



Techno-Economic Assessment of Appropriate Sustainable Open Defecation Mitigation Systems in North-Central Nigeria

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ABSTRACT

Open Defecation (OD) continues to be a major public health problem and obstacle for development in North-Central Nigeria due to various economic, infrastructural, and behavioural factors. A shift from simple toilet construction towards integrated approaches combining infrastructure, behavioral change, and market-based models have been suggested in the literature. In this study, spatial distribution, technological nature, user perceptions and techno-economic analysis of various anti-open defecation technologies in Nasarawa State, Niger State, and the Federal Capital Territory (FCT) were explored. Results showed that public toilets have varying spatial distributions, clustering at urban centers while sparsely or unevenly dispersed across rural areas. Water closets which were the most preferred accounted for 33.78% of public toilets in the study area, while mobile latrines and pour-flush toilets accounted for 29.73%, and 16.22% respectively. No compost toilets were found in the study area. An optimized public toilet was shown to be financially viable via techno-economic analysis, showing a positive NPV of ₦3.57 million and payback period of six years. Data on user perception revealed high latent demand (91.3%) and open defecation practice (71.3%) among users, due to hygiene problems, safety issues, and social taboos associated with it. This shows that a high willingness to change exists with continuation of OD.

Keywords: Open defecation, Public toilets, Techno-economic evaluation, Sanitation technologies, Community-led total sanitation

INTRODUCTION

Open Defecation (OD) is still a significant obstacle to the attainment of Sustainable Development Goal 6 (clean water and sanitation) and SDG 3 (good health and well being) especially in sub-Saharan Africa. OD refers to the disposal of human excreta in open areas like bushes, drains, water bodies, abandoned structures, and other communal or peri communal areas instead of using any purpose-built toilets or latrines (Olagbemide and Oluropo, 2025). OD continues to affect around 12% of the World's population, with a significant number of people living in South Asia and sub-Saharan Africa (Olagbemide and Oluropo, 2025; Fagunwa et al., 2023).

Nigeria is ranked as one of the countries with the highest number of individuals who practice OD. According to findings from the 2021 WASH NORM report, approximately 48 million Nigerians still engage in open defecation and only 8% of the population practice clean handwashing (FMWR et al., 2022). In more recent reports, it is found that OD is still highly prevalent with evident disparities in North-South and rural-urban areas and that certain States in the Middle Belt and North Central corridor have persistently high prevalence of OD (Gayawan et al., 2023; Atangana and Oberholser, 2022; Fagunwa et al., 2023).

OD is closely linked with poverty, inability to have access to better sanitation, low levels of education, sociocultural practices, and geographic or urban/rural planning limitations (Olagbemide and Oluropo, 2025; Abubakar, 2018; Abubakar, 2017; Kalu et al., 2019). The research based on National Demographic and Health Survey (NDHS) data shows that place of residence, region, household wealth, education, and ethnicity have a significant influence on OD (Abubakar, 2017; Abubakar, 2018). OD can be practiced even in households that have toilets because of behavioural, psychological, and environmental causes like toilet contamination, acceptance of defecation norms in the community, or unavailability of public toilets outside the home (Olapeju and Olapeju, 2022; Olapeju, 2022). OD has a serious health burden. It pollutes soil and water, promotes the spread of water related parasitic infections (protozoa, helminths, and nematodes) and other enteric diseases, which contribute to morbidity and mortality, especially in

children (Amadi et al., 2024). It is also associated with the wider environmental pollution and can be related with the patterns of antimicrobial resistance in the case of poor sanitation (Fagunwa et al., 2023).

A variety of policies and programmatic responses have been implemented in Nigeria, such as Community Led Total Sanitation (CLTS) and the “Clean Nigeria: Use the Toilet” campaign to ensure that the country becomes open defecation free by 2025 (Olagbemide and Oluropo, 2025; Sawyerr and Adepoju, 2019; Abdulkadir et al., 2023; Agha et al., 2024). However, assessments show both success and failure. Many communities triggered under CLTS revert to OD due to structural failures of latrines, lack of durable and appropriate technologies, weak follow-up, and insufficient integration of behavioural and enforcement measures (Sawyerr and Adepoju, 2019; Agha et al., 2024). There is thus a growing recognition that sustainable OD elimination requires not only community mobilisation but also technologically appropriate, economically viable, and spatially well-planned sanitation systems, including public toilets in high-use spaces like markets, transport nodes, and informal settlements (Farouk et al., 2024; Olapeju and Olapeju, 2022; Olapeju, 2022; Muktar et al., 2024).

In the North-Central region of Nigeria, rapid urbanisation, mixed rural-urban landscapes, and high levels of mobility, intensify the need for robust anti-OD technologies and effective spatial planning of public convenience facilities. Empirical evidence on the spatial distribution, technological features, and techno-economic performance of public toilets as OD-mitigation systems in North-Central Nigeria, however, remains limited.

This study will therefore attempt to; examine the spatial distribution and types of public toilets in North Central Nigeria; determine the technological specifications for sustainable OD mitigation technologies that are technically robust, context appropriate, and economically feasible in North Central Nigeria; and analyze the techno economic viability of appropriate anti-OD technologies suitable for the region. The literature review will be discussed in the subsequent section. This will be followed by the methodology, results, discussion

and policy implications for mitigating open defecation in North-Central Nigeria.

LITERATURE REVIEW

There has been a well-established complex interaction of socioeconomic, demographic, and locational determinants of OD. Analyses of NDHS data show that OD is significantly influenced by rural residence, geopolitical region, wealth index, household head's level of education, ethnicity, and gender (Abubakar, 2017; Abubakar, 2018). Northern and Middle Belt States tend to have higher OD prevalence than much of the South, with a clear North–South spatial gradient (Atangana & Oberholster, 2022; Gayawan et al., 2023). Wealth and inequality are particularly central. In Africa, the poorest are estimated to be over 40 times more likely to practice OD than the wealthiest, even after adjusting for education and residence (Fagunwa et al., 2023). Within Nigeria, households with limited income, living in informal or topographically challenging settlements and with poor access to piped water, tend to rely on unimproved sanitation or OD (Abubakar, 2017; Kalu et al., 2019).

OD and its vulnerabilities are clustered as highlighted by spatial and geostatistical analyses. Indicatively, local spatial autocorrelated techniques used in a Nigerian town indicated that there were high risk areas of OD around water bodies and inner residential areas with limited or poorly constructed public toilets (Mukhtar et al., 2024). Similarly, national-scale spatio-temporal modelling demonstrates persistent OD “hotspots” in certain clusters of States, including parts of the North-Central and adjoining regions (Gayawan et al., 2023).

Public Toilets, Planning, and Open Defecation

Although much work in the literature focuses on household sanitation, the role of public toilets and public-private conveniences in shaping OD behaviour is increasingly being recognized. In an urban Nigerian metropolis, mapping of OD sites and public-private conveniences using GPS and nearest neighbour analysis showed strong spatial associations between OD hotspots and areas with inadequate or poorly distributed public toilets (Farouk et al., 2024). Monetary charges for toilet use, inconvenient locations, and inadequate

numbers of facilities were key perceived drivers of OD (Farouk et al., 2024).

Other planning-oriented studies in Nigeria argue that effective management of toilets, interventionist measures (e.g., provision of facilities at bus terminals, markets, and open spaces), and punitive measures (e.g., sanctions, signposts prohibiting OD) significantly enhance planning capacity to reduce OD (Olapeju and Olapeju, 2022; Olapeju, 2022). In Ogun State, empirical modelling identified positive and significant correlations between planning variables, including landscaping of open spaces, the availability of bus terminals that have toilets, and improved water schemes with OD prevention indicators (Olapeju and Olapeju, 2022). The results indicate that geospatial planning of public toilets, coupled with efficient management and behavioural interventions, are essential in ensuring sustainable OD free environments in fast urbanising, as well as, peri-urban environments.

Sustainability of Sanitation Systems and Technological Approaches

The sanitation situation in Nigeria is characterized by the presence of different types of pit latrines, toilets that empty into a septic tank, and a relatively small percentage that is connected to the sewerage network (Abubakar, 2017). In the country, approximately 44% of the households use pit latrines of various types, 10% have toilets that empty into septic tanks, and just about five percent have sewer networks, with one-third having no sanitation facility (Abubakar, 2017).

Lack of technological solutions is a factor that adds fragility and non sustainability to OD reduction gains. An example is a CLTS assessment in rural communities that discovered that in a few years many households returned to OD due to the collapse of the simple, cheaply made pit latrines made of logs or wooden slabs or were soon filled up (Sawyer & Adepoju, 2019). In these settings, the lack of permanent substructures, insufficient attention to soil conditions, inappropriate design of superstructures, and a deficit of maintenance plans weakened the quality of the toilets in terms of their durability and acceptance by the users (Sawyer & Adepoju, 2019; Kalu et al., 2019).

The perception of the user, psychological considerations, and norms also determine sustainability. The psychological models that have

been implemented in Nigerian States indicate that the perceptions of risks (e.g., feeling sick because of dirty toilets), attitudes towards cleanliness, social expectations regarding the location of defecation and regulating shared toilets have a significant impact on whether people use existing facilities or persist in OD (Olapeju, 2022). This highlights that technical design should be complemented with comfort, cleanliness, privacy and cultural acceptability.

On the African level, the focus is on the necessity of evidence based and specific sanitation efforts with a priority based on the severity and poverty rates of the region in terms of OD (Fagunwa et al., 2023). The combination of sanitation availability, environmental pollution, and the increasing threat of microorganisms, including antimicrobial resistance, further justifies the need to have well-developed, safely controlled sanitation technology (Fagunwa et al., 2023; Amadi et al., 2024).

Techno-economic Perspectives on Sanitation and Public Toilets

Techno-economic evaluation of sanitation systems involves the evaluation of both technical performance (e.g., reliability, durability, effectiveness of the treatment, environmental safety) and economic feasibility (costs of capital and operation, potential of revenue, life-cycle costs). Several strands of studies in Nigeria and sub-Saharan Africa indicate that key economic factors that are limiting include:

- i. Costly initial expenses on better individual toilets in low-income settlements where water supply is not to be depended on, make shared or collective possibilities attractive (Abubakar, 2017; Olapeju & Olapeju, 2022; Fagunwa et al., 2023).
- ii. Public-Private Partnerships (PPP) in the management of public conveniences have been suggested to decentralize expenses and enhance quality of management, especially in transport growth and markets (Farouk et al., 2024).
- iii. CLTS programs based on pure household self-investment in low-cost pit latrines may collapse in cases where structural durability and life-cycle costs have not been taken into account; collapsing pits create extra rebuilding expenses and may deter further use of the

toilets (Sawyerr & Adepoju, 2019; Agha et al., 2024).

Simultaneously, new methods with the help of systems modelling and software engineering have been examined in order to incorporate behavioural change interventions, Water, Sanitation, and Hygiene (WASH) system components, and data-driven decision-support, which points to the possibility of intelligent planning of sanitation interventions (Okewu et al., 2020).

Nevertheless, a lack of region-specific studies that incorporate spatial distribution of toilets, technological characterization, and express techno-economic assessment of the diverse sub-regions of Nigeria is still lacking, with the North-Central zone being one of them. This study adds to the redress of that gap.

METHODOLOGY

Study Area

The study was carried out in North-Central Nigeria, particularly, Nasarawa, and Niger States, and the Federal Capital Territory (FCT). Niger, the Federal Capital Territory (FCT) and Nasarawa in have different population and urban-rural structures that affect livelihoods and sanitation issues. The state of Nasarawa, especially the southern region, is mainly rural with agriculture as the main source of livelihood that is susceptible to the changes in climatic conditions caused by deforestation, unsustainable farming methods, and the impact of urbanization, such as flooding, extreme temperatures; and environmental factors which lead to poor soil quality, complicating the construction and maintenance of latrines (Oruonye et al., 2025). Rapid urbanization is observed in the FCT, where there is a mix of housing quality. Approximately 13% of houses do not have a toilet and the quality of waste disposal is not high, which indicates infrastructural insufficiency (Kanayochukwu and Dogo, 2019). Niger State has a similar rural-urban split with dominant livelihoods in farming and herding. The nomadic lifestyle of herders contributes to persistent OD due to mobility and cultural perceptions against latrine use (Kingpriest et al., 2024). Nationally, about 32% of Nigerian households practiced OD in 2013, with rural areas (24%) disproportionately affected compared to urban areas (8%), influenced by residence location, wealth, level of education,

ethnicity, and gender (Abubakar, 2018). Climatic conditions such as irregular rainfall and soil erosion in these regions necessitate latrine designs that consider soil stability and water table levels to prevent contamination and structural failure.

Research Design

The study adopted a mixed-methods cross-sectional design, combining:

- i. geospatial survey of existing public toilets and OD-mitigation facilities;
- ii. technical assessment of toilet technologies and system components;
- iii. techno-economic analysis of selected technology options; and
- iv. key interviews to contextualise performance, management, and acceptability.

Sampling and Data Collection

The research entails a four-step multi-stage sampling technique:

The first stage was the purposive selection of the North Central out of the six geopolitical zones in Nigeria with the stage two being the purposive selection of the FCT, Nassarawa State and Niger State out of the 6 States and FCT in the zone. Stage three is the selection of 10% of the local government areas/councils in the FCT, Nassarawa and Niger States, making a total of six local governments areas. In the fourth stage, respondents were selected. 3 sanitation experts were purposively selected in each of the local governments in the FCT and two States and the Head, Sanitation Department and 1 Sanitation expert were purposively selected in the State Environmental Protection Agencies of the FCT, Nassarawa and Niger States. Also, one University in each of the FCT and the two states were purposively selected, namely, the Federal University of Technology, (FUT) Minna, Niger State, the University of Abuja, Abuja, FCT, and the Federal University, Lafia, Nassarawa in order to select 5 Environmental Waste Management researchers. One hundred and fifty residents of the study area were randomly selected to determine their perception on the use of public toilets.

Selection of States and Local Government Areas

Nasarawa, Niger, and the FCT were purposively selected to represent varied urban-rural gradients, economic structures, and policy environments

within North-Central Nigeria. Within each state/FCT, a multi-stage approach was used:

- i. selection of LGAs with documented sanitation challenges or high population growth;
- ii. identification of key **public spaces**; markets, motor parks, major road corridors, institutions, and slums/informal settlements within each LGA; and
- iii. mapping and enumeration of public toilets, public-private conveniences, and other OD-mitigation facilities in these locations.

Geospatial Mapping of Public Toilets

Handheld GPS devices were used to capture the coordinates of each identified public toilet and related facility (e.g., communal latrines), following similar approaches in other Nigerian and African spatial sanitation studies (Sawyer & Adepoju, 2019; Farouk et al., 2024; Muktar et al., 2024). Data were brought in through GIS software (e.g. ArcGIS or QGIS) to:

- i. form point layers of public toilets and, where feasible, familiar OD sites;
- ii. superimpose with road base maps, water bodies and settlement patterns; and
- iii. proximity and buffer analysis in order to determine services coverage and exposure to population.

Spatial pattern measures, including nearest neighbor statistics or local indicators of spatial association (LISA), were used to assess the similarity between the distribution of facilities, that is whether it is clustered, random, or dispersed (Farouk et al., 2024; Muktar et al., 2024).

Technological Characterization

To record: A structured checklist was made to document:

- i. Sanitation type (e.g. water closet to septic tank, ventilated improved pit (VIP), pour flush latrine, , composting toilet, ecological sanitation, simple pit latrine);
- ii. Substructure (design of pits, depth, lining, materials, clearance over groundwater);
- iii. Superstructure (materials, privacy, accessibility, ventilation, lighting);
- iv. Waste control (emptying, desludging access, treatment or disposal);
- v. Water source and security;

- vi. Use of energy (when necessary, e.g., pumps, lighting);
- vii. Indicators of maintenance regime and cleanliness.

Structural condition, cleanliness, odour, and functionality were observed and scored using observational scoring methods and photographs (where allowed), like other sanitation assessments (Abubakar, 2017; Sawyerr and Adepoju, 2019; Kalu et al., 2019).

Techno-economic Data

To assess economic viability, data were collected through:

- i. Formed interviews with facility managers/operators (public authorities, private concessionaires, community groups);
- ii. Inspection of construction documents as they exist;
- iii. Material and labour cost surveys in the market.

The majority of cost elements were:

- i. First capital expenditure (land, building materials, labour, plant);
- ii. Operation and maintenance (water, cleaning materials, personnel, dumping charges, small repairs);
- iii. Revenue sources (user fees, rentals, subsidies, cross subsidy of commercial activities);
- iv. Assumptions on lifespan of key components.

Where applicable, time horizons and discount rates applicable to the infrastructure in Nigeria were used to estimate net present costs and payback periods.

User Perspectives and Behaviour

The following surveys were conducted with users and non users:

- i. frequency/circumstances of toilet use by the self vs OD;
- ii. Concepts of price, hygiene, security, and affordability;
- iii. Obstacles and enablers of regular use, based on the psychological models like RANT/RANAS (risk, attitude, norm, ability, and management factors) (Olapeju, 2022);
- iv. Needs based on gender, consideration of disability and privacy and security.

Data Analysis

GIS Analysis: Calculation of density of toilets, average distance of toilet to key public areas, and distribution of under served areas. Spatial overlay and correlation analyses were performed where available and data on OD incidents were presented to examine the connections between facility distribution and OD hotspots (Gayawan et al., 2023; Farouk et al., 2024; Muktar et al., 2024).

Descriptive statistics: Frequencies and cross-tabulations summarising types of technologies, ownership/management models, and functional status.

Techno-economic assessment: Life-cycle cost analysis of selected representative technologies, comparison of cost per user per day, and estimation of break-even user fees given realistic demand, following principles applied in broader WASH and sanitation economics literature (Abubakar, 2017; Olapeju & Olapeju, 2022; Fagunwa et al., 2023).

RESULTS

Spatial Distribution of Public Toilets

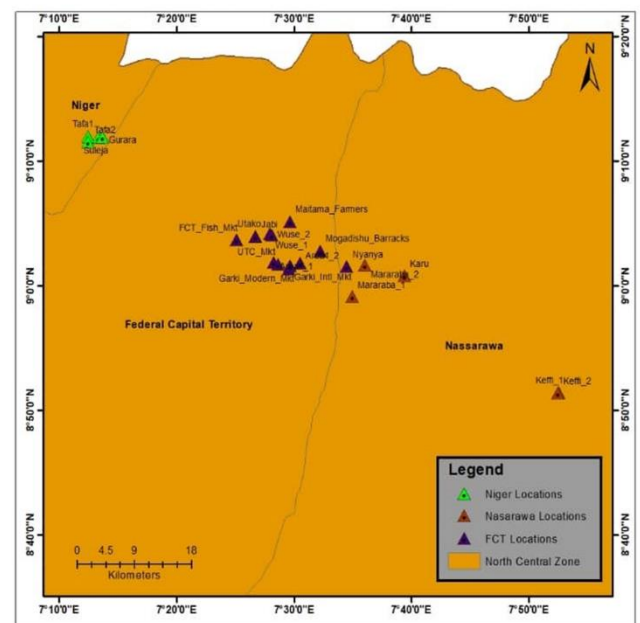


Figure 1: Spatial Distribution of Public Toilets in the Study Area

The North Central region in Nigeria is located on Latitude 10° 20' 00"N and Longitude 7° 45' 00"E and it consist of six states and the federal capital territory. Figure 1 shows the distribution of available public toilets in the study area. The points

were denoted using the following coordinates and computer software (Arc GIS 10.3) was also used in processing and analyzing of data generated from field. FCT (Abuja Municipal Area Council) consisting of Utako (Lat. 9°3'59" 67 and Long. 7°26'4186"), Jabi (Lat. 9°3'5913" and Long. 7°26'41'86), Wuse (Lat. 9° 4'1167" and Long. 7°27'5405"), Wuse 2 (Lat. 9°4'462"and Long. 7°28'392"), Area 1 (Lat. 9°1'5286"and Long. 7°28'1506"), Area 1b (Lat. 9°1'4933"and Long. 7°29'8800"), Garki (Lat. 9°02'2500"and Long. 7°49'1900") Garki 2 (Lat. 9°02'690" and Long. 7°49'360"), Garki (Lat. 9°02'93" and Long. 7°47'710"), Kado (Lat. 9°06'170"and Long. 7°41'840") . Nassarawa state consisting of Keffi (Lat. 8°51'2461" and Long. 7°52'2984"), Keffi 2 (Lat. 8°51'2461" and Long. 7°52'2498"), Maraba (Lat. 8°59'1049" and Long. 7°34'544"), Maraba 2 (Lat. 9°02'7700"and Long. 7°60'0400"), Karu (Lat. 9°04'845"and Long. 7°38'82").

Niger state consisting of Suleja (Lat. 9°11'54"and Long. 7°13'19"), Tafa (Lat. 9°11'62"and Long. 7°12'26"), Tafa 2 (Lat. 9°11'35" and Long. 7°12'26"), Gurara (Lat. 9°11'57"and Long. 7°13'42"). The spatial distribution showed clusters in some places, indicating that the public toilets in those places are close to one another. In the FCT, the location of the public toilets is not scattered across the city but located in close proximity to one another in an uneven distribution. Farouk et al. (2024), in a study on the distribution of public toilets in the FCT arrive at a similar conclusion that, the provision of public convenience services in FCT is poorly provided; and that the available public toilets and restroom facilities in the area are unevenly distributed. Similarly, in a study conducted by Muktar et al. (2024), they arrived at a conclusion that public conveniences are not evenly distributed in North Central Nigeria.

Types and Technological Characteristics of Public Toilets

It is evident in Table 1 that the sanitation horizon is influenced by diversity of infrastructure, the application of diverse management models, and profound disparities in the quality of structures and reliability of hygienic conditions. These factors have profound implications on the strategies of open defecation mitigation in the region. This is also contextualised in Figure 2. The most common facility that was surveyed is the Water Closet type

(WC) that is linked to the sewer or septic systems and constitutes 33.78% of the sample (n = 25). Although this number could indicate a fairly high level of sanitation, WC facilities are not only the prerogative of a relatively developed sanitation level but also are largely located in the domestic environment or in an institution with limited availability in the open environment. In this framework, the presence of water can be intermittent, which restricts their effectiveness in reducing open defecation in the open or peri-urban environment (Abubakar, 2017; Odjegba et al., 2021; Alda-Vidal et al., 2024).

The second most prevalent category is mobile and portable latrines with 29.73% (n = 22) suggesting a substantial amount of transient, privately operated infrastructure frequently used in markets and motor parks and intermittently managed by the public or under PPP management. These are not connected to piped water but differ significantly in the state of structures and ventilation, which is reflected in the lack of proper permanent public sanitation facilities as well as in the entrepreneurial vacuum occupied by individuals (Onyeaghala et al., 2024; Hassan et al., 2024). Pour-flush latrines are 16.22% (n = 12) and dependent on steady water supply to operate effectively, making them prone to seasonal shortages common in Nigeria (they are privately or communally managed with some NGO assistance). However, their performance is highly dependent on user behavior and availability of water (Abubakar, 2017 Ventilated Improved Pit (VIP) latrines take 14.86% (n = 11) and are arguably the best-suited technology given the conditions as they are resistant to disruption by water and have a quantifiable increase in hygiene. Many units have cement or brick lining, covered slabs, and fly-traps vent pipes, and are operated through community or government schemes.

Unlined pit latrines represent 5.41% (n = 4) of the total though they denote the most disproportionate risk to public health, are likely to contaminate groundwater, lack ventilation or superstructure promoting disease transmission, and continue to be used, which underlines the absence of adequate enforcement and local investment (Atangana & Oberholser, 2022). Interestingly, there are no composting toilets found in the study area (0%), which could be considered sustainable low-resource solutions, indicating that there are some

Table 1: Types and Characteristics of Public Toilets in North-Central Nigeria

Toilet Facility Type	Freq. (n = 74)	%	Structural Condition	Structural Condition	Structural Condition	Water Supply	Management Mode
			<i>Lined Pit (%)</i>	<i>Adequate Superstructure</i>	<i>Effective Ventilation</i>	<i>Reliability & Functionality</i>	<i>Public / Private / PPP / Community</i>
Water Closet (WC) to Sewer/Septic	25	33.78 %	N/A (cistern-flush)	Enclosed, permanent; mostly concrete/brick	Mechanical extract fan or window	Piped water required; high reliability dependency	Mostly private (household) or institutional; limited PPP in public facilities
Pour Flush Latrine	12	16.22 %	N/A (pit or septic linked)	Typically, semi-permanent slab; variable quality	Minimal — relies on water seal	Requires consistent water supply for flushing; vulnerable to seasonal shortages	Private or community-managed; some NGO-supported models
Ventilated Improved Pit (VIP) Latrine	11	14.86 %	60–70% lined (cement/brick)	Covered slab, partial walls; vent pipe essential	Vent pipe (fly-trap design); effective when maintained	No water required for operation — resilient to supply disruptions	Community or government-managed; some donor-funded
Composting Toilet	0	0.00 %	N/A	N/A	N/A	N/A	N/A
Simple Pit Latrine (Unlined)	4	5.41 %	0% lined — earthen walls; groundwater contamination risk	Basic/absent superstructure; often makeshift	None (odour and fly nuisance common)	No water needed; but smell and flies indicate poor hygiene conditions	Household self-managed; minimal oversight
Mobile / Portable Latrine	22	29.73 %	N/A (no pit; holding tank)	Prefabricated; condition varies by age and upkeep	Limited; dependent on unit design	No piped water needed for basic operation; hand-wash station requires supply	Private operator’s dominant; PPP in markets/motor parks; sporadic public management

Note: Frequencies reflect primary survey data from the North-Central Region of Nigeria (n = 74). Structural condition estimates (lining, superstructure, ventilation) are drawn from field observation indices and published benchmarks

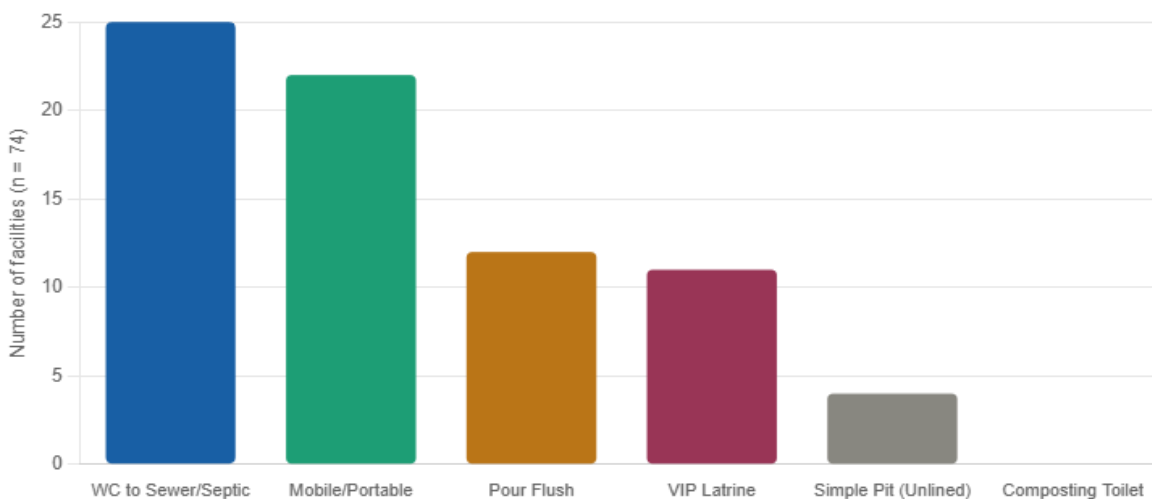


Figure 2: Textual Analysis of the Types and Characteristics of Public Toilets in North-Central Nigeria

obstacles, including lack of awareness, absence of technical support, or cultural influences that can be examined specifically to develop sustainable sanitation avenues (Abubakar, 2017; Atangana and Oberholser, 2022). In general, this distribution highlights a disintegrated sanitation ecosystem where no single technology prevails, which is not managed consistently, and facilities that rely on infrastructure such as WCs and pour-flush latrines are vulnerable. Therefore, sustainable open defecation reduction strategies should focus on low-dependency solutions, such as VIPs, reinforce PPP frameworks of portable facilities, and investigate barriers to the adoption of composting toilets (Abubakar 2017; Atangana & Oberholster, 2022; Alda-Vidal et al., 2024).

Techno-economic Viability of Appropriate Anti-open Defecation Technologies Suitable for North-Central Nigeria

User Perceptions and Behavioural Insights

The continuous discrepancy between availability of sanitation facilities and user behaviour can be critically analyzed using the Theory of Planned Behaviour (TPB) which emphasizes the need of cognitive awareness in assisting behavioural change as indicated in Table 2. Although there is high awareness of the available facilities (85.3%), open defecation (OD) is still common meaning that there is a disconnection where knowledge fails to reflect on practice. Almost a third of the participants have inadequate knowledge of the

Table 2: User Perceptions and Behavioural Insights on Public Toilet Use in North-Central Nigeria

Perception Construct	Variable	Freq. (n=150)	(%)	Behavioural Implication
<i>Awareness & Cognitive Perception (Theory of Planned Behaviour – Attitude component)</i>				
Awareness of public toilet facilities	Aware of at least one public toilet in their community	128	85.3%	High awareness does not translate to use; awareness–use gap indicates structural deterrents
Knowledge of OD health risks	Correctly identified ≥ 2 health risks of OD (e.g. cholera, typhoid)	102	68.0%	Knowledge gap among 32% suggests need for targeted health communication campaigns
Perceived cleanliness	Rate public toilets in area as "clean" or "very clean"	27	18.0%	Low hygiene perception is the single strongest predictor of avoidance behaviour and OD preference
Perceived safety	Feel "safe" using public toilets (especially women/girls)	41	27.3%	Gender-based insecurity is a major structural barrier; female respondents report fear of harassment
Perceived dignity / privacy	Agree that existing facilities offer adequate privacy	35	23.3%	Dignity deficit drives high-income and female users toward OD in bush/fields; design improvement needed
Willingness to use improved facility	Would use a clean, safe public toilet if available nearby	137	91.3%	Strong latent demand confirms behaviour is facility-constrained, not preference-driven; supports infrastructure investment case

health risks associated with OD, which indicates that the perception of risks is not supported by health messaging, which is a key factor in behavioral change (Yogananth and Bhatnagar, 2018; Kurniatillah et al., 2023). The poor quality

of the state of toilet facilities has significant impact on the attitudinal factors since only 18.0% of them believe that the toilets are clean and 23.3% view them as dignified, meaning that the facilities are commonly viewed as hostile instead of convenient

places for safe collection and disposal of human waste (Biswas *et al.*, 2020; Das *et al.*, 2024). The effects of safety on women are disproportional, as only 27.3% of them feel safe using such facilities, which highlights the structural barriers that are gendered and go beyond personal mere preference (Saleem *et al.*, 2019; Kurniatillah *et al.*, 2023).

Notably, there is a high latent demand to have better sanitation facilities (91.3% willing to use better facilities), meaning that OD is a response to poor infrastructure more than a cultural entrenchment. Therefore, interventions should shift focus from awareness campaigns to improving hygiene maintenance, incorporating gender-sensitive

design, and enhancing security measures to convert this demand into sustained toilet use (Nastiti *et al.*, 2025; Buana & Soewondo, 2025; Das *et al.*, 2024). Table 3 revealed that the persistence of open defecation (OD) is sustained by powerful social structures rather than just infrastructural deficits, as evidenced by 59.3% of respondents perceiving OD as acceptable and 64.0% living in households where it is regularly practiced. It means that OD can be viewed as a socially supported norm instead of deviance, and community-based total sanitation (CLTS) strategies that utilize community behavior change through such mechanisms as disgust and shame are essential (Sigler *et al.*, 2015; Gauri *et al.*, 2018).

Table 3: User Perceptions and Behavioural Insights on Public Toilet Use in North-Central Nigeria Based on Subjective Norms & Social Influence

Perception Construct	Variable	Freq. (n=150)	(%)	Behavioural Implication
Community norm on OD	Perceive OD as "normal/acceptable" in their community	89	59.3%	Normative acceptance of OD reduces motivation to seek alternatives; CLTS-type community mobilisation required
Peer / household influence	Household members also practice OD regularly	96	64.0%	Intra-household OD practice reinforces behaviour through social modelling; family-unit interventions are most effective
Social stigma against OD	Report that OD is stigmatised / looked down upon in community	48	32.0%	Weak stigma environment reduces social sanctions on OD; majority normalisation undermines individual attitude change
Current OD practice	Practise OD at least once per week	107	71.3%	OD is habitual and entrenched; habit disruption requires combined infrastructure, normative, and motivational levers
Frequency of public toilet use	Use public toilet at least once per week when available	39	26.0%	Very low regular use rate underscores that supply alone is insufficient; demand-side behaviour change is equally critical
Preferred alternative to OD	Would prefer household latrine over public toilet if supported	118	78.7%	Strong preference for household-level solutions suggests community toilet blocks may be supplementary to, not replacements for, household latrine programmes
Willingness to pay (WTP)	Willing to pay ₦50–₦100/visit for a clean, functional public toilet	94	62.7%	Moderate WTP provides partial cost-recovery basis; hybrid public-private financing models are viable
WTP for eco-sanitation (ECOSAN) option	Willing to pay same/more for a sustainable/eco-friendly design	72	48.0%	Nearly half accept sustainable technology premium; communication of resource-recovery benefits could raise acceptance

The reported social stigma of 32.0% is relatively low, which further stresses the necessity of interventions aimed at changing normative environments, instead of increasing the awareness only. The fact that habitual OD practice is at 71.3%, whereas regular toilet use in the population is at 26.0% only, proves that passive infrastructure provision does not suffice to break habitual routines (Odagiri et al., 2017; Ngwu, 2017). The tendency to prefer household latrines (78.7%) to public facilities indicates that community toilet blocks must be used in addition to household-level investment in sanitation systems, as opposed to substituting them, which is consistent with the results that the maintenance of household latrine use requires social norms and access on the

household level (Odagiri et al., 2017; Thulin et al., 2021). The mediocre readiness to pay more (62.7%) to have better facilities and the acceptance of the eco-sanitation options (48.0%) suggest that hybrid funding models and sustainability-oriented interventions can be used in case the co-benefits, such as the recovery of resources, are convincingly presented (Yulyani et al., 2025) On the whole, combined policies that include normative acceptance, household infrastructure preferences, and financing systems are needed to ensure sustainable changes in OD (Kuang et al., 2020).

The result showed that the cost of building the preferred toilet type which is the water closet with sections for male and female is ₦10,186,155.

Table 4: Techno-Economic Assessment of Appropriate Anti-Open Defecation Public Toilet Suitable for North Central Nigeria

S/N	DESCRIPTION	AMOUNT (₦)
1	CAPITAL COST	
	i. Cost of Land	500,000.00
	ii. Cost of Building	10,186,155.00
	iii. Cost of Solar PV System	1,500,000.00
	iv. Borehole, Tanks, and Scaffold	940,000.00
	Sub-Total	₦13,126,155.00
2	ANNUAL OPERATING COST	
	i. Staff Salaries	
	Manager (₦20,000/month × 12)	240,000.00
	Supervisor (₦20,000/month × 12)	240,000.00
	Cleaners × 2 (₦15,000/month × 12)	360,000.00
	Security Guard × 1 (₦30,000/month × 12)	360,000.00
	ii. Building Maintenance	50,000.00
	iii. Advertisement & Promotions	50,000.00
	iv. Utilities	12,000.00
	Sub-Total-Operational Cost	₦ 1,312,000.00
3	PROJECTED ANNUAL REVENUE	
	Expected Users per Day:	3,600,000.00
	100 users/day × ₦100/use × 360 days	
	Sub-Total-Annual Revenue	3,600,000.00
4	EXPECTED ANNUAL PROFIT	
	Net Annual Profit (Revenue – Operational Cost)	₦ 2,288,000.00
5	FINANCIAL INDICATORS & PROFITABILITY INDEX	
MARR	Minimum Attractive Rate of Return	20%
SV	Salvage Value (at 20%) — Annual Depreciation	₦ 1,409,410.00
	Net Present Value (NPV)	₦ 3,571,467.00
	Payback Period	6 Years

Notes:

- All monetary values are expressed in Nigerian Naira (₦) and Capital cost figures represent one-time investments.
- Operational costs and revenue projections are on an annual basis, assuming 360 operational days per year.
- MARR = Minimum Attractive Rate of Return. NPV computed at 20% discount rate over the project lifecycle.
- A Profitability Index > 1.0 and positive NPV indicate financial viability of the proposed sanitation facility.

It comes with a yearly operating cost of ₦1,312,000, and an expected yearly revenue of ₦3,600,000 while the expected yearly profit of ₦2,288,000 was arrived at. This study showed a net present value (NPV) of ₦3,571,467 and a payback period of 6 years which revealed that the building of a public toilet in the study area is a viable venture that should be embarked upon.

CONCLUSION

The research concluded that reduction of open defecation (OD) depends on social norms and behavioural change substantiating the techno-economic evaluation of sustainable OD mitigation systems in North-Central Nigeria. It has been found that infrastructure cannot work without the consideration of the strong social frameworks that enable OD practices because normative acceptance and habitual behaviour play a strong role in sanitation decisions (Abubakar, 2018; Fagunwa et al., 2023). Household latrine preference compared to the public facility, and moderate willingness to pay for a better sanitary system indicate the necessity to create custom, community-sensitive investments that would integrate the right technology with financing models that are sensitive to local trends and economic conditions (Abubakar, 2018; Olapeju et al., 2020). Furthermore, the experience of Nigeria and other low-income contexts points to the fact that sustainability is based on long-life infrastructure, proper administration, and continuous interaction with the community to avoid the relapse to OD, which is frequently observed because of the facilities breakdown or ineffective social control (Sawyer and Adepoju, 2019; Delaire et al., 2022). Considering these insights in techno-economic planning would mean that the interventions are not just technologically and economically viable, but acceptable socially and behaviourally. This holistic strategy promotes the policy suggestions that recommend mixed investments in household-level sanitation systems, norm-shifting programs, including community-led total sanitation (CLTS), and incentive-based financing models based on local conditions (Olapeju and Olapeju, 2022; Olagbemde and Oluropo, 2025). Ultimately, achieving lasting OD reduction in North-Central Nigeria requires techno-economic solutions embedded within a framework that addresses social norms, economic capacity, and infrastructure

durability simultaneously, thereby enhancing public health outcomes and advancing sustainable development goals.

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