Supplementary Materials

Willingness-to-pay and costs for alternative novel manual emptying services for onsite sanitation facilities in an informal settlement of Nairobi, Kenya

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S1. Questionnaire Sheet (English version)

(L)…Question for landlords only, (T)… Question for tenants only

No.	Question	Hint	Required
1	Are you a tenant or landlord?		yes
2	How often do you or does your landlord remove faecal waste from the toilet on average?	(ex. Every 4 months, twice a year, etc. Try to avoid vague expressions such as "a few" or "several".)	yes
3	When was the last time faecal waste was removed from the toilet?	(ex. 4 months ago, 6 weeks ago, etc. Try to avoid vague expressions such as "a few" or "several")	yes
4	Have you ever called an emptying service by yourself?		
5 (L)	Have your tenants ever called an emptying service by themselves?		
6 (L)	How many drums of sludge did you remove last time?	No. of drums	yes
6 (T)	How many drums of sludge did you remove last time?	No. of drums (If you called emptiers with other tenants, please provide the total number of drums you and other tenants requested.)	
7	How much did you pay for the sludge emptying last time?	KES/drum	
8	Did you pay it by cash, or M-Pesa?	For those who have paid the emptying fee before only	
9	How many drums of sludge do you want to remove when your pit gets full next time?	Please count the volume with a 200L drum	yes
10	Please watch a video and then answer the following questions. (Option 1: Standard Plan) Would you pay this amount of money for the emptying **Option 1**?	(KES/drum) Enumerator, randomly show a price card to the participant.	yes
11	Would you then pay this amount of money for the emptying Option 1?	(KES/drum) Enumerator, randomly show a price card to the participant.	yes
12	How much would you be willing to pay for the emptying Option 1?	Please be mindful of your household income and circumstances and answer the amount of (KES/drum).	yes
13	(Option 2: Small-Amount Plan) Would you pay this amount of money for the emptying Option 2?	(KES/drum) Enumerator, randomly show a price card to the participant.	yes
14	Would you then pay this amount of money for the emptying Option 2?	(KES/drum) Enumerator, randomly show a price card to the participant.	yes
15	How much would you be willing to pay for the emptying Option 2?	Please be mindful of your household income and circumstances and answer the amount of (KES/drum).	yes

16	How many drums of sludge would you empty with the price you answered for Option 2?	Please count the volume with a 200L drum	yes
17	Age		yes
18	Gender		yes
19	Education level	highest level you have received	yes
20	How many people are in your household?	the total number of household members residing in a dwelling unit	yes
21	What is the total monthly income of your household?	if there is someone who lives away from here sends money to your household, please include the transfer.	yes
22 (T)	How much rent do you pay per month?		
22 (L)	How much rent do you collect in total per month in this plot?		
23	Does the landlord live in this plot?		yes
24	How long have you lived in your current plot?		yes
25	Do you (or does anyone in your household) have M-Pesa?		yes
26	How many toilets are there in your plot?		yes
27	How many households are there in your plot?		yes
28	Are there any agreement between the landlord and tenants regarding emptying fees?	(ex. Emptying fee will be deducted from rent if tenants pay it)	yes
29	Please briefly explain about the agreement.		
30	Do you think the rent includes fees to maintain the toilet available?		yes
	Enumerator, please check the sanitation facility being used in the plot.		yes

S2. Verbatim transcript of the video used for WTP survey (English translation)

Please carefully watch this video and let us hear your opinion about the options.

Emptying human waste is an important job to keep your toilets clean and available. However, the emptying work can be unhygienic. For example, service workers sometimes do not have necessary equipment such as protective gear or sealable drums, which could result in polluting your community and eventually cause health problems.

Here, we propose a new emptying service to improve the situation.

New service

In this option, workers wear protective gear such as masks, gum boots and gloves. They will never be intoxicated. The workers are well-trained and will use equipment like sealable drums so that the emptying work will be hygienic enough. Human waste removed from toilets will be taken to a treatment facility, so it won't be discharged into rivers.

When using this service, two options are available.

The first option is the Standard plan. In this Standard Plan, there is no upper limit of emptying. In other words, the more you pay, the more sludge you can remove. We collect waste according to the volume that you request. You need to pay a standard fee which is charged per drum.

The second option is the Small-amount plan. In this option, you can empty the waste up to 3 drums. One drum is 200 L. The more you pay, the more waste you can remove, but you can't request four or more drums. In return, you can use the service at a reduced fee. Therefore, Option 2 is suitable when you need a smaller amount of emptying or you have a limited budget.

Here is a summary. This new service has a good quality with professional workers and hygienic operation. As for the emptying volume, Standard Plan accepts an unlimited volume of emptying, but, under Small-Amount Plan, you can request up to three drums. The fee per drum will be more expensive for Standard Plan, while Small-Amount Plan offers a reduced fee.

This is the end of this video. If you have any questions, please feel free to ask our staff.

(The full video in Swahili is available here: https://youtu.be/BQqXwHShufQ)

S3. Validation of WTP

To verify the WTP elicited from the open-ended answers, WTP statistically estimated from the dichotomous choices (yes/no answers) were analysed by a maximum likelihood estimation with STATA 18 using the "doubleb" command.(1, 2). A participant can answer "yes, yes; yy", "yes, no; yn", "no, yes; ny", or "no, no; nn" to the first and second dichotomous questions. Here, let the probability that a participant answers "yy" be Pr^{yy}, and similarly, the probability of "yn" is expressed as Pr^{yn}, "ny" as Pr^{ny}, and "nn" as Pr^{nn}. Let the first price bid be T_1 and the second price bid be T_2. Each probability of dichotomous answers takes the form of (i) - (iv).

$$Pr^{yy} = \Pr(T_1 < T_2 \leq WTP)$$

$$= (T_2 \leq WTP) \quad (i)$$

$$Pr^{yn} = \Pr(T_1 \leq WTP < T_2) \quad (ii)$$

$$Pr^{ny} = \Pr(T_2 \leq WTP < T_1) \quad (iii)$$

$$Pr^{nn} = \Pr(WTP < T_2) \quad (iv)$$

To estimate parameters using maximum likelihood estimation, the log-likelihood function is described as

$$lnL = \sum_{i=1}^{N} \left(d_i^{yy} \ln Pr^{yy} + d_i^{yn} \ln Pr^{yn} + d_i^{ny} \ln Pr^{ny} + d_i^{nn} \ln Pr^{nn} \right) \quad (v)$$

where d^{yy}, d^{yn}, d^{ny}, and d^{nn} are indicator variables that take values of 1 or 0 depending on the participant's dichotomous answers: when the answers are "yes, no", the value of d^{yn} is one and the others are zero. Assuming that WTP can be modelled by the following equation,

$$WTP_i = z_i\beta + u_i \quad (vi)$$

where z_i is a vector of explanatory variables, β is a vector of parameters, u_i is a error term, and that $u_i \sim N(0,\sigma^2)$, and substituting the equation (i) – (iv) and (vi) to (v), β and σ can be estimated by maximum likelihood estimation.

Figure S1 shows the comparison of WTP elicited by the two methods: WTP directly calculated from the open-ended answers after double-bounded dichotomous choice questions which was explained in the main text, and WTP estimated from the maximum likelihood estimation as explained above. The mean WTP amounts for the Standard Plan and the Small-amount Plan were higher when estimated by a maximum likelihood function by 8% and 5%, respectively, but the 95% confidence intervals overlapped for the Small-Amount Plan.

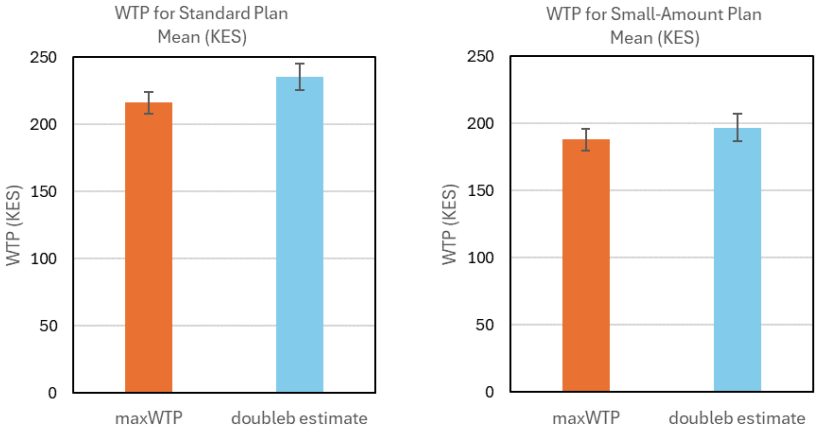


Figure S1. Comparison of WTP elicited by different approaches. The orange bars show mean WTP elicited from the open-ended answers after double-bounded dichotomous choice questions. The blue bars shows mean WTP estimated by a maximum likelihood estimation using the "doubleb" command in STATA.

コメントの追加 [IR1]: useful results!

S4. Normality of Residuals of Multi-Regression Model

Residuals are approximately normally distributed when using the log-transformed WTP data.

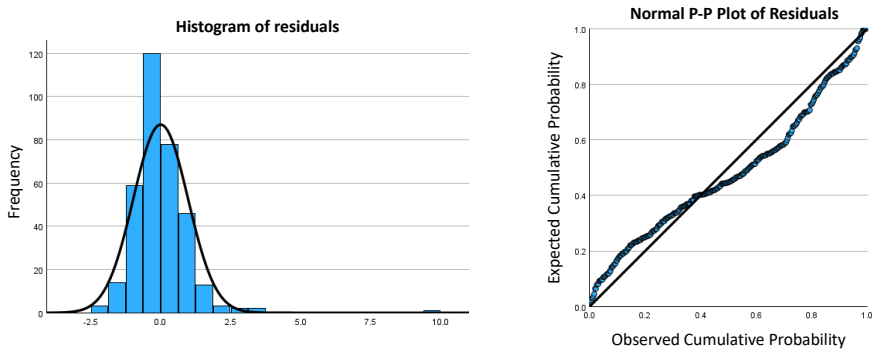


Figure S2. Histogram of residuals of the regression model that takes crude max WTP before log-transformation (outlier included) as the dependent variable and the normal P-P plot of residuals.

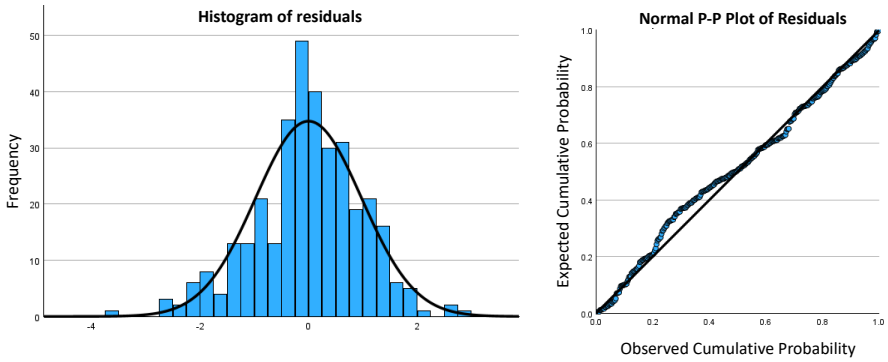


Figure S3. Histogram of residuals of the regression model that takes log-transformed max WTP (outlier excluded) as the dependent variable and the normal P-P plot of residuals.

S5. Cost Analysis

Spreadsheet model

General Market Condition Estimate

ID	Item	Data	Unit	How data obtained
a	Number of Households in Korogocho	34,000	people	Iddi et al. 2021 (3)
b	Household size (average)	5.3	people/household	Survey data
c	Proportion of manually emptiable toilets	50%	-	Greene et al. 2021 (4)
d	Households sharing one toilet (median)	6	households/toilet	Survey data
e	Number of emptiable toilets	535	toilets	=a/b*c/d
f	Emptying interval (median)	4	month	Survey data
g	Number of emptying events per toilet per year	3	events /toilet/year	=12/f
h	Number of emptying events per year in Korogocho	1604	events/year	=e*g
i	Emptied volume last time (median)	5	drums/event	Survey data
j	Annual volume of sludge collected in Korogocho	8,019	Drums	=e*g*i
k	Number of drums to carry per day (260 working days a year)	31	drums/day	=j/260
l	Number of emptying event per day (260 working days a year)	6.2	events/day	=h/260

Operational Expenditure (OPEX)

ID	Item	Data	Unit	How data obtained
A	Emptying events per day	Input α	event (household)	α= 1, 2 or 3
B	Emptying volume	Input β	drums	β= 1~10
C	Number of emptiers	3	people	Field observation (Tomoi, qualitative study)
D	Wage rate	50	KES/person/drum	Field observation (Tomoi, qualitative study)
E	Labour cost per day	-	KES/day	=B*C*D

F	Transport distance	12.7+*d*	km	Korogocho ~Mtaa Project Transfer Station at Mukuru =12.7 km (one way) *d* = 0.5 *A (km)
G	Tricycle capacity (upper limit)	10	drums	Semiyaga et al. (2022) (5)
H	Fuel efficiency	5.5	km/L	Market data
I	Fuel cost	195	KES/L	Market data
J	Transport cost per day	-	KES/ day	=F*2/H*I

K	Dumping fee	50	KES/drum	Rate at Mtaa Project Transfer Station (6)

L	Dumping cost per day	-	KES/day	=B*K

M	OPEX per day	-	KES/day	=E+J+L
N	OPEX per drum	-	KES/drum	=M/B

Capital Expenditure (CAPEX)

ID	Item	Data	Unit	How data obtained
O	Tricycle purchase	250000	KES	Semiyaga et al. (2022) (5)
P	Loan interest	20%	Annual interest	Market data
Q	Loan period	4	years	Market data
R	Replacement period (useful life of Tricycle)	5	years	Assumption
S	Maintenance cost rate per year	5%	of tricycle price/year	Assumption
T	Total cost per year	77500	KES/year	={O+P*O+ P*O(1-1/Q)+P*O(1-1/Q*2)+P*O(1-1/Q*3)+P*O(1-1/Q*4)}/R+O*S
U	PPE cost	3400	KES/person	Market data. Mask, globe, gumboots, goggles
V	Replacement period	2	year	Assumption
W	PPE cost per year per person	-	KES/year/person	=U/V
X	PPE cost per year	-	KES/year	=W*C
Y	Equipment (200 L drum)	4500	KES/pc	Market data
Z	Replacement period	3	Years	Assumption
A’	Number of drums	10	Pc	Assumption
B’	Equipment cost (drum) per year	15,000	KES/year	=Y/Z*A’
C’	Equipment (bucket)	200	KES/pc	Market data
D’	Replacement period (bucket)	1	year	Assumption
E’	Number of buckets	10	pc	Assumption
F’	Equipment cost (bucket) per year	2,000	KES/year	=C’/D’*E’
G’	CAPEX	99,600	KES/year	=T+X+B’+F’
H’	CAPEX per working day (260 days)	1,335	KES/day	=G’/260
I’	CAPEX per household	-	KES/household	=H’/A
J’	CAPEX per drum	-	KES/drum	=H’/B
K’	OPEX + CAPEX per day	-	KES/day	=M+H’
L’	OPEX + CAPEX per household	-	KES/household	=K’/A
M’	OPEX + CAPEX per drum	-	KES/drum	=K’/B

コメントの追加 [HT2]: As for the loan interest, I have searched five Kenyan banks/financiers and took the rough average, 20%.
NCBA Bank: 18.1%
Diamond Trust Bank: 16%
HAKKI: 23%

Also, as far as I found, the loan period was up to 4 yrs, so it is reflected in the calculation too

コメントの追加 [IR3]: I would hope it would eb more than this, but good to be conservative. Could do a sensitivity analysis where it’s 10yrs

コメントの追加 [HT4R3]: With a 10-year replacement interval, the cost was reduced by 14 KES/drum. This analysis is not included in the Fig S6 since it already has data on the vehicle replacement period.

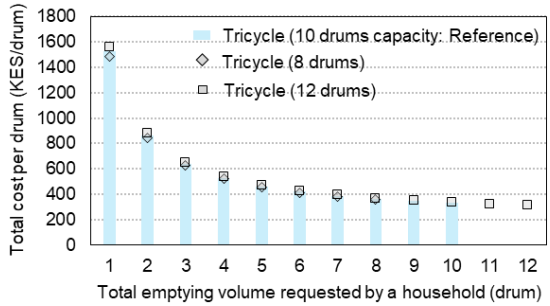


Figure S4. Sensitivity analysis on tricycle capacities. The tricycle capacity was increased/decreased by 20% and the purchase cost was increased/decreased by 10% from the reference level (10 drums of capacity, 250,000 KES).

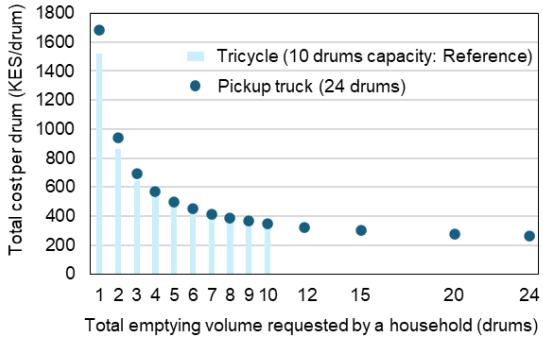


Figure S5. Sensitivity analysis on vehicle types. Instead of a tricycle (10 drums of capacity, 250,000 KES, fuel efficiency of 5.5 km/L), a pickup truck is used (24 drums, 500,000 KES, fuel efficiency of 6.7 km/L). (5)

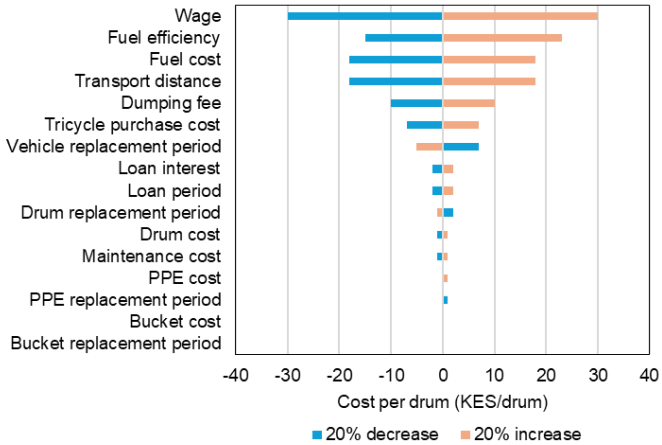
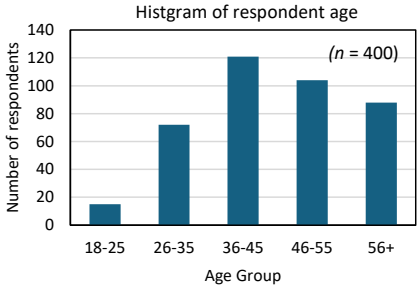
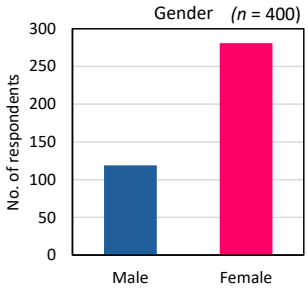


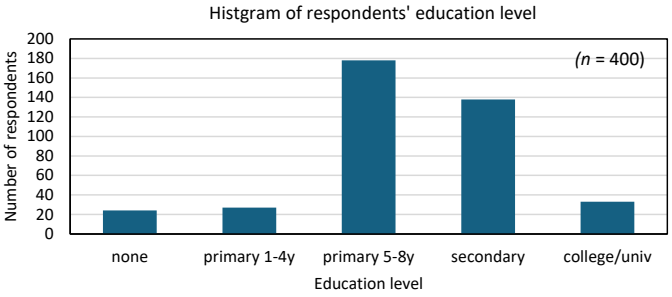
Figure S6. Sensitivity analysis on other parameters. Under a scenario where one household requests 10 drums and a motorized tricycle is used, all other parameters were increased/decreased by 20%.

S6. Characteristics of Participants

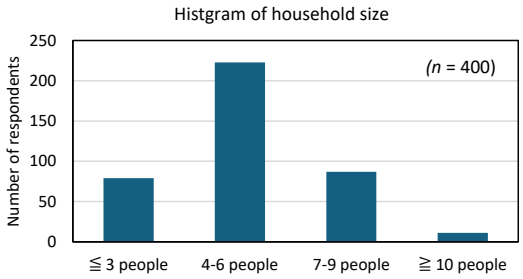
Gender, Age, Education

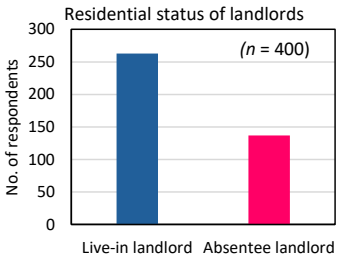


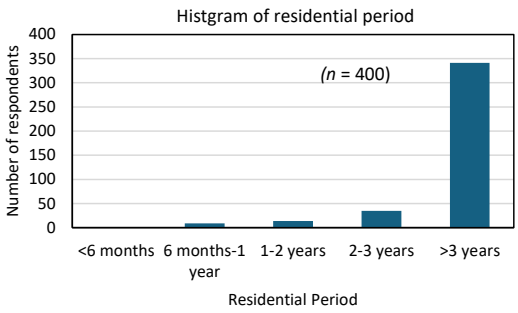


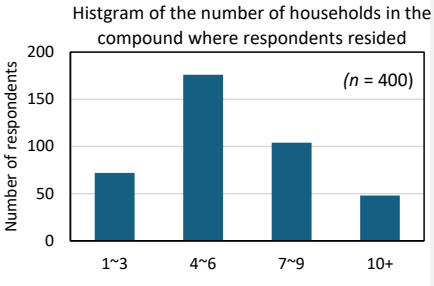


Household Characteristics

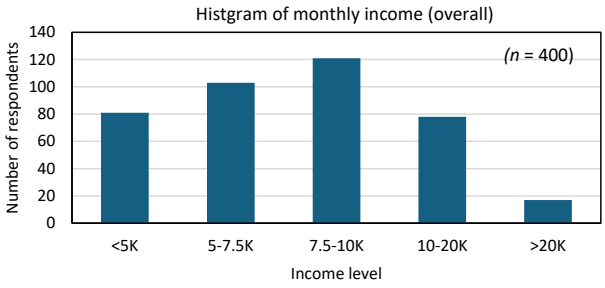


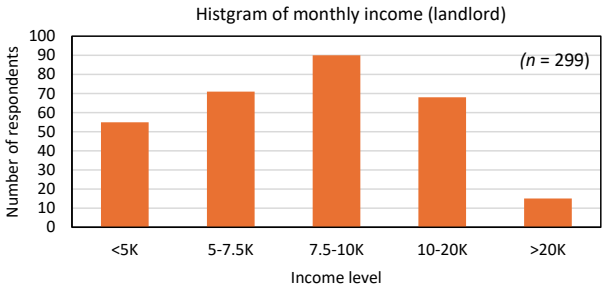


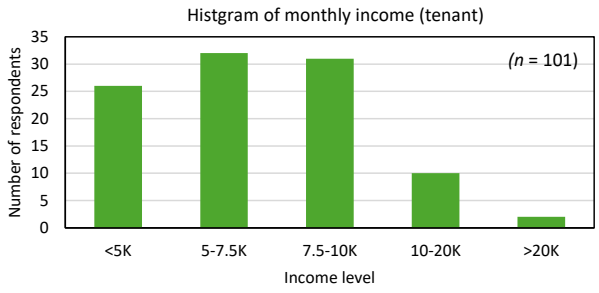


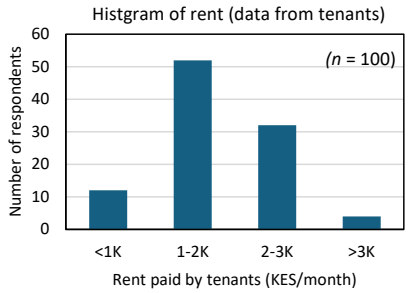


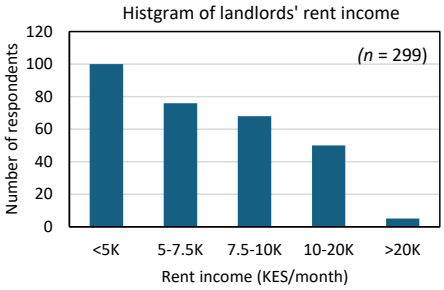
Financial Situations



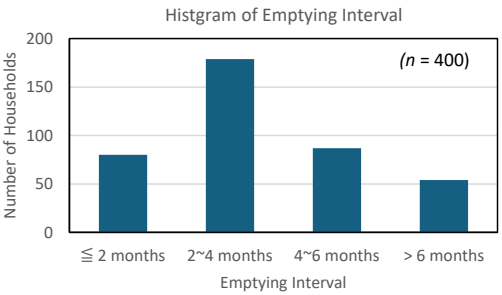


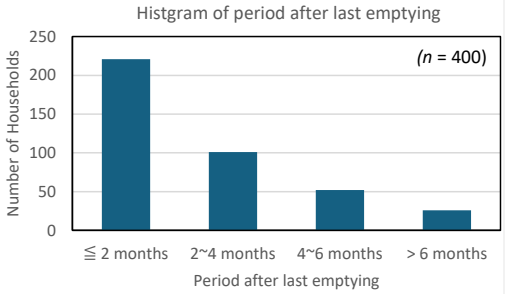


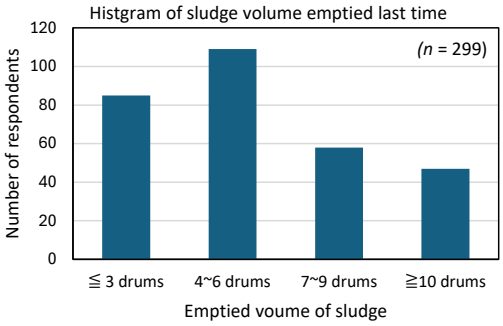


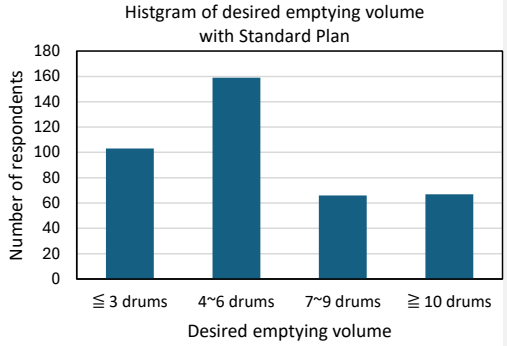


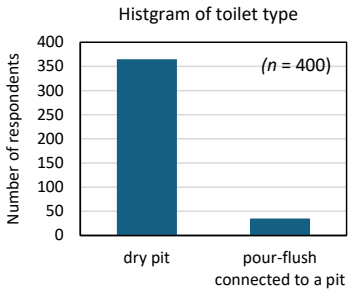
Characteristics Concerning Faecal Sludge Management

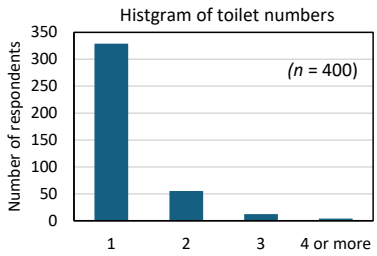




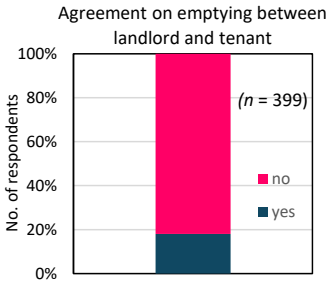


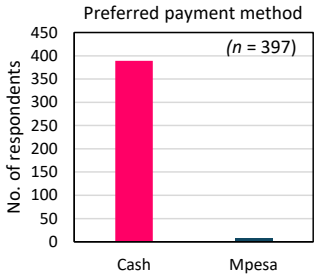


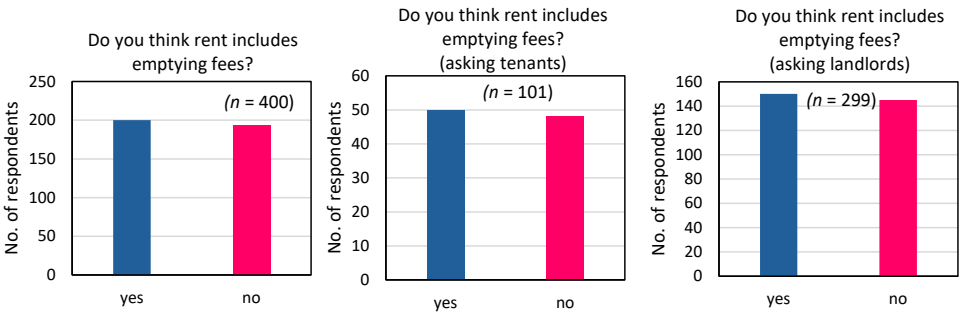




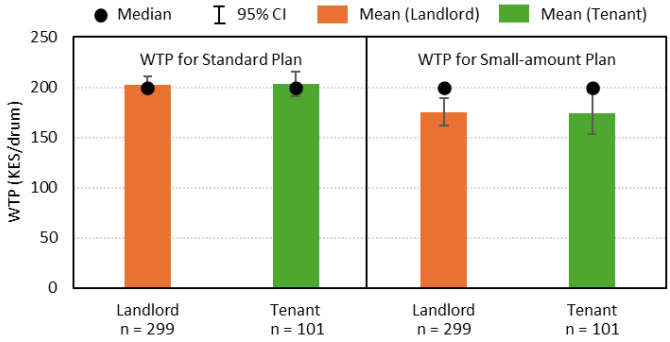
Perception about Payment for Emptying Services







Willingness to Pay for Emptying Services by Respondent Type



S7. Results of a multi-regression model of log-transformed WTP for the Small-amount Plan (R^2 = 0.113, p < 0.001 for F-test)

Explanatory variable	Level	Beta	Standardised Beta	t-value	p-value
(constant)		3.962		11.113	<.001
Age	18-25 (ref)				
	26-35	-.303	-.299	-2.654	**.008**
	36-45	-.266	-.334	-2.440	**.015**
	46-55	-.247	-.301	-2.236	**.026**
	55+	-.310	-.364	-2.765	**.006**
Sex	Male (ref)				
	female	-.032	-.040	-.728	.467
Education level	Uneducated (ref)				
	primary_1-4 year	.013	.009	.130	.897
	primary_5-8 year	-.036	-.049	-.444	.658
	secondary	.004	.006	.053	.958
	College/university	-.057	-.044	-.555	.579
Monthly household income	<10,000 KES (ref)				
	10,000 – 20,000 KES	.041	.046	.847	.398
	>20,000 KES	.149	.087	1.606	.109
ln (fee paid last time for informal emptying)		.280	.252	4.584	**<.001**
Number of households in the compound		.012	.169	2.868	**.004**
Volume the respondent wants to empty next time (drum)		-.017	-.202	-3.380	**<.001**
respondent lives in the compound		-.011	-.012	-.228	.820
there is an agreement on emptying between landlord and tenant	No (ref)	-	-	-	-
	yes	-.061	-.065	-1.196	.233

Reference

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