Research Paper

Understanding values of sanitation users: examining preferences and behaviors for sanitation systems

Zakiya A. Seymour, Eugene Cloete, Margaret McCurdy, Mira Olson and Joseph Hughes

ABSTRACT

Sanitation policy and development has undergone a paradigm shift away from supply-driven toward behavioral-based demand-driven approaches. This shift to increase sanitation demand requires multiple stakeholders with varying degrees of interest, knowledge, and capacity. Currently, the design of appropriate sanitation technology disconnects user preference integration from sanitation technology design, resulting in fewer sanitation technologies being adopted and used. This research examines how preferences for specific attributes of appropriate sanitation technologies and implementation arrangements influence their adoption and usage. Data collected included interviews of 1,002 sanitation users living in a peri-urban area of South Africa; the surveyed respondents were asked about their existing sanitation technology, their preferences for various sanitation technology design attributes, as well as their perspectives on current and preferred sanitation implementation arrangements. The data revealed that user acceptability of appropriate sanitation technology is influenced by the adoption classification of the users. Statistically significant motives and barriers to sanitation usage showed a differentiation between users who share private sanitation from those who use communal sanitation facilities. The user acceptability of appropriate sanitation systems is dependent on the technical design attributes of sanitation. The development of utility functions detailed the significance of seven technical design attributes and determined their respective priorities.

Key words | sanitation adoption, systematic behavioral changes

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HIGHLIGHTS

- Highlights the new sanitation adoption group of partakers.
- Demonstrates the motivations for sanitation usage in peri-urban communities.
- Demonstrates the barriers to sanitation usage in peri-urban communities.
- Explores the link between sanitation adoption status, motives, and barriers and the utility of certain technology.

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INTRODUCTION

Access to adequate and equitable sanitation and hygiene for all is a current target of the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) 2030 agenda for Sustainable Development (UNICEF & WHO 2019). Despite this goal and the recognition of sanitation as a basic human right, little progress has been made toward reducing the percentage of the world's underserved population. Expanding the definition of 'improved sanitation' to include sewage treatment prior to disposal suggests that, in 2010, 4.1 billion people – nearly twice the previous estimate of 2.6 billion people – were identified as lacking access to improved sanitation (UNICEF & WHO 2012; Baum *et al.* 2013). Target-based, health-driven sanitation initiatives have been unable to provide significant sustainable sanitation coverage in developing regions. This indicates that substantial changes must be made to design and implement approaches.

The approaches executed in the developed world over the last century are often unsustainable in developing nations. These 'conventional' methods are designed as water-based collection systems where human excreta are collected at points of generation, aggregated with additional wastes (including other human, industrial, and commercial wastes) in complex piping systems, and then transferred for centralized treatment and appropriate disposal. Established institutional structures, stringent water quality requirements, and prescriptive treatment technologies frame these approaches to design and implement sanitation systems that are highly regulatory based. Political instability, water scarcity, unreliable energy supply, and capital constraints challenge the development of regulatory-based sanitation systems in developing regions. Population growth and rapid urbanization, specifically in peri-urban areas, exacerbate the challenges of providing sanitation access in these regions (Black & Fawcett 2008).

When regulatory-based systems can be established, governing agencies must supplement these approaches if access is to be provided across a wide range of socioeconomic levels. Individuals in higher socioeconomic classes living adjacent to peri-urban communities benefit from having relatively adequate, conventional sanitation service delivery. However, informal growth of squatter areas, population density, and challenging topography often exclude the extension of this service delivery into peri-urban areas (Paterson *et al.* 2007). For higher socioeconomic classes, little social acceptance is needed when conventional approaches are designed and implemented; thus, there is no need for them to be active participants in their sanitation decision-making process (Paterson *et al.* 2007). However, minimal or lack of user participation has been identified as a key barrier toward increasing access to sanitation approaches that serve the impoverished (Paul 1958; McPherson & McGarry 1987; UN 2010). This study focused on Kayamandi, a peri-urban area outside of the Stellenbosch, South Africa. Areas within Kayamandi can be loosely broken into two categories that include: formal developed areas which have electrification, paved roads, waterborne sewerage, piped household, and water connections, as well as informal squatter areas that included substandard housing, community sanitation facilities, and communal water taps.

Little motivation exists for disadvantaged sanitation users to pay, operate, and maintain systems properly if they are not provided with opportunities to engage in the decision-making process (Paterson *et al.* 2007). Previous studies have attempted to gather user perspectives on sanitation technology using contingent valuation techniques (Whittington *et al.* 1993a, 1993b; Altaf 1994; Altaf & Hughes 1994; Fujita *et al.* 2005). These studies determine the maximum amount an individual would be willing to pay for sanitation technologies. While these studies engage sanitation users in the decision-making process, they constrain users to choose options based upon their ability to pay, not necessarily their preferences for the chosen sanitation technology. The need to develop sanitation products specifically for the peri-urban users was highlighted recently by Paterson *et al.* (2007); in coining the phrase 'pro-poor sanitation technologies'. They presented simplified sewage as an affordable, appropriate sanitation solution designed for users located in high-density areas.

Additionally, there is need for engineers to design user-centered sanitation solutions, engage with implementing communities, and collaborate with social scientists to provide lasting sanitation technology solutions (Paterson *et al.*

2007). The absence of user preference integration into sanitation systems represents a true disconnect between the development of appropriate sanitation technology and the deployment of acceptable and affordable technology. As engineers begin to design and develop a new generation of sanitation products and services, innovative approaches are needed to articulate user preferences within the design process if sanitation implementations are to be a means for increasing access to sanitation.

The objective of this study was to examine the impact that individual preferences and behaviors have on the use of sanitation systems in peri-urban communities in South Africa. The outcomes of this study also have implications for similar communities across Sub-Saharan Africa. Specifically, this study identifies influential attributes of sanitation systems by investigating user perspectives and behavioral patterns in one community and determines preferred options for sanitation alternatives. For the purposes of this study, user preferences for sanitation are measured for technical (design) attributes and arrangement (implementation) attributes. Sanitation technical attributes refer to the various design specifications that detail operation modes of sanitation technology, including attributes for water reuse, excreta disposal, and excreta resource recovery. Sanitation arrangement refers to implementation attributes, including aspects for placement, quantity, and ownership. The former attributes have direct design implications on developing appropriate sanitation technology. The latter attributes have direct policy and programmatic implications on determining access and coverage to sanitation. Collectively, the technical and arrangement attributes describe sanitation systems. It is theorized that coupling user preferences with sanitation technology design and implementation arrangement will increase the usage of improved sanitation systems.

METHODS

Sampling site

This work focuses on sanitation users located in the community Kayamandi, a peri-urban settlement under the jurisdiction of the City of Stellenbosch, South Africa. Kayamandi fits the United Nation's definition of an informal settlement, meaning that residents have 'no security or tenure vis-à-vis the land or dwellings they inhabit', there is a lack of 'basic services and infrastructure', and may not follow regional building regulations or be located in a hazardous area (United Nations Task Team on Habitat III 2015) Stellenbosch is separated into 22 wards; four of the wards are exclusive to Kayamandi, while another ward includes other surrounding areas (Fourth Generation 2017, p. 20). A census conducted in 2011 by Statistics South Africa determined Stellenbosch had a population of 155,733 people (Department: Statistics South Africa Republic of South Africa 2011). However, a socioeconomic profile released by the Western Cape Government reported that the population would reach 182,372 people by the year 2020 which can be confirmed by the next census scheduled for 2021 (Fourth Generation 2017, p. 38; Socio-Economic Profile 2017, p. 2). The population increase has intensified demand for municipality service delivery, including water and sanitation services.

Survey design

Structured in-person interviews were designed to investigate motives and barriers for the use of private, shared, and public communal sanitation facilities for respondents with varying levels of sanitation system adoption. Respondents were questioned on:

- existing sanitation practices and their respective level of satisfaction;
- stated motives and barriers to sanitation system usage; and
- socioeconomic and demographic characteristics.

Previous approaches for classifying adoptive or non-adoptive practices (Jenkins & Curtis 2005; Jenkins & Scott 2007; Hernandez *et al.* 2009; Santos *et al.* 2011) were modified to differentiate between the types of sanitation facilities used and to classify individuals using them. This modification was necessary to classify sanitation users who use private household sanitation that share sanitation facilities with others (i.e., the landlord, other family members, etc.). For this study, private sanitation users – individuals who do not share sanitation facilities with anyone outside their household – are considered *adopters*. Shared sanitation users – individuals who share sanitation facilities with others, but the accessibility of these facilities is exclusive to a particular group of individuals – are considered *partakers*. Public sanitation users – individuals who use communal sanitation facilities available to anyone in the community – are considered *non-adopters*.

The combination of open-ended and close-ended questions allowed for probing and informative answers regarding specific motives and barriers. Open-ended questions were asked first, followed by close-ended questions; in some instances, sanitation users mentioned determinants in the open-ended section that were also addressed in the close-ended section.

Surveying methods

A total of 1,002 sanitation users were interviewed over a 4-month period from August 2012 to December 2012. For sanitation users to participate in the study, they had to be at least 18 years old and reside at the surveyed dwelling at least four nights a week. The specific demographics of the community can be seen in Table 1. To assist with the data collection, four enumerators (two males and two females) were trained in the administration of the questionnaire. Enumerators were fluent in both questionnaire languages: isiXhosa and English.

Ethical approval prior to commencing any field testing was provided by both the Institutional Review Board (IRB) at the Georgia Institute of Technology as well as the Ethics Committee for Human Research at Stellenbosch University.

Table 1 | Demographic characteristics of sample population

Characteristic ($N = 1,002$)	Sample description
Sex of respondent	
Male	51.50%
Female	48.50%
Age of respondent (in years)	
18–34	63.40%
35–65 +	36.60%
Median age group (% of population)	25–34 (39.4%)
Highest level of education completed	
Primary	26.70%
Secondary/Trade School/College/University	73.30%
Employment	
Paid employment within the last 3 months	44.30%
Type of dwelling	
Formal	46.80%
Informal	53.20%
Head of household	
Yes	54.80%
Household size	
Average	4.4
Median	4
Households with at least four residents	57.40%
Occupancy	
Owned and fully paid off	8.30%
Owned but not yet paid off	1.00%
Rented	7.40%
Occupied rent-free	82.20%

Maximum difference scaling

The MaxDiff model was developed by Louviere as a quantitative approach to determine relative priorities (preferences) among a set of items (Louviere *et al.* 2015). To assist with determining relative priorities, MaxDiff relies on comparisons provided within a given set of choices. The model is an extension of the comparative judgment approach of pairwise comparisons (Thurstone 1927). In traditional approaches to pairwise comparisons, comparative judgments are made between two mutually exclusive items, such that an individual can express a preference for one item over the other or indifference between the two items. The number of pairwise comparisons needed to consider all possible item pairs is contingent upon the number of items, n, such that the required number of pairwise comparisons is equal to $n(n-1)/2$. When there are a considerable number of items, the number of pairwise comparisons needed to provide a complete analysis can add to response burden.

The theoretical framework of MaxDiff is based upon random utility theory (McFadden 1973), which posits that the satisfaction (utility) that individual i can obtain from item j in choice set s can be decomposed into a deterministic, V_{isj}, and random error ε_{isj} components:

$$U_{isj} = V_{isj} + \varepsilon_{isj}$$

Assuming that a linearly additive indirect utility function gives the following:

$$U_{isj} = V_{isj} + \varepsilon_{isj} = X'_{isj}\beta_j + \varepsilon_{isj}$$

where X'_{isj} is the vector of attributes of the jth good as viewed by the ith individual in the sth choice set, and β_j is the coefficient vector to be estimated. When the preferred operation mode of individual i matches the operation mode of the sanitation technology being examined, $U = 1$; when they do not match, $U = 0$. Thus, if sanitation alternative j matches all the preferred operation modes of individual i, the utility that individual i would receive from alternative j would be and the individual would be considered perfectly satisfied with the alternative.

MaxDiff reduces the number of pairwise comparisons (and thereby potential response burden) by increasing the number of items in a given comparison (to at least more than two items) and asking individuals to determine the best and worst items (or most important and least important items, respectively) in a given comparison. By analyzing all possible pairs in a given comparison, an individual then selects the pair that provides the maximum difference based upon his/her preference (or importance). Through this sequential analysis, called best-worst scaling, an evaluation of the majority of possible pairs provided in the comparison can be inferred, resulting in an implied ranking of the items. For example, consider the analysis of five ($n = 5$) alternatives: A, B, C, D, and E. Using the traditional method of pairwise comparisons, ten pairwise comparisons are required to examine all possible arrangements. Using the MaxDiff method of best-worst scaling, if an individual considers A the best item and E the worst item, the 7 of the 10 pairwise comparisons are also inferred

$$A > B, A > C, A > D, A > E, B > E, C > E, D > E$$

By asking an individual to determine the maximum difference pairs given in subset choice sets that provide four of the comparable items (i.e., ABCD, ABCE, ABDE, ACDE, and BCDE), all ten pairwise comparison relationships can be inferred.

Depending on desired comparison, items are framed either as objects, attributes, or alternative profiles (Flynn 2010). As objects, items are used in determining preferences, concepts, or opinions without any descriptive attributes being considered (Finn & Louviere 1992). As attributes, items are used to examine the impact of attributes and their subsequent levels based on a common scale, allowing for direct attribute level comparison of alternatives (Louviere *et al.* 1994). As alternative profiles, items are developed in a similar fashion as discrete choice experiments; in this comparison, individuals are asked to select the most appealing and least appealing options (Flynn 2010).

RESULTS

This study investigated motivating and barriers of sanitation usage. Ninety percent of the residents preferred sanitation technology that allowed them to sit (they have a raised seat) as well as used water as a conveyance mechanism (Figure 1).

The utility model that individual i derives from selecting a specific sanitation technical attribute from a subset choice set s is represented as where X denotes the four of seven technical attributes selected for that choice set. Results of the MaxDiff model estimate the coefficient vectors for each respective attribute. As the vectors of the coefficient are estimated on a relative scale, one of the attributes serves as the reference level. With the attribute excreta flow as the reference level, the attribute conveyance has the largest impact on utility, or user satisfaction compared with the other attributes. The attribute with the least impact is the anal cleansing method. Each attribute is considered to be statistically significant on impacting utility, having p-values less than 0.001 (Table 2).

To determine if the impacts of the attributes were homogenous across the demographic and socioeconomic characteristics of the sample population, further analyses were conducted to investigate the differences between various subgroups of the population.

The chi-square test of independence was used to analyze the statistical independence of frequencies between the residents who indicated a preference toward one technical attribute operation mode. Residents who were indifferent

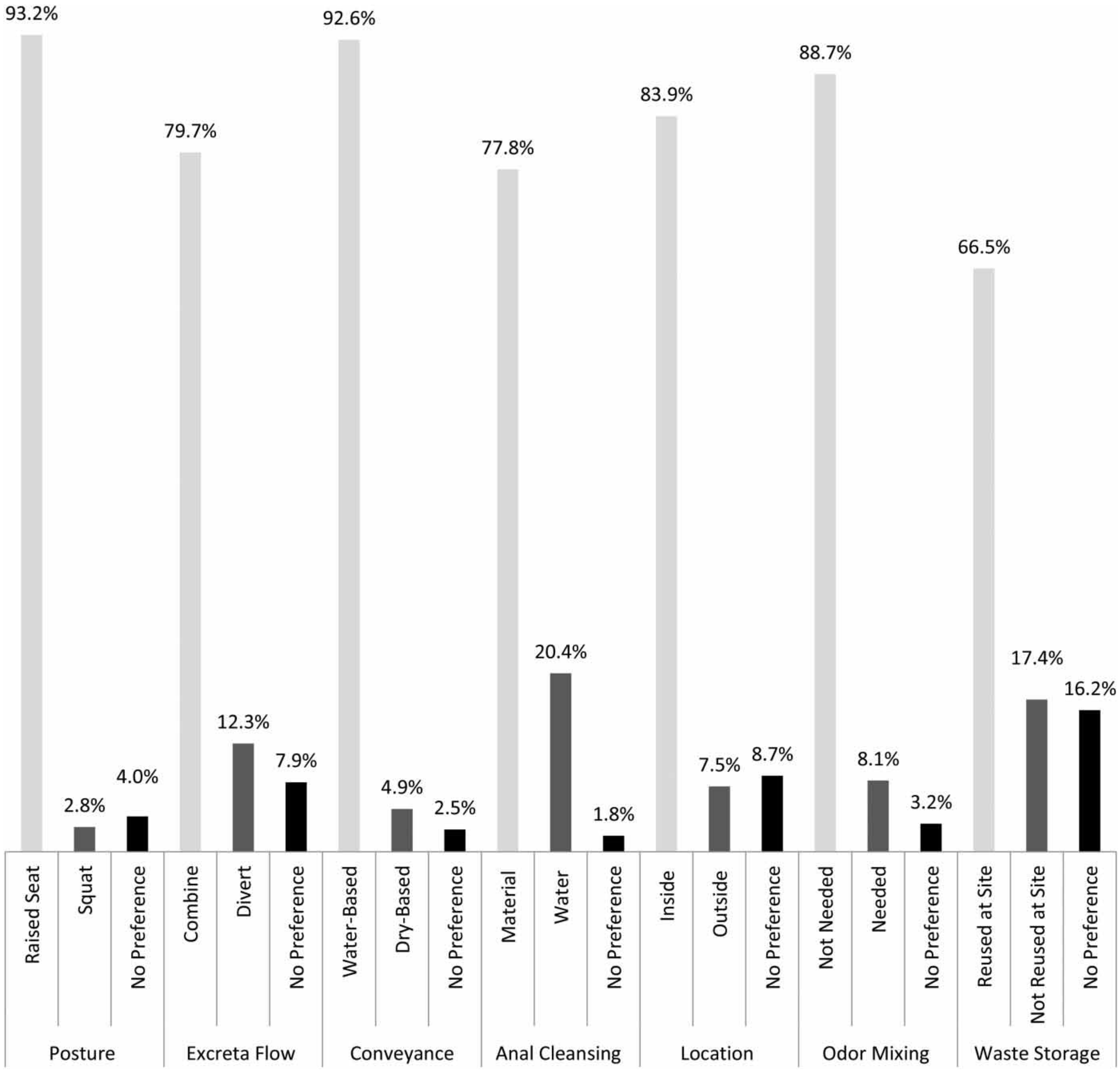

Figure 1 | Relative priorities among sanitation technical attributes among 1,002 surveyed respondents (Seymour 2013).

Table 2 | Coefficient estimates of sanitation technical attributes

Technical attribute	Parameter estimate	Standard error	p-value	Centered parameter estimate	Probability scaled parameter estimate
Posture	0.34244	0.04230	<0.0001	0.09593	0.1515
Excreta Flow				−0.24650	0.1076
Conveyance	0.63221	0.04360	<0.0001	0.38570	0.2024
Anal Cleansing	−0.30529	0.04209	<0.0001	−0.55180	0.0793
Location	0.33698	0.04624	<0.0001	0.09047	0.1507
Odor Control	0.40768	0.04559	<0.0001	0.16117	0.1617
Waste Storage	0.31154	0.04537	<0.0001	0.06503	0.1469

to an operation mode for a specific attribute were excluded from the analysis.

Table 3 presents the percentage of individuals with certain preferences for technical attributes based upon their descriptive characteristic subgroups. In addition to these preferences, the table also describes the percentage of subgroups that indicated a lack of preference for the respective operational mode. The *p*-values presented in the table detail the statistical significance among the descriptive characteristic subgroups for each technical attribute. Some respondent characteristic subgroups, such as age and employment status within the last 3 months, had a minimal impact on the significance of the various attribute levels. Between the age subgroups, there was only a statistical significance in the selection of preferred operation modes of waste storage. Younger respondents preferred to reuse the waste containers, while higher percentages of older respondents preferred to not reuse the containers or indicated no preference between the operational modes. The statistical significance of employment status of the respondent was dependent on the impact of the preferred location of sanitation technology. Individuals employed in the last 3 months indicated a higher preference toward having their sanitation facility located outside than those who were not employed.

Other respondent characteristics had a statistically significant influence on the preferred operation levels of the attribute operation modes. When considering the technical attributes, the gender of the respondent and the head of household status influenced the preferred operation mode. Gender preferences were found throughout all technical attributes. While women preferred to combine their excreta flow and to use material for their anal cleansing method, men preferred their sanitation technology to be located inside their household and to reuse the waste storage containers. Men also indicated higher lack of preferences than women for several of the technical attributes, including posture and excreta flow. Although clear gender preferences were observed, the questions were asked to respondents in a neutral way with each question being asked in the same manner.

Head of household status was a determinant characteristic for the majority of the technical attributes. Individuals considered heads of their respective households indicated higher preferences to divert their waste flow streams and to not reuse their waste storage containers. Heads of households also indicated a higher lack of preference of location of sanitation technology.

Information residents provided about their preferred attribute operation mode and their relative priorities between the attributes was used to calculate individual utility functions for the various sanitation technologies. To assist with determining the utility function for each technology, the parameter estimates of the utility function are adjusted to consider the total number of attributes and then rescaled so that all seven attributes are included in the utility function. The utility function for the seven attributes is

$$U_{ij} = \sum_{r=1}^{R} X_{ir}\beta_{jr} + \varepsilon_{ij}$$

$$\begin{aligned} U_{ij} = {} & X_{i_{\text{posture}}}\beta_{j_{\text{posture}}} + X_{i_{\text{excreta flow}}}\beta_{j_{\text{excreta flow}}} + X_{i_{\text{conveyance}}}\beta_{j_{\text{conveyance}}} \\ & + X_{i_{\text{anal cleansing}}}\beta_{j_{\text{anal cleansing}}} + X_{i_{\text{location}}}\beta_{j_{\text{location}}} \\ & + X_{i_{\text{odor control}}}\beta_{j_{\text{odor control}}} + X_{i_{\text{waste storage}}}\beta_{j_{\text{waste storage}}} \end{aligned}$$

where X_{ir} is individual *i*'s preferred operation mode of attribute *r*, β_{jr} is the estimated parameter coefficient of the respective attribute. In total, 59 sanitation technology alternatives were examined. When the preferred operation mode of individual *i* matches the operation mode of the sanitation technology being examined, $X_{ir} = 1$; when they do not match, $X_{ir} = 0$. Thus, if sanitation alternative *j* matches all of the preferred operation modes of individual *i*, the utility that individual *i* would receive from alternative *j* would be and the individual would be considered perfectly satisfied with the alternative. Using the principles of utility maximization, sanitation technology alternatives with the higher levels of utility would represent the alternatives that would be most preferred by the individual. Depending on an individual's preferred operation mode and relative priorities for technical attributes, multiple sanitation technologies could have the same utility and be considered the most preferred.

Considering that a small number of sanitation technologies would be able to provide maximum utilization $U_{ij} = 1$, various amounts of minimum utilities were

Table 3 | Preferences and statistical significance of technical attributes for select user characteristics

	Age (years)		Education level		Employed 3 months		Gender		Type of user			Type of water source		Household size		Home ownership		Head of household	
	18–34	35–65 +	Primary	Secondary	Yes	No	Female	Male	Private	Shared	Public	Private	Public	Members	> 4 members	Yes	No	Yes	No
Posture																			
Sit	93.17	93.11	95.31	92.32	92.04	94.41	98.00	88.45	91.29	93.36	94.75	93.76	92.41	95.01	91.78	90.57	93.46	93.88	92.35
Stand	3.17	2.20	2.53	2.93	3.52	2.10	1.24	4.31	3.37	3.13	2.10	2.75	2.90	1.90	3.50	4.72	2.59	3.40	2.43
Indifferent	3.66	4.69	2.16	4.75	4.44	3.49	0.76	7.24	5.34	3.51	3.15	3.49	4.69	3.09	4.72	4.71	3.95	2.72	5.22
p-value	0.3876		0.6824		0.1810		0.0020		0.5210			0.8609		0.1222		0.2053		0.4011	
Excreta Flow																			
Combined	79.46	80.22	86.69	77.05	82.13	77.82	91.51	68.68	70.87	79.3	88.28	80.69	78.57	81.8	78.22	81.14	67.92	74.86	85.36
Diverted	12.32	12.36	7.91	14.05	12.30	12.01	4.76	19.46	18.49	11.33	7.29	12.39	12.28	11.35	13.07	10.77	25.47	16.01	7.88
Indifferent	8.22	7.42	5.40	8.90	5.57	10.17	3.73	11.86	10.64	9.37	4.43	6.92	9.15	6.85	8.71	8.09	6.61	9.13	6.76
p-value	0.9754		0.0046		0.8769		<0.0001		< 0.0001			0.9274		0.3483		<0.0001		<0.0001	
Conveyance																			
Water	92.65	92.46	95.22	91.57	92.71	92.51	94.3	90.98	92.16	92.94	92.74	93.73	91.18	94.99	90.8	94.34	92.37	91.87	93.17
Dry	4.63	5.31	3.68	5.34	4.47	5.06	3.16	6.47	5.60	5.10	4.03	4.80	4.98	2.39	6.73	4.72	4.90	4.54	5.47
Indifferent	2.72	2.23	1.10	3.09	2.82	2.43	2.54	2.55	2.24	1.96	3.23	1.47	3.84	2.62	2.47	0.94	2.73	3.59	1.36
p-value	0.6485		0.2535		0.6832		0.0160		0.6254			0.8282		0.0018		0.9036		0.5601	
Anal Cleansing																			
Material	77.92	77.65	83.82	75.53	80.94	75.8	84.13	71.71	67.13	81.96	85.22	75.28	80.95	79.24	76.77	53.77	80.73	75.76	80.87
Water	20.16	20.67	13.60	22.93	17.88	21.76	13.08	27.11	30.62	17.25	12.63	22.88	17.23	19.81	20.74	42.45	17.67	22.35	17.31
Indifferent	1.92	1.68	2.58	1.54	1.18	2.44	2.79	1.18	2.25	0.79	2.15	1.84	1.82	0.95	2.49	3.78	1.6	1.89	1.82
p-value	0.8629		0.0014		0.1112		<0.0001		< 0.0001			0.0282		0.6292		<0.0001		0.0503	
Location																			
Inside	84.59	82.63	76.75	86.6	84.91	83.27	75.95	91.3	84.46	83.14	83.83	88.35	78.36	84.65	83.30	86.79	83.52	78.29	90.21
Outside	7.87	6.72	9.59	8.63	5.66	8.65	10.13	4.94	6.21	9.02	7.55	4.62	10.93	6.00	8.53	4.72	7.78	8.95	5.92
Indifferent	7.54	10.65	13.66	4.77	9.43	8.08	13.92	3.76	9.33	7.84	8.62	7.03	10.71	9.35	8.17	8.49	8.70	12.76	3.87
p-value	0.6067		0.0547		0.0882		0.0003		0.4569			<0.0001		0.1494		0.2527		0.0276	
Odor Mixing																			
Not Needed	88.33	89.29	92.81	87.08	88.01	90.49	88.41	88.93	86.83	87.94	90.89	89.25	87.97	86.76	91.27	85.85	89.01	86.94	89.96
Needed	8.52	7.42	5.04	9.31	8.67	6.73	9.73	6.60	8.40	8.56	7.55	7.83	8.46	10.28	5.19	7.96	9.43	10.81	6.13
Indifferent	3.15	3.29	2.15	3.61	3.32	2.78	1.86	4.47	4.77	3.5	1.56	2.92	3.57	2.96	3.54	6.19	1.56	2.25	3.91
p-value	0.5440		0.0230		0.2509		0.0921		0.8140			0.6928		0.0039		0.5613		0.0101	
Waste Storage																			
Reused at Site	68.72	62.64	61.87	68.29	70.23	64.76	56.31	76.07	55.46	66.42	76.82	67.94	64.73	71.23	63.00	62.26	67.00	65.24	68.17
Not Reused at Site	15.64	20.33	23.74	14.88	16.51	16.79	25.05	10.12	26.33	17.19	9.11	16.39	18.53	13.68	20.07	19.87	17.17	20.63	13.32
Indifferent	15.64	17.03	14.39	16.83	13.26	18.45	18.64	13.81	18.21	16.39	14.07	15.67	16.74	15.09	16.93	17.87	15.83	14.13	18.51
p-value	0.0409		0.0015		0.5798		<0.0001		< 0.0001			0.3182		0.0044		0.5358		0.0069	

calculated, from $U_{ij} > 0.0$ (a minimum of one preferred operation mode of individual i matches with one of operation modes the sanitation technology j) to $U_{ij} \approx 1.0$ (all preferred operation modes of individual i match with the operation modes of sanitation technology j).

Across all sanitation technologies, fewer sanitation users are satisfied as the minimum utility level required increases. In most cases, the number of satisfied sanitation users decreases significantly at a utility level greater than or equal to $U = 0.9$. Some sanitation technologies – including dry toilets, cistern flush toilets, and urine-diverting flush toilets – have a high variance in the number of satisfied sanitation users, indicating that user satisfaction is dependent on the sanitation technologies begin designed and implemented in manners that are preferred by the proposed sanitation users. Cistern flush toilets designed and installed with the most preferred attribute operation modes have the potential to be the most acceptable of the sanitation users, having a maximum of 502 users satisfied the number of users satisfied with cistern flush toilets decreases to 470 users. Simple changes to the operation mode greatly impact the number of users satisfied with the technology. For example, a simple operation mode change from material-based anal cleansing to water-based anal cleansing decreases the number of users who view the sanitation technology as most preferred from 470 to 156 users. The least preferred sanitation technologies are urine-diverting dry toilets, with an average of eight users indicate that sanitation technology their most preferred, regardless of the operation modes selected.

The results support a need to consider motives and barriers for sanitation usage of partakers separately from adopters and non-adopters. As an adoption group, partakers have the option of using a sanitation facility that is shared among several households as well as one that is publicly open to the community. Adopters use private sanitation facilities that only their household has access to, while non-adopters only use sanitation systems open to the entire community.

When openly asked about their motives for usage (Table 3) and compared with statistical data in Figure 2, there is evidence that partakers value shared sanitation

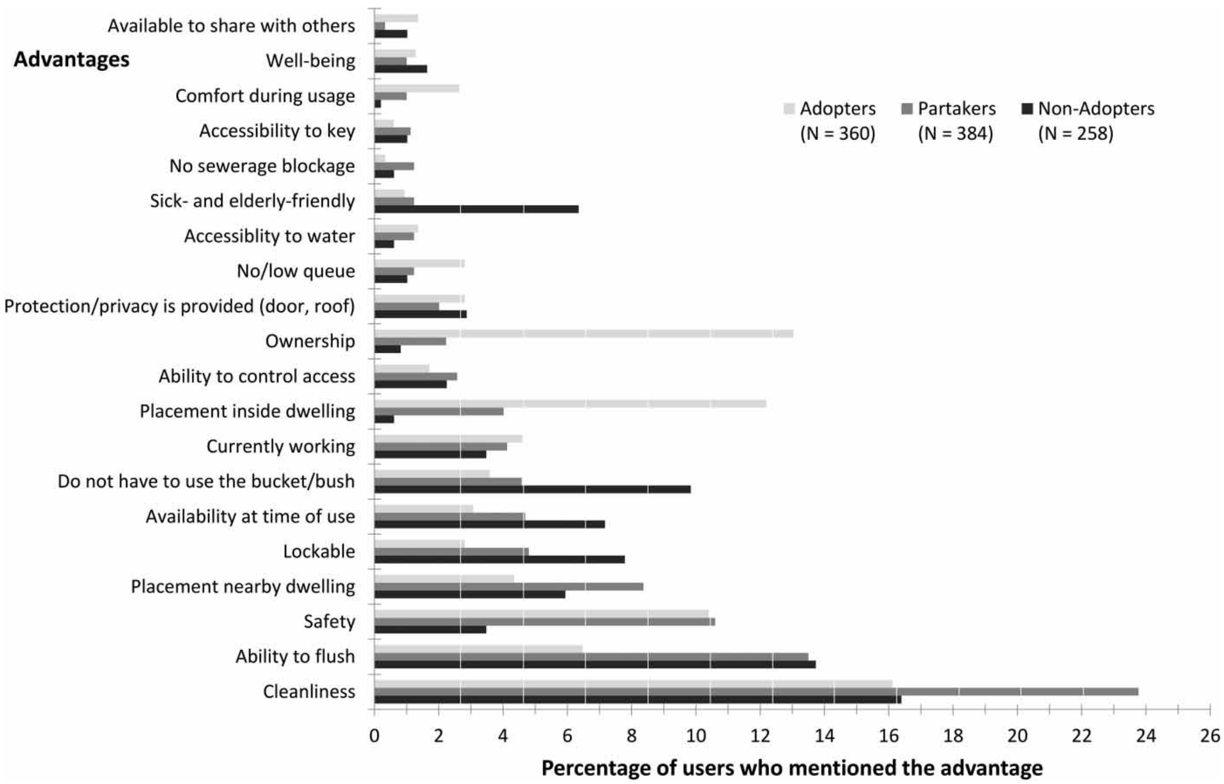

Figure 2 | Percentage of responses identifying advantage of sanitation system attributes for adopters, partakers, and non-adopters, respectively, of sanitation facilities, as collected from open-ended questions of 1,002 respondents (Seymour 2013).

being placed nearby their homes and the ability to use sanitation that flushes. When compared with the adopters, both groups valued environments where sanitation access is controlled, a clear motive differencing the use of sanitation for non-adopters.

In contrast, when compared with the non-adopters separately, partakers viewed their sanitation facilities as advantages due to their cleanliness and ability to use them at night. All adoption groups, regardless of classification, view sanitation as beneficial to their well-being.

Barriers to sanitation usage indicate that unsafe environments, long queues, and facilities considered too far away continue to deter usage (Figure 3). Although partakers view controlled access as a benefit to their current sanitation practices, they still feel that they share with too many individuals – a sentiment also felt by non-adopters. Partakers view their sanitation as safe as adopters do, and the fear of an unsafe environment suggests their desire to not use public shared sanitation facilities. With the majority of respondents in the sample population having access to cistern flush toilets, the study was able to focus on the difference between user adoption classes.

Shared private sanitation may be a viable way to increase access to improved sanitation; however, determining the appropriate number of households as well as which households should share the facilities can be difficult. In this study, partaker households were able to determine who was given access to the sanitation facility. In most cases, partakers shared with neighbors and family members. In broad implementation schemes where municipalities or agencies want to increase access through shared sanitation, the inability for households to choose their fellow partakers may deter usage of the sanitation system.

DISCUSSION

Current perceptions and past experiences with a certain sanitation technology can influence a user's preferences for that sanitation technology. Rather than eliciting

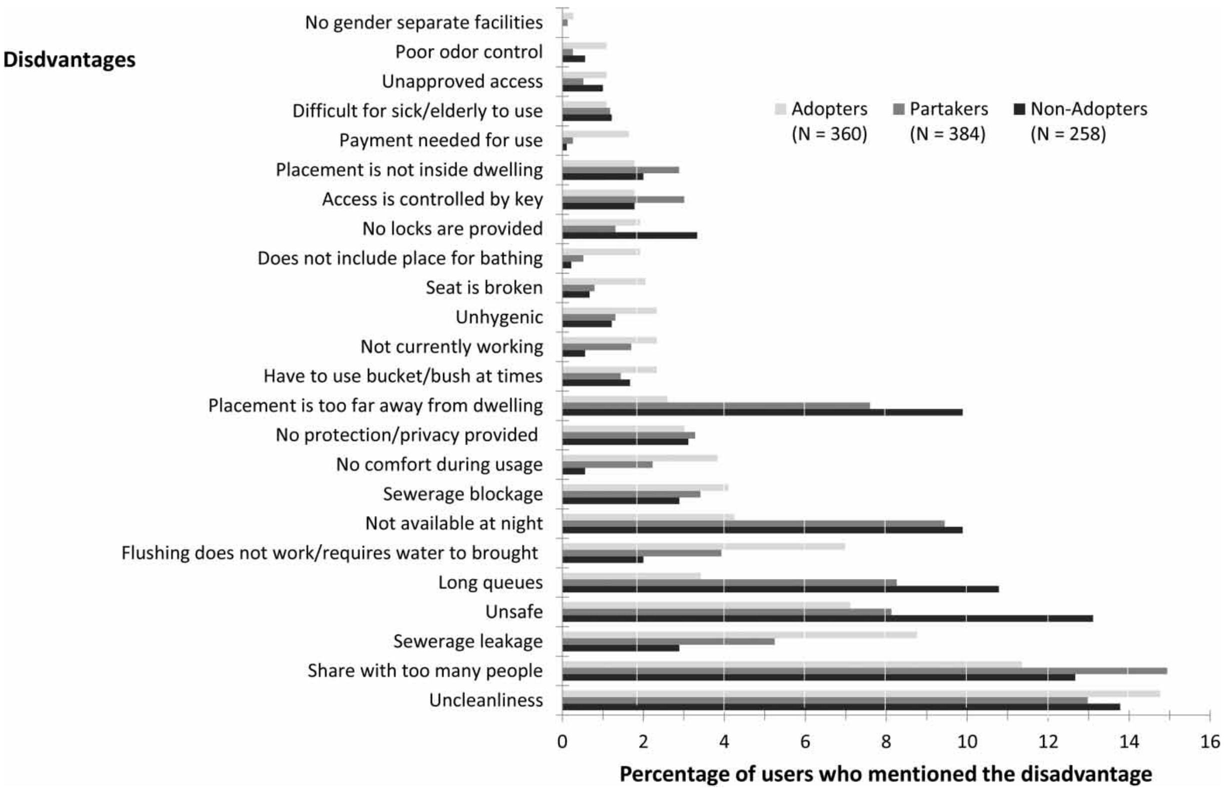

Figure 3 | Frequency of responses identifying disadvantages of sanitation system attributes for adopters, partakers, and non-adopters of sanitation facilities, as collected from open-ended questions of 1,002 respondents (Seymour 2013).

preferences about the sanitation technology in general, MaxDiff scaling is a novel approach to compare the attributes of various sanitation technologies. MaxDiff scaling has several advantages over the approach of conducting contingent valuation experiments. Further user choice information is provided with MaxDiff scaling than from traditional discrete choice experiments, allowing a further understanding of what attributes about a sanitation technology are preferred over others. Additionally, MaxDiff can assist with examining the influence user characteristics have on preferences toward sanitation technology. Having a better understanding about user preferences can assist in informing the decision-making process regarding sanitation technology design and implementation. The research suggests that sanitation users have preferences that can influence their acceptance of the design and implementation of sanitation technologies. The application of the MaxDiff model demonstrates the ability to examine the impact sanitation technical attributes have on user acceptance as well as the relative priorities users place on various technical attributes. Furthermore, the study illustrates that sanitation users place higher importance on their preferred operation mode to convey their excreta wastes. With over 90% of the population preferring sanitation technology that is water-based, technologies with this conveyance approach are more likely to be accepted by the community. However, conveyance is only one attribute that impacts user acceptance, as evident in approximately half of the sample population being no more than 80% satisfied with a cistern flush toilet installed in a certain manner.

Decisions around sanitation technology design and implementation are complex. Sanitation technologies must be efficient in minimizing human contact with excreta as well as removing harmful pathogens from fecal matter. As decision makers are determining the appropriate sanitation technologies, the study suggests that clear consideration must be given to how the user will ultimately be asked to interact with the sanitation technology. Ultimately, sanitation technology design and implementation must occur with user preferences in mind. Sanitation technologies must be designed and installed in manners that allow the user to interact with the technology in the preferred operation mode.

Consensus in the literature before this work has typically grouped these individuals as a subset of non-adopters – individuals who use communal sanitation facilities. Using an alternative approach, this work identified several motives and barriers of these users to sanitation usage that are statistically significant from non-adopters. Identifying this new class of users as partakers, this research suggests that they value the ability to use sanitation that flushes as well as shorter walking distances to use their sanitation facility. Furthermore, partakers value the cleanliness of their sanitation facilities as well as the ability to use them at night. Shared sanitation continues to advance as an implementation approach to providing access. Understanding this group of users provides a foundation in furthering sanitation interventions, specifically those being implemented in informal settlements and other resource-challenged areas. Using the current United Nation's definition of improved sanitation, between 2000 and 2017, 2.1 billion people globally gained access to basic sanitation services. In Sub-Saharan Africa, the number of people who have access to unimproved sanitation increased from 190 to 319 million. Additionally, the number of people with access to shared improved sanitation facilities doubled (UNICEF & WHO 2019). Using the reclassification of these users identified in this work assists in developing new user-specific intervention approaches.

Furthermore, this reclassification of shared sanitation users clarifies the linkage between sanitation definitions and user adoption classifications. Current definitions of sanitation access identify shared sanitation as a type of sanitation classification, without differentiating shared sanitation facilities that provide for controlled access from those that are communal. With this reclassification, shared sanitation facilities can be identified based on implementation arrangements. This work presents evidence that design attributes can be ranked using a generalized multinomial logit valuation metric for a given sanitation user. Applied to this research using maximum difference scaling, this metric accurately predicted value preferences for seven technical attributes of sanitation technology. This is a significant improvement over prior work in the field, which investigated preferences for sanitation technology while neglecting which attributes of the technology were influencing those preferences. Conversely, this work demonstrates that the attributes of sanitation technology do not have equal importance to the sanitation user. Parameter estimations detailed the significance of technical attributes and determined their respective priorities. Specifically, the application of the maximum difference scaling reveals the higher priority sanitation users place on using water-based conveyance in sanitation technologies and the lower priority placed on anal cleansing approaches.

This work sought to advance the understanding of the value preferences of sanitation users in hopes of developing new approaches to increase global sanitation coverage. It details a new classification methodology as well as optimization and simulation techniques to examine sanitation users and their preferences. While it addresses the impact of those preferences on sanitation technology design and implementation practices, further work is needed toward using these findings to influence policy.

Focusing on partakers as a new class of sanitation users, future research is needed to develop sanitation intervention schemes directed toward shared controlled usage of sanitation as a mechanism to improve sanitation coverage. Specifically, the determination of the optimal number of preferred households to share sanitation must be determined to ensure that access has a sense of controllability. Additionally, it needs to be determined how to allocate ownership and accountability responsibilities for partakers shared sanitation facilities.

More research is needed to replicate the approaches used in this work in other sanitation settings. The specificity of the data collection process was limited to sanitation users in a peri-urban context specific to the community of Kayamandi. To determine the prevalence the characteristics of sanitation users that served as a basis of the work, similar studies should be performed in the rural and urban settings. Sanitation users in these environments can have different socio-cultural and socioeconomic constraints than those living in peri-urban areas. Gathering additional data from different settings will assist in understanding those settings.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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