

Adaptation Process for Improved Solid Waste Management in Port Harcourt Metropolis

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Abstract

This study analyses the adaptation process for improved solid waste management in Port Harcourt Metropolis, with a focus on addressing core values of public health, environmental sustainability, community engagement, operational efficiency, economic viability, and civic responsibility. Targeting key locations such as Borokiri, Old Port Harcourt Town, Rukpokwu, Trans Amadi, and others that represent over 50% of the metropolis, this research aims for a comprehensive analysis with minimised bias. The research is grounded in a positivist philosophy, employing a quantitative approach and a descriptive research design to systematically collect and analyse empirical data. The study population encompassed residents and professionals within Port Harcourt Metropolis. A simple random sampling technique was used, with the sample size determined via Taro Yamane's formula, yielding 400 participants. Data were collected using a structured, close-ended questionnaire, and the 203 retrieved responses were analysed using descriptive statistics including frequencies, percentages, means, and standard deviations with IBM SPSS Statistics, Version 23. The findings of the study revealed, firstly, a profound dissatisfaction with current waste management practices and infrastructure, evidenced by a collective mean score of 1.36 across key metrics, indicating strong resident disagreement with their efficacy. Furthermore, respondents strongly endorsed proposed adaptation processes (Average Mean=4.79), such as increasing waste collection frequency (Mean=4.78), ensuring adequate worker welfare (Mean=5.00), and enhancing community involvement (Mean=5.00). In conclusion, the study establishes that rectifying Port Harcourt's waste management crisis necessitates a comprehensive, integrated approach that concurrently addresses legislative, infrastructural, financial, and community engagement gaps. The recommendations propose the formulation of robust policy frameworks, substantial investment in infrastructure and technology, the implementation of continuous public education, and the fostering of public-private partnerships to achieve a cleaner, safer, and more sustainable urban environment.

Keywords: Adaptation, Mitigation, Solid Waste Management, Port Harcourt

1.0 Introduction

Effective waste management is integral to safeguarding environmental health, ensuring public safety, and fostering sustainable urban development. In the Port Harcourt Metropolis, the convergence of rapid urbanisation and inadequate infrastructure has intensified existing waste management challenges, elevating risks to both community wellbeing and ecological stability. Within this context, systematic risk analysis and mitigation become imperative to enhance operational efficiency and protect urban populations. As noted by Cookey *et al.* (2019), a robust assessment of waste management risks necessitates a dual methodological approach:

quantitative techniques yield measurable, statistical evaluations of system performance, whilst qualitative methods provide depth by capturing stakeholder perceptions, experiences, and attitudes. The integration of these approaches facilitates a holistic diagnosis of operational shortcomings, behavioural trends, and institutional weaknesses that collectively influence waste management efficacy in the city. Mitigation, as conceptualised by Adama *et al.* (2021) drawing upon World Health Organization (2009) guidelines, refers to interventions that reduce or limit the adverse impacts of hazards and associated disasters. Applied to solid waste management, mitigation strategies are designed to prevent or minimise pollution, curtail disease outbreaks, and alleviate other detrimental consequences arising from systemic inefficiencies. These strategies typically encompass forward-looking preventive planning, responsive mechanisms for early intervention, targeted infrastructural upgrades, and sustained engagement with stakeholders all of which contribute to building urban resilience. Globally, effective waste management is recognised as a cornerstone of sustainable development. Ajaero *et al.* (2023) emphasise that proficient handling of waste through coordinated collection, transportation, treatment, and disposal is crucial for maintaining hygienic urban environments, conserving natural resources, and supporting long-term ecological sustainability. For Port Harcourt, advancing solid waste management demands adaptive processes that synthesise legislative reform, proactive community involvement, and innovation in operational practices. As demographic profiles shift, technologies evolve, and climatic variables change, adaptive risk management grows increasingly vital in developing waste systems that are both resilient and responsive. An adaptable framework empowers municipal authorities to anticipate, address, and recover from emerging environmental and public health risks linked to inadequate waste disposal. Therefore, this study posits that improving waste management in Port Harcourt Metropolis hinges on a comprehensive, holistic approach to risk mitigation one that aligns firmly with sustainable development principles. Such an approach should amalgamate scientific analysis, inclusive stakeholder collaboration, and ongoing adaptation to effectively safeguard both the populace and the environment. Through this integrated perspective, the study seeks to contribute actionable insights towards building a cleaner, healthier, and more sustainable urban future for Port Harcourt. Thus, the aim of the study is to analyse the adaptation process for improved solid waste management in Port Harcourt Metropolis.

The objectives of this study are to:

- i. Assess the current waste management practices and infrastructure in Port Harcourt Metropolis.
- ii. Determine the adaptation processes required to improve solid waste management systems in the study area.

The following research questions guides this study:

- i. What are the current waste management practices and infrastructure in Port Harcourt Metropolis?
- ii. How can waste management systems be adapted to improve solid waste management in study area?

1.1 Scope of the Study

Port Harcourt Metropolis, the capital of Rivers State in southern Nigeria, has a population of approximately 1,356,000 within a warm climate averaging 24–30°C. This study focuses on its constituent towns including Borokiri, Old Port Harcourt Town, Trans Amadi, Oyigbo, Diobu, GRA Phase II, Eagle Island, Nkpolu-Oroworukwo, Mgbuosimini, Rumuola, Mgbuoba, Iwofe, Ogbogoro, Airport road and Choba areas characterised by poor waste management. It assesses current practices and infrastructure through data collected from key stakeholders such as the

Rivers State Ministry of Environment, RIWAMA, estate surveyors, and the public, examining policies and practices from 2020–2024 to enable comprehensive analysis.



(a) Indiscriminate Disposal Points of Solid Waste in Rukpokwu, Obio/Akpor LGA



(b) Waste Retrieval Points of Solid Waste on Rumuokoro – Rumuigbo Road, Obio/Akpor LGA

Figure 1: Current Solid Waste Management Practices in Port Harcourt Metropolis

Source: Researcher's Survey, (2024)

2.0 Literature Review

This chapter establishes the intellectual foundation for the study by synthesising relevant theoretical perspectives, conceptual clarifications, and empirical evidence. It is structured into three main sections: The Theoretical Framework, which integrates three complementary theories to analyse the problem; the Conceptual Review, which dissects the core concepts underpinning the research; and the Empirical Review, which examines prior studies directly related to the study's objectives. Collectively, this review justifies the research focus and identifies the specific gap this study aims to fill.

2.1 Theoretical Framework

A robust theoretical framework is essential for understanding the complex, multi-faceted nature of risk mitigation and adaptation in urban waste management. This study does not rely on a single theoretical lens but integrates three distinct yet complementary perspectives: a macro-sociological theory, a micro-operational methodology, and behavioural theories. This tripartite integration allows for a holistic analysis that spans societal context, systemic processes, and human agency, providing a comprehensive foundation for investigating the waste management crisis in Port Harcourt Metropolis.

2.1.1 Ulrich Beck's Risk Society Theory

The primary macro-sociological lens for this study is Ulrich Beck's **Risk Society Theory**, introduced in his seminal work *Risk Society: Towards a New Modernity* (1986). Beck's thesis posits that late modern society is fundamentally characterised by the management of "manufactured risks" dangers that are not natural but are produced by the very processes of industrialisation, technological advancement, and economic development that define modernity (Antonilli, 2022). Unlike pre-industrial hazards such as famines or plagues, these manufactured risks are often invisible, delayed in their effects, global in their implications, and inherently reflexive. "Reflexivity" here refers to the way these risks force society to confront and adjust to the unintended consequences of its own progress, creating a cycle where modernisation generates risks that necessitate further modernisation of regulatory and management systems. The application of Risk Society Theory to Port Harcourt's waste management crisis is profoundly apt. Port Harcourt, as the hub of Nigeria's oil and gas industry, epitomises the kind of rapid, resource-intensive industrial progress that Beck describes. The city's transformation and the substantial waste it generates including hazardous industrial waste are direct by-products of this "manufactured" prosperity (Akintunde, 2017). The environmental degradation, public health hazards, and infrastructural failures stemming from improper waste disposal are not acts of nature but are socially produced, systemic consequences of urban and industrial activity.

This study leverages several of Beck's key concepts to frame its analysis:

- (a) **Manufactured Risks:** The operational and environmental risks in Port Harcourt's waste system such as leachate contamination, air pollution from burning, and disease outbreaks are quintessential manufactured risks. They result from human decisions (or indecisions) regarding urban planning, industrial policy, and environmental governance.
- (b) **Globalisation of Risk:** While manifested locally, Port Harcourt's waste challenges are part of broader global patterns of urban environmental stress in the Global South. The theory encourages viewing local solutions within an international context, suggesting that best practices and cooperative frameworks can be adapted from elsewhere (Alabi, Ogundele, Alabi & Adebayo, 2022).
- (c) **Reflexive Modernisation:** This is the most critical concept for this study. It denotes the necessity for institutions, governments, and societies to critically reflect upon, learn from, and adapt their systems in response to the risks they have created. The pervasive dissatisfaction with current waste management practices, as revealed by this study's survey data, acts as a social catalyst for this reflexivity. It pushes stakeholders from government agencies to community groups towards a systemic re-evaluation of policies, infrastructure investments, and public engagement strategies. The study explicitly posits that Beck's theory "encourages the

local government and stakeholders to critically evaluate and adjust waste management practices to international best practices on risk mitigation strategies."

Thus, Risk Society Theory provides the overarching narrative, framing Port Harcourt's waste crisis not as a simple logistical failure but as a systemic outcome of its developmental path. It underscores that solutions must be equally systemic and reflexive, involving continuous learning and adaptation at the institutional and societal levels.

2.1.2 Hazard and Operability Study (HAZOP) Methodology

To complement Beck's broad societal focus with precision, the study adopts the **Hazard and Operability Study (HAZOP)** methodology as an analytical framework. Originally developed in the chemical industry by Imperial Chemical Industries (ICI) in the 1960s, HAZOP is a structured, systematic technique for identifying potential hazards and operational problems in complex processes (Suryadi, Islami, & Ramadhan, 2023). While Beck's theory helps explain *why* systemic risks exist, HAZOP provides a rigorous tool for identifying *what* and *where* the specific, tangible operational failures are. The HAZOP methodology is characterised by its use of "guide words" (e.g., "NO," "MORE," "LESS," "AS WELL AS," "PART OF") applied to key parameters of a process (e.g., flow, pressure, temperature) within a defined "node." This structured brainstorming, conducted by a multidisciplinary team, prompts the identification of credible deviations from design intent, their causes, consequences, and existing safeguards. In this research, HAZOP is not applied as a live workshop but as a guiding analytical lens to deconstruct the waste management process chain in Port Harcourt. The entire system from generation and storage to collection, transport, processing, and final disposal is treated as a series of interlinked operational nodes. For instance; applying the guide word "NO" to "waste collection" leads to the identification of "no collection for extended periods," a deviation strongly agreed upon by 94.1% of respondents as a key risk; also applying "MORE" to "waste volume at public receptacle" highlights the risk of overfilled and insufficient bins, another significant finding; moreover, the guide word "PART OF" applied to "waste stream" can help analyse the risks associated with improper segregation of hazardous components. This structured approach enables the study to move from abstract notions of risk to the pinpoint identification of specific, operational failures: vehicle breakdowns, machinery malfunctions at processing facilities, unauthorised disposal due to inadequate policing, and leachate leaks from poorly managed landfills. By using HAZOP as a framework, the study ensures its analysis of operational risks is systematic, comprehensive, and directly linked to actionable points within the waste management lifecycle.

2.1.3 Environmentally Responsible Behaviour (ERB) and Environmental Citizenship Model (ECM) Theories

Recognising that technical solutions and policy reforms are insufficient without public cooperation and behavioural change, the study turns to behavioural theories. It draws upon the **Environmentally Responsible Behaviour (ERB) theory**, proposed by Hines, Hungerford, and Tomera (1987), and the closely related **Environmental Citizenship Model (ECM)** by Hungerford and Volk (1990). These theories delve into the human dimension, explaining the psychological drivers and barriers to public participation in environmental stewardship. The ERB theory posits that an individual's propensity to act in an environmentally responsible manner is influenced by a combination of factors: an *intention to act*, a *sense of personal responsibility*, *knowledge* of both the issues and actionable strategies, and an *internal locus of control* (the belief that one's actions can make a difference). This theory helps to interpret the survey's finding of resident "indifference." This indifference can be reconceptualised not merely as apathy but potentially as a consequence of deficient knowledge

about proper waste management, a feeling of powerlessness ("What can I do?"), or a weak sense of personal responsibility towards a problem perceived as the sole duty of the government (Ayotamuno, 2020). The study uses this model to diagnose the gaps in Port Harcourt's public engagement. Current, sporadic awareness campaigns may only address entry-level variables, failing to foster a deeper sense of ownership or to empower citizens with the practical knowledge and agency needed for sustained behavioural change such as consistent waste segregation at source or participation in community clean-up initiatives. By integrating ERB and ECM, the study argues for moving beyond simplistic awareness-raising. The failure of waste segregation, for instance, is not just a logistical or infrastructural issue but a behavioural one, rooted in a context where the necessary psychological and social conditions for environmental citizenship have not been established. Consequently, the study's recommendation for enhanced, continuous, and empowering public education and community involvement programmes is a direct application of these theories. They aim to build knowledge, foster a sense of collective ownership, and empower residents to transition from passive waste generators to active participants and stakeholders in the waste management system.

2.1.4 Synthesis of the Theoretical Framework

The theoretical framework of this dissertation is a carefully constructed, multi-layered edifice. **Beck's Risk Society Theory** provides the macro-sociological narrative, framing Port Harcourt's crisis as a quintessential problem of manufactured risk in a modernising, industrial urban centre. It establishes the *why* and the *context*. The **HAZOP methodology** offers the analytical precision to dissect the operational lifecycle of waste management, identifying specific points of failure with engineering rigour. It answers the *what* and *where* of operational risk. Finally, the **ERB theory and ECM** delve into the human element, explaining the psychological barriers to public participation and providing a roadmap for fostering the community engagement and sense of civic duty that is indispensable for any sustainable solution. They address the *who* and *how* of behavioural change.

This multi-theoretical integration is the study's core strength. It acknowledges that a challenge as complex as urban waste management cannot be understood through a single disciplinary lens. By weaving together these perspectives, the research provides a comprehensive diagnostic tool that is as attentive to faulty trucks and policy gaps as it is to the societal structures and individual mindsets that underpin the entire system. It demonstrates that mitigating risk and adapting processes in Port Harcourt requires not just new infrastructure or regulations, but a reflexive societal shift towards environmental citizenship, guided by a clear-eyed, systematic understanding of the operational hazards at hand.

2.2 Conceptual Review

A clear understanding of the core concepts is fundamental to any scientific inquiry. This section dissects and defines the key constructs that underpin this study: risk, risk mitigation and adaptation, waste, and waste management. By exploring their dimensions, interrelationships, and specific manifestations in the context of Port Harcourt, the conceptual review establishes the semantic and analytical boundaries of the research.

2.2.1 The Concept of Risk

Risk is a pervasive and multifaceted concept central to modern environmental governance, economic planning, and social policy. In the context of waste management, it encompasses the uncertainties and potential adverse consequences that arise from inadequate systems, poor governance, technological failures, and environmental pressures (Kumar, 2022). The International Organization for Standardization (ISO) 31000 framework defines risk as "the

effect of uncertainty on objectives," highlighting both the unpredictability of future events and their potential to impede goals such as environmental protection, public health, and sustainable urban development. The evolution of the risk concept, particularly within environmental studies, owes much to Ulrich Beck's "Risk Society" thesis. Beck (1986) argued that late modernity is characterised by the increasing production of *manufactured risks* those generated by human activity (industrialisation, urbanisation, technological innovation) rather than natural processes. Waste management in Port Harcourt is emblematic of this. The city's growth as an industrial hub has generated complex waste streams that exceed the capacity of its management systems, creating environmental and health risks that are direct by-products of its development trajectory (Abah & Ohimain, 2022).

Risk in urban waste management is not monolithic but an interplay of several interconnected categories:

- (a) **Operational Risks:** Failures within processes and infrastructure, such as irregular collection schedules, vehicle breakdowns, insufficient landfill capacity, or malfunctioning processing equipment (Arshad *et al.*, 2021; Ayotamuno, 2020).
- (b) **Environmental Risks:** Adverse impacts on ecosystems, including soil and groundwater contamination from leachate, air pollution from open burning or decomposition, and the disruption of drainage systems leading to flooding (Massoud *et al.*, 2023; Ajaero *et al.*, 2023).
- (c) **Social Risks:** Emerge from community opposition (e.g., NIMBY - Not In My Backyard syndrome), public health hazards, and the inequitable distribution of waste facilities, often burdening poorer neighbourhoods (Chang *et al.*, 2020).
- (d) **Economic & Regulatory Risks:** Stem from financial constraints, fluctuating market conditions for recyclables, weak policy enforcement, and poor investment climates (Zhu *et al.*, 2021; Adama, Abubakar & Idris, 2021). In Port Harcourt, these risks are acute and compounded by rapid urbanisation, weak institutional capacity of agencies like the Rivers State Waste Management Agency (RIWAMA), and significant gaps between policy formulation and implementation (Abah & Ohimain, 2022). The risk landscape is further complicated by global challenges such as climate change, which intensifies flooding and waste dispersal (Dimitri *et al.*, 2019), and transboundary issues like e-waste, governed by international conventions like the Basel Convention (2019). Operationalising the concept of risk for this study involves identifying the specific sources of uncertainty in Port Harcourt's waste system (e.g., funding shortfalls, public apathy, infrastructural decay), assessing their perceived likelihood and impact (as captured in the survey), and using this analysis to prioritise mitigation and adaptation efforts. Understanding risk as a dynamic, multi-dimensional construct is the first step towards its effective management.

2.2.2 The Concept of Risk Mitigation and Adaptation Processes

While interconnected, mitigation and adaptation represent two distinct but complementary strands of risk management, both critical for sustainable urban waste systems in dynamic contexts like Port Harcourt. **Risk Mitigation** refers to proactive strategies and actions taken to reduce the *probability* of a risk occurring or to lessen its *severity* should it occur. It focuses on addressing the root causes of risks. In waste management, mitigation is often anticipatory and involves:

- (a) **Technological/Infrastructural Interventions:** Upgrading collection fleets, developing engineered sanitary landfills with leachate control, investing in material recovery facilities (MRFs), and adopting waste-to-energy technologies (Ajaero *et al.*, 2023; Akande & Olorunnisola, 2018).

(b) **Policy and Regulatory Measures:** Formulating robust legislation, ensuring consistent enforcement, and establishing clear standards for waste handling and disposal (Hudson, Hunter & Peckham, 2019; Adama *et al.*, 2021).

(c) **Stakeholder Engagement:** Implementing continuous public education campaigns, fostering community-based initiatives, and building partnerships with the private sector and NGOs to improve compliance and shared responsibility (Adewale & Oyewole, 2020; Alabi *et al.*, 2022).

(d) **Economic and Financial Mechanisms:** Securing adequate and sustainable funding through budgets, user fees, public-private partnerships (PPPs), and incentives for recycling businesses (Abah & Ohimain, 2022; Davies, 2023).

Adaptation, in contrast, involves adjusting systems, institutions, and behaviours to better cope with, manage, or exploit the *impacts* of risks that cannot be fully eliminated, or to prepare for future changes. It acknowledges the dynamic nature of risk and focuses on building resilience. In Port Harcourt, adaptation is essential due to:

(a) **Unstoppable Drivers:** Ongoing rapid population growth and urban expansion (Macrotrends, 2023).

(b) **Evolving Waste Streams:** The increasing volume and complexity of waste, including growing shares of e-waste and packaging plastics (Baldé *et al.*, 2017).

(c) **Climate Change Impacts:** Increased rainfall intensity and flooding that exacerbate waste-related pollution and disrupt services (Sam *et al.*, 2023; Massoud *et al.*, 2023).

Adaptation processes therefore include:

(a) **Institutional Adaptation:** Building flexible, learning-oriented governance structures that can coordinate across agencies and adapt policies based on performance monitoring (Alabi *et al.*, 2022).

(b) **Technological Adaptation:** Integrating smart technologies (e.g., GPS for routing, sensors for bin fill-levels) and data analytics for real-time, responsive management (Olawale & Sun, 2023; Bhuyan *et al.*, 2025).

(c) **Social Adaptation:** Fostering long-term behavioural change through environmental citizenship education that moves beyond awareness to empowerment (Hadjichambis & Paraskeva-Hadjichambi, 2020; Akintunde, 2017).

(d) **Infrastructural Adaptation:** Designing waste facilities with climate resilience in mind, such as locating landfills away from floodplains and creating robust drainage for transfer stations (Aucamp, 2017; Dimitri *et al.*, 2019).

The distinction is crucial; mitigation tries to prevent the problem, while adaptation tries to live with or reduce the harm from the problem. For Port Harcourt, an effective strategy requires both. Mitigation efforts (e.g., enforcing a ban on open burning) will reduce immediate air pollution. Simultaneously, adaptation measures (e.g., building community resilience to flooding caused by waste-clogged drains) are needed to manage the ongoing challenges. The two processes are mutually reinforcing, forming an integrated risk management cycle essential for long-term sustainability.

2.2.3 The Concept of Waste

The conceptualisation of "waste" has evolved significantly. It is no longer viewed simply as unwanted refuse but as a complex socio-technical and economic phenomenon. At its most basic, waste refers to materials discarded after use. However, this definition is increasingly inadequate in a world focused on resource efficiency and the circular economy. A more

nanced understanding recognises that "waste" is often a matter of perspective and context what is discarded in one process can be a resource in another. In urban centres like Port Harcourt, waste is both a visible symptom of systemic failure and a potential locus for sustainable development interventions.

Key conceptual dimensions include:

(a) **Classification:** Waste can be categorised by source (municipal, industrial, hazardous, construction) or composition (organic, plastics, paper, inert). Municipal Solid Waste (MSW) is the primary stream in Port Harcourt, with a high organic fraction that presents both a disposal challenge and an opportunity for composting or energy recovery (Ayotamuno, 2020; Ajaero *et al.*, 2023).

(b) **Waste as a Resource:** The circular economy paradigm reframes waste as a potential resource. The organic fraction can be composted or digested for biogas. Recyclables like plastics, metals, and paper have economic value. This shift in perspective is critical for moving from a linear "take-make-dispose" model to a more sustainable system (Kaza *et al.*, 2018; Akande & Olorunnisola, 2018).

(c) **Socio-economic and Behavioural Dimensions:** Waste generation is tied to consumption patterns, lifestyle, and income levels. Public attitudes, awareness, and cultural norms heavily influence disposal behaviours, such as the prevalent indiscriminate dumping in Port Harcourt (Adewale & Oyewole, 2020; Ikiriko *et al.*, 2023).

(d) **Environmental and Health Implications:** Conceptually, improper waste management represents a transfer of material from the human domain back into the environment in an uncontrolled, harmful manner, leading to pollution, disease vectors, and ecosystem damage (Cookey *et al.*, 2019). For this study, understanding "waste" in its full complexity is essential. It is not just the *object* of management but a *flow* that reflects the city's metabolism, a *problem* that poses risks, and paradoxically, a potential *asset* that can contribute to energy security, job creation, and environmental conservation if managed innovatively.

2.2.4 The Concept of Waste Management

Waste management encompasses the integrated activities, infrastructure, and governance systems for handling waste from generation to final disposal, serving as a critical indicator of urban governance (Kaza *et al.*, 2018). In Port Harcourt, the reality deviates from the ideal waste hierarchy due to systemic fragmentation among agencies and contractors (Ikpe & Onwumere, 2022), a persistent policy-implementation gap (Hudson *et al.*, 2019; Okoli *et al.*, 2020), and severe infrastructural deficits (Binafeigha & Enwin, 2017; Eze *et al.*, 2023). Chronic underfunding constrains services (Adama *et al.*, 2021), while the informal sector fills crucial yet unsupported recycling roles (Cookey *et al.*, 2019; Ike *et al.*, 2018). Public participation remains a decisive factor for success (Adewale & Oyewole, 2020). Consequently, this study conceptualises waste management as a complex socio-technical system, necessitating a holistic approach that integrates technical, governance, financial, and behavioural dimensions to mitigate risks and enhance adaptive resilience.

2.3 Empirical Review

Empirical literature on Port Harcourt's waste management consistently reveals systemic failures. Studies document inefficient collection, reliance on open dumping, inadequate infrastructure, and a lack of sanitary landfills or recycling facilities (Binafeigha & Enwin, 2017;

Udo & Uchegbu, 2020; Nkwocha & Onyegbu, 2021), alongside significant environmental impacts like leachate contamination (Nwankwoala & Onukogu, 2018; Eze *et al.*, 2023). Operational risks such as service disruptions, irregular collection, and environmental hazards from vehicle breakdowns and runoff are well-identified (Adama *et al.*, 2021; Odunsi, 2022; Ward *et al.*, 2022; Sam *et al.*, 2023). Root causes include institutional weaknesses, poor funding, weak policy enforcement (Obuah & Okon, 2017; Okoli *et al.*, 2020), and socio-economic factors like public apathy and rapid urbanisation (Adewale & Oyewole, 2020; Auwalu & Bello, 2023). For adaptation, research advocates infrastructure modernisation, technology integration, inclusion of the informal sector (Cookey *et al.*, 2019; Olawale & Sun, 2023), and emphasises community engagement and public-private partnerships (Sarid & Goldman, 2021; Alabi *et al.*, 2022; Abah & Ohimain, 2022). This evidence directly informs the study's four core objectives.

2.4 Summary and Identification of Gap

The reviewed literature provides a robust foundation, affirming the severity of waste management challenges in Port Harcourt and outlining associated risks, causes, and potential solutions. The theoretical frameworks offer sophisticated lenses for analysis, while the conceptual review clarifies the core constructs. Empirically, studies have ably diagnosed general inefficiencies and some specific problems.

However, a critical gap persists. While existing research often examines these aspects infrastructure, risks, causes, solutions in isolation or in loose association, there is a paucity of structured, integrated studies that concurrently and systematically investigate the *current state of infrastructure*, the *precise operational risks* arising from it, the *root causes* of failed mitigation, and then use this diagnostic to propose a *coherent set of adaptation processes* within a single, focused study on Port Harcourt Metropolis. This study is designed to fill this void. It employs an integrated theoretical framework to conduct a comprehensive analysis that links assessment, risk identification, causal diagnosis, and adaptive strategy formulation into a seamless inquiry, aiming to produce a targeted, actionable framework for sustainable solid waste management in the city.

3.0 Methodology

This research adopts a positivist philosophy with an ontological orientation, grounded in the belief that waste management phenomena in Port Harcourt possess observable structures and causal relationships discoverable through empirical analysis (Ihuah, 2015). A descriptive research design was adopted (Omodan, 2024). Primary source obtained through structured closed-ended questionnaire and secondary source were existing literature. Government staff (Rivers State Ministry of Environment and RIWAMA), Estate Surveyors and Valuers and the general public constitute the population of the study. A purposive sampling technique was adopted for the study. A Sample size of four hundred (400) participants; was determined using the Taro Yamane's formula. However, after distribution and retrieval of the questionnaire only 203 were returned constituting 57.5%, hence formed the valid sample size. A Close-ended Questionnaire was used to obtain quantitative data. SPSS v.23 statistical tools was deployed for descriptive statistics. Face, Content, and Construct Validity was adopted. A pre-test was carried out on 68 respondents, which yielded a Cronbach's Alpha value of 0.71 indicating a 71% reliability, hence acceptable and showing that the instrument is internally consistent and reusable.

4.0 Findings

The study achieved a high response rate of 57.5%, enhancing data credibility and representativeness. Diverse respondents (RIWAMA staff, estate surveyors, landlords, and ministry staff) provided a comprehensive view of waste management. Additionally, most respondents had 11-15 years of experience, increasing data reliability. Quantitative and qualitative methods bolstered findings. This approach aligns with recommendations from Salami *et al.* (2019) who emphasise the importance of supplementing moderate response rates with alternative methods to ensure data robustness.

Results on the research objectives and questions are further presented below:

Table 1: Descriptive Statistics of Current Waste Management Practices in Port Harcourt Metropolis

S/N	Waste Management Practice	Sum	Mean	SD	Remark
1	Waste separation before disposal	294	1.45	0.61	SD
2	Proper storage in bins/bags	355	1.45	0.70	SD
3	Waste placed at retrievable points	243	1.20	0.54	SD
4	Daily door-to-door collection	252	1.25	0.61	SD
5	Waste monitoring by owners	264	1.30	0.54	SD
6	Adequate public bins nearby	238	1.15	0.57	SD
7	Labelled public bins	235	1.16	0.49	SD
8	Manned public bins	220	1.08	0.37	SD
9	Clean public bins	245	1.21	0.59	SD
10	Public awareness by waste agents	221	1.09	0.35	SD
11	Clean waste trucks	214	1.05	0.23	SD
12	Welfare for waste officials	220	1.08	0.28	SD
13	Easy communication with officials	491	1.71	1.92	D
14	Use of ICT gadgets	227	1.12	0.32	SD
15	Prompt official response	224	1.10	0.31	SD
16	Community involvement	250	1.23	0.54	SD
17	Regular recruitment of workers	211	1.04	0.20	SD
18	Waste staff are professionals	871	4.02	1.53	SD
19	Continuous staff training	233	1.07	0.52	SD
20	Waste recycling practices	287	1.41	0.49	SD
Average Mean and Std. Dev.			1.36	0.59	Strongly Disagree

Source: Researcher Data, (2024), SPSS v.23 Output

Analysis of Current Waste Management Practices in Port Harcourt Metropolis

Survey results (Table 1) reveal high dissatisfaction with solid waste management in Port Harcourt. Major issues include inadequate waste separation (33% discontent), poor waste storage (94.1% discontent, mean score 1.45), ineffective waste positioning (84.7% discontent, mean score 1.20), and inconsistent collection (83.3% discontent, mean score 1.25). Insufficient monitoring and lack of public waste receptacles also contribute to public dissatisfaction. Community engagement is notably lacking, with 81.8% dissatisfied, while 91.6% report

inadequate welfare for waste management staff. Despite recognizing employee professionalism, an overall mean score of 1.36 across practices underscores a need for improvement. Comparative studies (Adewale & Oyewole, 2020; Abah & Ohimain, 2022) emphasize community involvement and public awareness as critical to effective waste management. Consistent with findings from Ikiriko *et al.* (2023) and Adama *et al.* (2021), urbanization is expected to increase waste production, necessitating adaptive strategies. Risk Society Theory (Abah & Ohimain, 2022) further supports the need for continual evaluation of waste management strategies to address evolving challenges. For Port Harcourt, adopting international best practices, such as bagging, regular collection, and continuous monitoring, is essential to enhance waste management and mitigate systemic risks from environmental degradation.

Table 2: Descriptive Statistics on Mitigation and Adaption Practices on Solid Waste Management Systems in the Study Area

S/N	Mitigation and Adaptation Practices	Sum	Mean	SD	Remark
1	Increasing the frequency of waste collection	971	4.78	0.41	SA
2	Adequate maintenance of waste collection trucks	1015	5.00	0.00	SA
3	Implementing consistent waste collection schedule	925	4.56	0.50	SA
4	Improving road networks	958	4.72	0.45	SA
5	Increase number of waste collection points	952	4.69	0.47	SA
6	Ensuring safe transportation of waste	911	4.49	0.50	SA
7	Providing adequate PPE	1015	5.00	0.00	SA
8	Reduce delays in reaching disposal sites	1007	4.96	0.20	SA
9	Safe handling of hazardous waste	1015	5.00	0.00	SA
10	Implementing strict safety protocols	950	4.68	0.47	SA
11	Ensuring waste disposal sites	1015	5.00	0.00	SA
12	Prevent environmental contamination	911	4.49	0.50	SA
13	Expanding facilities for hazardous waste	1015	5.00	0.00	SA
14	Better management of landfill sites	958	4.72	0.45	SA
15	Reducing open burning of waste	993	4.89	0.31	SA
16	Enforce compliance	963	4.74	0.44	SA
17	Introducing stricter penalties	1015	5.00	0.00	SA
18	Enhancing communication of waste management policies to residents	944	4.65	0.48	SA
19	Increasing inspections	1015	5.00	0.00	SA
20	Regular updates	945	4.66	0.48	SA
21	Ensuring sufficient funding	926	4.56	0.50	SA
22	Keeping the cost of waste affordable	885	4.36	0.48	SA
23	Allocating more resources for waste	912	4.49	0.50	SA

24	Strengthening PPP	903	4.45	0.50	SA
25	Encouraging residents to contribute financially	991	4.88	0.33	SA
26	Increasing public education	875	4.35	0.62	SA
27	Regular sensitization campaigns	1015	5.00	0.00	SA
28	Introducing waste segregation	1015	5.00	0.00	SA
29	Adopting innovative communication technologies	979	4.82	0.38	SA
30	Increasing community involvement	1015	5.00	0.00	SA
31	Implementing structured policy reforms	945	4.66	0.48	SA
32	Investing in waste management infrastructure	1015	5.00	0.00	SA
33	Daily collection of waste from homes, business, etc.	981	4.83	0.37	SA
34	Instituting 24-hour manned public bin	1015	5.00	0.00	SA
35	Installing instant washing equipment	1015	5.00	0.00	SA
36	Replacing waste bags frequently	958	4.72	0.45	SA
37	Locating more disposal points	1015	5.00	0.00	SA
38	Providing cleaning materials at dumpsites	955	4.70	0.46	SA
39	Implementing educational community programs	1015	5.00	0.00	SA
40	Monitoring private waste management companies	971	4.78	0.42	SA
Average Mean and Std. Dev.			4.7	0.41	Strong Agree

Source: Researcher Data, (2024), SPSS v.23 Output

Analysis of Mitigation and Adaption Practices on Solid Waste Management Systems in the Study Area

The responses from Respondents as captured in Table 4 highlight critical areas for solid waste management improvements, emphasizing frequent waste collection (88% agreement), regular truck maintenance (100% agreement), and reliable collection schedules to enhance operational efficiency. Improving road networks (86% support) and expanding collection points (96% agreement) are also prioritized for accessibility and reducing illegal dumping. Safety measures, including PPE and protocols for handling hazardous waste, were emphasized alongside enforcing waste regulations and community involvement. These findings align with international waste management research, supporting frequent collection, regular vehicle maintenance, and enhanced infrastructure. For example, Nwosu (2021) and Eze *et al.* (2023) emphasize that inadequate collection can lead to health risks, and poor infrastructure hampers efficiency. The Environmental Citizenship Model (ECM) underpins the need for community engagement in waste efforts, as highlighted by dissatisfaction with public receptacles (88.2%) and welfare provisions (91.6%) for waste personnel. This model encourages collective responsibility, motivating residents to actively participate in sustainable waste practices. Effective waste management can also boost real estate development by improving health, safety, and urban aesthetics, as documented by Akintunde (2017) and WHO (2018). These

improvements increase property values and attract investors, aligning with Sustainable Development Goals and global waste initiatives (World Bank, 2018; World Economic Forum, 2020). Addressing these challenges fosters a cleaner, more attractive Port Harcourt, supporting economic growth and sustainable urban development, hence, the proposed framework in Figure 2: Figure 2 shows the framework for Port Harcourt's waste management which integrates legislative policies, waste segregation, daily collection, recycling, safe disposal, logistics, and continuous monitoring. Legislative policies establish guidelines, incentives, and compliance mechanisms with community involvement (WHO, 2018). Waste segregation at source mandates households/businesses to separate biodegradable and non-biodegradable waste, supported by education and labelled bins. Daily collection ensures hygienic disposal via public dumpsites with amenities and rapid response systems (Ikiriko *et al.*, 2023). Recycling reduces landfill waste, generates revenue, and fosters community participation through buy-back schemes. Final disposal uses regulated landfills far from residential areas, with containment systems to minimize environmental hazards (Cookey *et al.*, 2019). Administrative control optimizes logistics, staff training, and policy alignment (Ekine *et al.*, 2018). Monitoring and evaluation track KPIs (for example, collection rates) and incorporate feedback for adaptive improvements (Eze *et al.*, 2023).

Framework for Sustainable Solid Waste Management in Port Harcourt

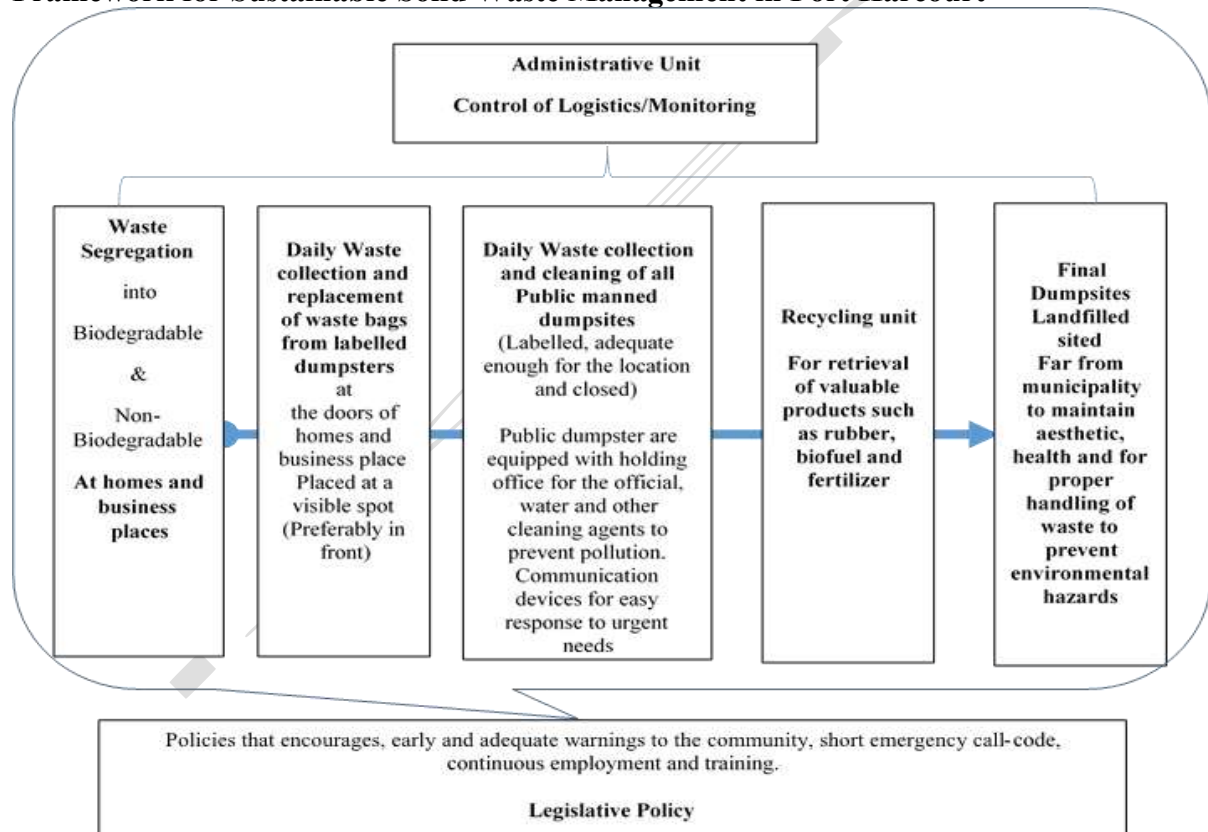


Figure 2: Framework for Sustainable Solid Waste Management in Port Harcourt Metropolis

Source: Researcher's Survey, (2024)

Expected benefits include:

1. Cleaner environment (reduced litter/odour).
2. Health/safety improvements (hygienic waste handling).
3. Economic opportunities (jobs, recycling revenue).
4. Sustainability (lower landfill use, resource conservation).
5. This holistic approach aligns waste management with urban development, enhancing public health, environmental resilience, and real estate growth.

Summary

The proposed framework (Figure 2) is the visual and conceptual embodiment of this inference. It is not a menu of options but a model of interconnected necessity:

(a) **Legislative and Policy Pillar as the Enabler:** The framework rightly places a robust policy foundation first. Inference from the study dictates that this must move beyond documents to include clear regulations on segregation, extended producer responsibility (EPR) for packaging, stringent penalties for non-compliance, and guidelines for PPPs. This creates the "rules of the game."

(b) **Waste Segregation at Source as the Critical Behavioural Node:** The framework's emphasis on segregation is directly inferred from the public's strong demand for it and the current abject failure in this area. Successful adaptation here depends entirely on the socio-behavioural pillar. It requires a massive, sustained education campaign (leveraging ECM) coupled with the provision of labelled bins (infrastructural adaptation) and potentially incentive schemes (economic adaptation).

(c) **Collection and Logistics as the Operational Engine:** The framework's focus on daily collection and optimised logistics is a direct response to the primary source of public dissatisfaction. Inference dictates that adaptation here requires investments in fleet modernisation and maintenance (capital), GPS-based route optimisation (technological adaptation), and professional training for staff (human resource adaptation).

(d) **Processing and Resource Recovery as the Value-Creation Hub:** The recycling and composting components of the framework infer a shift from viewing waste as a cost to seeing it as a resource. Adapting this node requires developing markets for recyclables, potentially through PPPs, and investing in Material Recovery Facilities (MRFs). This is where environmental goals align with economic opportunity and job creation.

(e) **Safe Final Disposal as the Environmental Safeguard:** The need for engineered sanitary landfills, inferred from the risks of leachate and open dumping, is non-negotiable for environmental protection. This is a high-cost, long-term infrastructural adaptation requiring significant funding and expert management.

(f) **Monitoring, Evaluation and Community Involvement as the Circulatory System:** Crucially, the framework envelops the entire process with continuous monitoring and pervasive community involvement. This is the reflexive learning loop. Data from monitoring (e.g., collection rates, contamination levels) must inform policy adjustments. Community involvement is not a one-off campaign but an embedded channel for feedback, co-management of neighbourhood points, and sustained behavioural reinforcement.

The ultimate inference from this holistic analysis is that execution must be phased, strategic, and participatory. A "big bang" approach is likely to fail. Priority must be given to immediately

restoring collection reliability and launching a city-wide "Segregation & Sensitisation" drive to build public momentum. Concurrently, work must begin on the longer-term financial and infrastructural plans for landfills and MRFs. Furthermore, this study allows for broader inferences beyond direct SWM. Effective adaptation, as outlined, would have significant positive externalities: Improved Public Health from reduced disease vectors; Enhanced Environmental Resilience through cleaner drains and reduced pollution; Economic Revitalisation via new jobs in the green economy and increased property values in cleaner neighbourhoods (a key concern for the estate management perspective within the study); and Strengthened Social Cohesion through community-based environmental action. Thus, investing in SWM adaptation is inferred to be a catalytic investment in the city's overall sustainable development, liveability, and economic competitiveness.

Summarily, Port Harcourt Metropolis stands at a critical juncture. This research has systematically diagnosed the severe ailments of its solid waste management system and, more importantly, has discerned a clear, consensus-based prescription for its recovery. The crisis, while severe, is not insurmountable. The inferences drawn chart a path from a state of manufactured risk and public dissent towards a future of reflexive modernisation, environmental citizenship, and integrated resource management. The blueprint is clear. The challenge now is one of leadership, collaboration, and unwavering commitment to translating this empirical framework into tangible action for a cleaner, healthier, and more sustainable Port Harcourt.

5.0 Conclusion

This study concludes that solid waste management in Port Harcourt is in a state of systemic failure, marked by infrastructural decay, unreliable services, and profound public dissatisfaction. However, a clear path forward exists. Stakeholders strongly endorse a holistic adaptation framework integrating reliable collection, infrastructure investment, strict safety enforcement, sustainable financing, and most critically the cultivation of environmental citizenship through sustained community engagement and education. Implementing this integrated approach is essential to transform the current crisis into an opportunity for public health, environmental sustainability, and resilient urban development.

5.1 Recommendations

To address these issues in the findings, the study suggests:

- i. **Enhanced Waste Management Practices:** Increase waste collection frequency and install more public waste bins. Invest in updated machinery for efficient processing.
- ii. **Address Operational Risks:** Implement a maintenance plan for equipment, provide training and PPE for staff, and contain landfill leachate effectively.
- iii. **Mitigate Waste Management Deficiencies:** Strengthen public awareness, enforce waste management laws, and secure funding for projects.
- iv. **Adapt Waste Management Systems:** Develop a centralized collection schedule, partner with private firms for recycling initiatives, and engage residents in community-driven projects.

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