiency and reduce the cost of service delivery (Moya et al., 2019). Thus, the insights provided in this study may help to inform policy strategies for increasing safely managed sanitation coverage across vulnerable communities in Haiti and comparable environments.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Oregon State University (IRB-2019-0284) University of Oregon (IRB 07102019.010) Government of Haiti (Rèf 1819-58). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

FV: Conceptualization, Methodology, Validation, Formal analysis, Data Curation, Writing—Original Draft, Writing - Review and Editing, Visualization. KCR: Conceptualization, Methodology, Supervision, Writing—Review and Editing. LAC: Supervision, Writing—Review and Editing. DT: Methodology, Supervision, Writing—Review and Editing. JL: Methodology, Supervision, Project administration, Writing—Review and Editing. EL: Conceptualization, Project administration, Writing—Review and Editing. SK: Conceptualization, Writing—Review and Editing, Funding acquisition.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.817142/full#supplementary-material

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