BARRIERS AND CRITICAL SUCCESS FACTORS FOR SUSTAINABLE HAZARDOUS WASTE MANAGEMENT IN MALAYSIA

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BARRIERS AND CRITICAL SUCCESS FACTORS FOR SUSTAINABLE HAZARDOUS WASTE MANAGEMENT IN MALAYSIA

By

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ABSTRACT

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CHIN YIK HENG

This study examines the barriers and critical success factors (CSFs) influencing sustainable hazardous waste management in Malaysia, in the context of rapid industrial growth, escalating scheduled waste generation, increasing disposal costs, and declining national environmental performance. Despite the existence of comprehensive regulatory frameworks under the Environmental Quality Act 1974 and its subsidiary legislations, sustainable practices such as waste recovery and waste-to-energy remain underutilized, resulting in continued reliance on secured landfilling and recurring incidents of illegal dumping. These challenges highlight the need for a deeper understanding of both impediments and enablers to sustainability within industrial hazardous waste management. The primary objective of this research is to identify and analyze the key barriers and CSFs affecting the adoption of sustainable hazardous waste management practices in Malaysia and to propose actionable strategies to enhance industry implementation. A mixed-methods research design was employed, integrating qualitative and

quantitative approaches to strengthen methodological robustness. The qualitative phase involved preliminary site visits, literature review, and informal consultations with competent personnel to establish contextual understanding and inform questionnaire development. The quantitative phase consisted of a structured survey administered to 103 competent environmental professionals across multiple industrial sectors. Survey data were analyzed using descriptive statistics, reliability testing, and Principal Component Analysis (PCA) to identify underlying latent constructs governing barriers and success factors. The analysis identified seven principal barrier components, with lack of awareness and outreach emerging as the most significant obstacle, followed by financial constraints, regulatory complexity, insufficient infrastructure, public perception issues, resource limitations, and uncertainty regarding hazardous waste characteristics and recovery potential. Conversely, five critical success factor components were extracted, with organizational drivers, particularly top management commitment, leadership support, and resource allocation, ranked as the most influential enablers. External obligations (regulatory and customer pressure), positive corporate reputation, beneficiary capabilities, and organizational imperatives were also found to play important roles in advancing sustainability efforts. To enhance the credibility and practical relevance of the findings, data validation was conducted through expert review. An industry expert certified in scheduled waste management evaluated the extracted components, rankings, and interpretations, confirming that the results accurately reflect current industry practices, cost considerations, and operational realities. Expert feedback further reinforced the importance of contractor

collaboration and economic feasibility in sustainable waste management decision-making. The novel contribution of this study lies in its integrated empirical framework that simultaneously maps barriers and CSFs within the Malaysian regulatory and industrial context, supported by statistical validation and industry verification. The findings provide practical insights for policymakers, regulators, and industry practitioners by demonstrating that sustainable hazardous waste management requires a dual strategy: mitigating awareness, regulatory, and resource barriers while leveraging leadership commitment, incentives, and reputational drivers. This research contributes to bridging the gap between regulatory intent and industrial practice and supports Malaysia's transition toward circular economy principles and long-term environmental sustainability.

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Date: 01 MARCH 2026

PERMISSION SHEET

It is hereby certified that **CHIN YIK HENG** (ID No: **19AGM05535**) has completed this dissertation entitled "**BARRIERS AND CRITICAL SUCCESS FACTORS FOR SUSTAINABLE HAZARDOUS WASTE MANAGEMENT IN MALAYSIA**" under the supervision of Ir. Ts. Dr. Wai Soon Han (Supervisor) from the Department of Environmental Engineering, Faculty of Engineering and Green technology, and Dr. Au Yong Hui Nee (Co-supervisor) from the Department of Economics, Teh Hong Piow Faculty of Business and Finance.

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APPROVAL SHEET

This dissertation entitled "**BARRIERS AND CRITICAL SUCCESS FACTORS FOR SUSTAINABLE HAZARDOUS WASTE MANAGEMENT IN MALAYSIA**" was prepared by CHIN YIK HENG and submitted as partial fulfillment of the requirements for the degree of Master of Engineering Science at Universiti Tunku Abdul Rahman.

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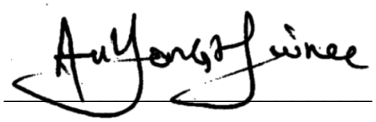

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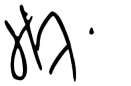
DECLARATION

I **CHIN YIK HENG** hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.



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COVID-19	Coronavirus Disease 2019
CSF	Critical Success Factor(s)
DOE	Department of Environment Malaysia
EPI	Environmental Performance Index
EQA 1974	Environmental Quality Act 1974
ISO14001	Environmental Management System
PCA	Principal Component Analysis
SPSS	Statistical Package for the Social Sciences
SW	Scheduled Waste

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CHAPTER 1.0

INTRODUCTION

1.1 Background

Rapid industrialization has been widely recognized as a major driver of hazardous waste generation, particularly in emerging economies where manufacturing, chemical processing, and electronic industries expand faster than environmental management capacity (UNEP, 2019; World Bank, 2018). Globally, hazardous and industrial wastes are increasing at a rate exceeding that of municipal solid waste, intensifying risks to environmental quality, public health, and regulatory compliance (Ferronato & Torretta, 2019; Kumar et al., 2023). International policy bodies such as the OECD and UNEP have therefore emphasized the transition from disposal-oriented systems toward sustainable hazardous waste management grounded in waste minimization, recovery, and circular economy principles (OECD, 2016; UNEP, 2019).

1.2 Hazardous waste growth in Malaysia

Malaysia reflects this global trend. Sustained industrial growth in manufacturing, construction, petrochemical, mining, and electronic sectors has resulted in a sharp increase in hazardous waste, locally classified as scheduled waste under the Environmental Quality (Scheduled Wastes) Regulations 2005. Scheduled wastes

encompass 77 waste streams grouped into five categories, ranging from metal-bearing and inorganic wastes to organic and mixed hazardous wastes.

DOE's Environmental Quality Report 2020 (Figure 1.1) indicate a dramatic escalation in scheduled waste generation, rising from approximately 4.00 million metric tonnes in 2019 to 7.19 million metric tonnes in 2020, representing a 79% increase within a single year. Similar rapid increases have been reported in other Asian economies and are commonly associated with intensified industrial activity, healthcare waste expansion, and operational disruptions during the COVID-19 pandemic (Agamuthu & Barasarathi, 2020; Thakur et al., 2023). Studies published in Waste Management and Environmental Science and Pollution Research caution that such abrupt growth often overwhelms existing treatment and recovery infrastructure, increasing reliance on disposal and the likelihood of non-compliance (Rout et al., 2016; Kumar & Samadder, 2024).

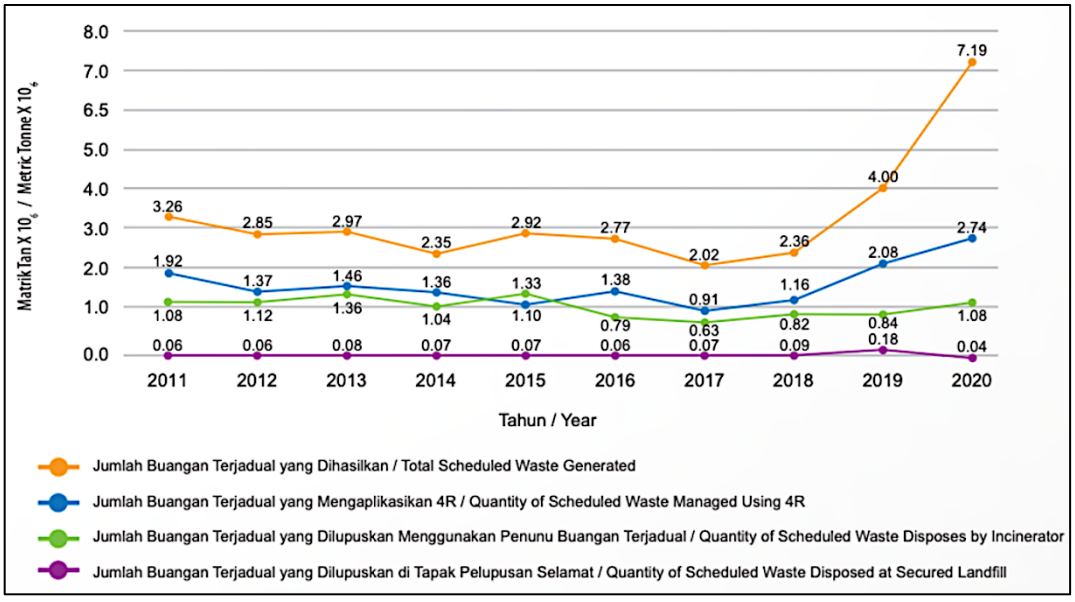

Figure 1.1: Scheduled Waste Management Trend, 2011-2020

1.3 Industrial concentration and infrastructure constraints

Hazardous waste generation in Malaysia is spatially concentrated in highly industrialised states, particularly Selangor, Johor, and Negeri Sembilan. Similar concentration patterns have been documented in China and India, where industrial clustering significantly amplifies environmental pressure while straining hazardous waste treatment capacity (Duan et al., 2008; Rout et al., 2016). Research indicates that when waste generation growth outpaces infrastructure development, industries tend to prioritise short-term compliance and disposal over sustainable recovery options (Caldera et al., 2019; Kumar et al., 2023).

Although Malaysia operates licensed incineration, treatment, recovery, and secured landfill facilities, the overall system remains limited relative to national waste volumes. International literature consistently identifies inadequate recovery infrastructure as a structural barrier to sustainable hazardous waste management in developing and middle-income economies (Ferronato & Torretta, 2019; Kumar et al., 2023).

1.4 Dominance of disposal-based practices

Despite regulatory provisions encouraging waste minimisation and recovery, hazardous waste management in Malaysia remains predominantly disposal-oriented. Excessive reliance on incineration and secured landfilling contradicts international sustainability hierarchies, which place disposal as the least preferred option due to long-term environmental liabilities (OECD, 2016; UNEP, 2019).

Even engineered landfills pose persistent risks related to leachate migration, containment failure, and intergenerational environmental burden (Rout et al., 2016).

A notable example is SW204 (heavy metal-containing sludge), which is the second largest hazardous waste streams generated by Malaysian industries. Although extensive research demonstrates the technical feasibility of reusing such wastes through co-processing in cement kilns or waste-to-energy applications (Thomanetz, 2012; Anett et al., 2018), DOE's Environmental Quality Report 2020 (Table 1.1) shows that only a fraction is recovered under the Special Management scheme, with the majority disposed of in sanitary landfills. Similar underutilisation of recovery pathways has been reported across developing economies, often driven by financial risk perception, regulatory uncertainty, and limited organisational readiness (Caldera et al., 2019; Kumar et al., 2023).

Table 1.1: Scheduled Waste Managed Under Special Management, 2020

BIL / NO.	KATEGORI BUANGAN / WASTE CATEGORY	KOD BUANGAN / WASTE CODE	SUMBER / SOURCE	METRIK TAN / METRIC TONNES	PERATUS (%) / PERCENTAGE (%)	KAEDAH PELUPUSAN / METHOD OF DISPOSAL)
1.	Enap Cemar Logam Berat / Heavy Metal Sludge	SW 204	Loji Rawatan Air Minuman / Drinking Water Treatment Plant	1,067,377.38	49.22	Tapak Pelupusan Sanitari / Reuse as Raw Material for Product
			Industri / Industry	6,348.70	0.29	
				48,734.45	2.25	
2.	Fly Ash & Bottom Ash	SW 104	Coal-Fired Power Plant	896,270.09	41.33	Guna Semula sebagai Bahan Mentah Pembuatan Produk / Sanitary Landfill
			Industri / Industry	140,443.27	6.48	
3.	Enap Cemar Mengandungi *Flouride* / Sludge Containing Flouride	SW 207	Industri / Industry	866.68	0.04	Guna Semula sebagai Bahan Mentah Pembuatan Produk / Reuse as Raw Material for Product
4.	Buangan yang Mengandungi Formaldehid, Resin, Serbuk Epoksi Terbuang / Waste Containing Formaldehyde, Resin, Discarded Epoxy Powder	SW 320, 325, 418	Industri / Industry	663.58	0.03	Tapak Pelupusan Sanitari / Sanitary Landfill
5.	Abu dari Enapcemar Kertas / Ash of Paper Sludge	SW 406	Industri / Industry	3,531.45	0.16	Tapak Pelupusan Sanitari / Sanitary Landfill
6.	*Activated Carbon* Terpakai / Spent Activated Carbon	SW411	Industri / Industry	3,728.00	0.17	Guna Semula sebagai Bahan Mentah Pembuatan Produk / Reuse as Raw Material for Product
7.	Enap Cemar Mineral / Mineral Sludge	SW 427	Industri / Industry	456.00	0.02	Guna Semula sebagai Bahan Agen Peneutralan / Reuse as Neutralizing Agent
8.	Buangan daripada Bahan Letupan Terpakai / Waste from the Use of Explosives	SW431	Industri / Industry	7.32	0.00	Kaedah Pembakaran / Slow Burning Method
			JUMLAH / TOTAL	**2,168,426.92**	**100.00**	

1.5 Economic pressure and environmental risk

The cost of hazardous waste treatment and disposal is consistently identified as a critical barrier to sustainability adoption. Studies in Journal of Cleaner Production and Environmental Management indicate that high compliance and disposal costs disproportionately affect small and medium-sized enterprises (SMEs), discouraging investment in sustainable alternatives and, in some cases, incentivising illegal disposal practices (Tumpa et al., 2019; Calvo et al., 2015). Malaysia's experience mirrors these findings, as evidenced by major pollution incidents such as the Sungai Kim Kim case (2019), which exposed thousands of

residents to toxic airborne chemicals and highlighted weaknesses in enforcement, awareness, and industry accountability.

International research demonstrates that such incidents are rarely isolated but instead reflect systemic failures in governance, awareness, and stakeholder coordination (Bui & Tseng, 2022; Ferronato & Torretta, 2019). Long-term studies further suggest that the environmental and health impacts of improper hazardous waste disposal often persist beyond immediate incidents, reinforcing the need for preventive and sustainable management strategies (Thakur et al., 2023).

1.6 Environmental performance and policy-practice gap

Malaysia's declining Environmental Performance Index (EPI) ranking, from 51st in 2014 to 63rd in 2016, signals broader challenges in translating environmental policies into effective outcomes. The EPI framework explicitly links hazardous waste management, pollution control, and environmental health indicators (Yale University, 2016). Comparative analyses show that countries achieving improved environmental performance typically prioritise organisational commitment, waste recovery, and enforcement effectiveness rather than compliance-driven disposal practices alone (OECD, 2016; Leonidou et al., 2017).

This divergence highlights a persistent policy–practice gap, widely discussed in sustainability literature, where strong regulatory frameworks coexist with limited implementation due to organisational, financial, technical, and behavioural constraints (Lozano, 2023; Rahman et al., 2023).

1.7 Research justification

Collectively, global evidence and national data demonstrate that Malaysia faces an escalating need for sustainable hazardous waste management. Rapid waste generation growth, continued dependence on disposal, rising economic pressure, recurring environmental incidents, and declining environmental indicators underscore the urgency of systemic improvement. However, international studies emphasise that technological solutions alone are insufficient; success depends on leadership commitment, regulatory clarity, stakeholder pressure, awareness, and organisational capability (Leonidou et al., 2017; Kumar et al., 2023; Rahman et al., 2023).

Within this context, a systematic, empirically grounded investigation of the barriers and critical success factors influencing sustainable hazardous waste management is essential to bridge the gap between regulatory intent and industrial practice. This study directly addresses this need by providing industry-validated evidence tailored to Malaysia's regulatory and operational environment.

1.8 Objectives

This study is aimed to determine the barriers and critical success factors for sustainable hazardous waste management in Malaysia. The outcome of this study is expected to be informative for both scheduled wastes generator and energy producer or user, that there are alternative ways of managing the scheduled waste in a sustainable and cost-effective way through waste recovery and waste-to-energy efforts. Following are the supporting objectives to be accomplished in this study:

i. To analyze the common barriers and critical success factors affecting the adoption of sustainable hazardous waste management through a systematic review of existing literature, site visits, and interviews with competent personnel.

ii. To identify the actual barriers and critical success factors for sustainable hazardous waste management as perceived by competent personnel within industries in Malaysia through surveys, factor analysis using statistical software, and validation of findings through expert review.

iii. To propose recommendations to further enhance sustainable hazardous waste management efforts.

CHAPTER 2.0

LITERATURE REVIEW

2.1 Key Issues in Sustainable Hazardous Waste Management

Sustainable hazardous waste management is widely recognised as a multidimensional challenge shaped by regulatory, economic, technical, organisational, and social factors. Both globally and in Malaysia, the shift from disposal-oriented practices towards more sustainable approaches, such as waste minimisation, resource recovery, and circular economy integration, continues to be hindered by persistent barriers. At the same time, successful implementation depends on the presence of specific enabling conditions or critical success factors. These issues are synthesised below into two main categories: barriers to sustainable hazardous waste management and critical success factors for its effective implementation.

2.2 Barriers to sustainable hazardous waste management

Sustainable hazardous waste management has been widely examined in the literature, particularly in the context of developing and newly industrialised economies. Despite the availability of regulatory frameworks and technological solutions, numerous studies consistently report persistent barriers that hinder the effective adoption of sustainable practices. These barriers are multi-dimensional,

encompassing regulatory, financial, technical, organisational, and social factors (Ferronato & Torretta, 2019; Kumar et al., 2023; Thakur et al., 2023). Understanding these constraints is essential for explaining the gap between policy intent and actual industry practice.

2.2.1 Complexity of legislation

Regulatory complexity is one of the most frequently cited barriers to sustainable hazardous waste management. Hazardous waste regulations are often characterised by extensive legal requirements, multiple approval layers, and frequent amendments, which increase compliance burden and uncertainty for industries (Webb & Geyer, 2019; Caldera et al., 2019). In developing countries, limited regulatory guidance and inconsistent enforcement further exacerbate this issue, particularly for small and medium-sized enterprises (SMEs) that lack legal and technical expertise (Derhab & Elkhwesky, 2023).

Studies have shown that overly complex regulations can unintentionally shift industry focus toward minimum compliance rather than proactive sustainability initiatives, such as waste recovery and circular economy practices (Lozano, 2023; Rahman et al., 2023). As a result, regulatory complexity often acts as a deterrent rather than an enabler of sustainable hazardous waste management.

2.2.2 Inadequate infrastructure and technological limitations

The availability of appropriate infrastructure is a critical determinant of sustainable hazardous waste management performance. Numerous studies report that

insufficient treatment, recovery, and recycling facilities limit the feasibility of sustainable waste management, particularly in emerging economies (Duan et al., 2008; Ferronato & Torretta, 2019). When infrastructure development fails to keep pace with industrial growth, industries become increasingly dependent on disposal-based options such as incineration and secured landfilling.

For example, in Malaysia, electronic industries contribute significantly to hazardous waste generation, but limited recovery facilities and treatment plants restrict the ability to manage these wastes sustainably (Chin & Yong, 2019). Additionally, improper storage facilities and outdated technologies in existing plants further exacerbate environmental risks. This issue is particularly severe in rural areas, where the absence of infrastructure forces improper disposal, such as open dumping and incineration, which contribute to pollution.

Technological limitations further constrain sustainability efforts. Advanced treatment and recovery technologies often require high capital investment and skilled operators, making them inaccessible to many organisations (Kumar & Samadder, 2024). Consequently, the lack of infrastructure and technological readiness remains a structural barrier that restricts the transition toward sustainable hazardous waste management systems.

2.2.3 Hazardous waste quantity

The quantity of hazardous waste significantly influences management strategies. Large waste volumes can overwhelm existing facilities, while small or inconsistent

waste quantities may render recovery and reuse economically unviable (Rout et al., 2016; Thakur et al., 2023).

The sheer volume of hazardous waste generated worldwide presents a significant challenge. According to Rout et al. (2016), increasing waste volumes have outpaced the capacity of existing management systems, leading to widespread non-compliance with environmental standards (Rout et al., 2016). For instance, industrial sectors like petrochemicals and manufacturing produce vast amounts of hazardous by-products, which require extensive resources to handle. Furthermore, urbanization and population growth have led to higher consumption patterns, increasing the waste burden. Effective waste reduction strategies, such as waste-to-energy technologies, remain underutilized due to financial and technological constraints.

2.2.4 Hazardous waste quality

Hazardous waste streams are often heterogeneous in nature, varying in toxicity, chemical composition, and physical characteristics, which complicates segregation, treatment, and recovery processes (Kumar et al., 2023).

For example, electronic waste often contains valuable metals like gold and copper, as well as harmful substances such as lead and mercury. The lack of segregation and pre-treatment processes further reduces the efficacy of recycling efforts (Kumar et al., 2023). In developing countries, improper handling of mixed wastes, such as biomedical and industrial waste, can result in toxic emissions and groundwater contamination, highlighting the need for specialized technologies.

Inconsistent waste quality has been identified as a major obstacle to waste-to-energy and co-processing initiatives, as fluctuating characteristics increase operational risks and regulatory uncertainty (Thomanetz, 2012; Moktadir & Ren, 2023). These constraints discourage industries from investing in sustainable alternatives and reinforce reliance on conventional disposal methods.

2.2.5 Lack of awareness about environmental sustainability

A widespread lack of awareness regarding the importance of environmental sustainability limits public and industrial engagement in hazardous waste management practices. Chin and Yong (2019) argue that insufficient knowledge about the environmental and health impacts of improper waste disposal discourages proactive measures (Chin & Yong, 2019). For instance, many small-scale industries lack awareness of sustainable waste treatment technologies, leading to non-compliance with environmental standards. Public misconceptions, such as the belief that recycling is overly complex or time-consuming, further hinder participation in waste reduction initiatives.

Inadequate training and absence of dedicated personnel further weaken organisational capacity, resulting in poor waste characterisation, inefficient decision-making, and compliance-focused practices (Derhab & Elkhwesky, 2023). Without sufficient knowledge and internal expertise, organisations are less likely to explore innovative and sustainable hazardous waste management solutions.

2.2.6 Poor networking

Collaboration among stakeholders, including industries, governments, and communities, is crucial for effective hazardous waste management. Poor networking results in fragmented efforts, missed opportunities for resource sharing, and duplication of efforts. For example, the lack of coordination between waste generators and treatment facilities often leads to delays and inefficiencies in waste handling. Chin and Yong (2019) suggest fostering partnerships through initiatives such as public-private partnerships (PPPs) and inter-industry collaborations to streamline waste management processes (Chin & Yong, 2019).

2.2.7 Public perception and social resistance

Public perception plays an influential role in hazardous waste management decision-making. Negative public attitudes toward hazardous waste facilities, often driven by health and environmental concerns, contribute to community resistance and the "Not In My Backyard" (NIMBY) phenomenon (Eguchi, 2020; Bui & Tseng, 2022). This resistance can delay or prevent the development of new treatment and recovery facilities, even when they comply with environmental standards. Lack of transparency and ineffective risk communication further intensify public opposition, increasing reputational risk for organisations and discouraging investment in sustainable waste management initiatives.

For instance, communities may protest the establishment of waste treatment plants due to concerns about air and water pollution. Transparency and active community engagement are critical to addressing these concerns. Chin and Yong

(2019) emphasize the importance of educational campaigns to build trust and mitigate resistance (Chin & Yong, 2019). For example, the involvement of local communities in decision-making processes has been shown to reduce opposition to waste management projects in regions such as Europe and North America.

2.2.8 Financial constraints and economic considerations

Financial barriers are consistently highlighted as a dominant challenge in hazardous waste management literature. High costs associated with treatment, recovery technologies, regulatory compliance, and skilled manpower disproportionately affect SMEs (Tumpa et al., 2019; Calvo et al., 2015). In many cases, sustainable waste management options are perceived as long-term investments with uncertain economic returns, making them less attractive compared to disposal-based solutions.

Financial limitations restrict the adoption of advanced technologies and infrastructure for hazardous waste management. The high costs associated with waste treatment facilities, advanced recycling systems, and skilled labor are often unaffordable for small- and medium-sized enterprises (SMEs). Kumar et al. (2023) highlight the role of government incentives, such as subsidies and tax breaks, in mitigating these financial barriers (Kumar et al., 2023). In regions like Southeast Asia, insufficient funding has resulted in the dependence on outdated, inefficient systems, exacerbating environmental degradation.

2.2.9 Lack of information

Insufficient data on hazardous waste generation, treatment capacities, and environmental impacts is a critical barrier to informed decision-making. Chin and Yong (2019) argue that a lack of accessible and reliable information limits the ability of policymakers to design effective waste management frameworks (Chin & Yong, 2019). For instance, waste tracking systems that provide real-time data are either absent or underutilized in many regions, resulting in improper disposal and illegal dumping.

2.2.10 Insufficient resources

The shortage of skilled personnel, advanced technologies, and financial resources hampers hazardous waste management efforts. Kumar et al. (2023) emphasize the importance of investing in capacity-building programs to train professionals in waste treatment technologies and regulatory compliance (Kumar et al., 2023). Additionally, outdated equipment in waste treatment facilities reduces efficiency and increases operational risks. In low-income countries, this resource gap is often exacerbated by limited access to international funding and technological support.

Empirical studies further suggest that insufficient financial incentives and limited access to funding mechanisms reduce industry motivation to adopt sustainable practices (Ali et al., 2023; Kumar et al., 2023). Without economic support, organisations tend to prioritise short-term cost minimisation over long-term environmental sustainability.

2.3 Critical success factors for sustainable hazardous waste management

While numerous barriers constrain sustainable hazardous waste management, the literature also identifies several critical success factors (CSFs) that enable effective implementation. These CSFs operate at organisational, regulatory, economic, and societal levels, and often function collectively rather than independently (Leonidou et al., 2017; Kumar et al., 2023).

2.3.1 Readiness of the hazardous waste beneficiary

The readiness of hazardous waste beneficiaries is crucial for the successful implementation of sustainable waste management practices. Chin and Yong (2019) argue that beneficiaries' readiness encompasses the capacity to adopt advanced technologies and infrastructural resources necessary for effective hazardous waste management. For example, the successful deployment of waste-to-energy technologies depends significantly on organizational readiness (Chin and Yong, 2019).

2.3.2 Benefits gained from sustainability efforts

Recognizing the tangible benefits of sustainability drives participation in waste management initiatives. Danish et al. (2022) highlight the economic advantages, such as reduced waste management costs and enhanced resource efficiency, achieved through sustainable practices. For example, the reuse of hazardous waste as raw materials reduces environmental footprints while enhancing profitability (Danish et al., 2022).

2.3.3 Regulatory pressure and stakeholder influence

External pressure from regulators, customers, and stakeholders is a powerful driver of sustainable hazardous waste management. Regulatory enforcement compels compliance, while customer and supply chain expectations encourage firms to adopt environmentally responsible practices to maintain competitiveness and reputation (Ali et al., 2023; Creadore & Castaldi, 2022).

Ali et al. (2023) suggest that external pressure increases accountability, compelling organizations to adopt sustainable practices. For instance, heightened scrutiny from stakeholders has led many industries to invest in green technologies and improve their hazardous waste management systems (Ali et al., 2023). Stakeholder pressure has been shown to accelerate the adoption of environmental management systems and innovative waste treatment solutions, particularly in export-oriented industries (Ni, 2015).

2.3.4 Adoption of ISO14001

The implementation of formal environmental management systems, such as ISO 14001, provides a structured framework for managing hazardous waste sustainably. Certification promotes systematic planning, monitoring, and continuous improvement, enhancing regulatory compliance and environmental performance (Ni, 2015; Pekaar & Demerouti, 2023). Empirical evidence indicates that organisations with ISO 14001 certification demonstrate better waste segregation, documentation, and sustainability integration compared to non-certified firms. This

has been particularly effective in developing economies, where firms adopting ISO14001 demonstrate superior waste management practices (Ni, 2015).

2.3.5 Corporate reputation and competitive advantage

A positive corporate image is an increasingly important driver of sustainable hazardous waste management. Organisations that demonstrate strong environmental responsibility benefit from enhanced brand reputation, customer trust, and stakeholder confidence (Karim & Rabiul, 2022). Ledi and Xemalordzo (2023) find that companies engaging in corporate social responsibility and sustainable practices enjoy improved brand reputation, which positively influences their market performance. Reputational benefits also attract investment and talent, creating a reinforcing cycle that supports continuous improvement in waste management practices.

2.3.6 Commitment from top management

Top management commitment is consistently recognised as the most influential success factor in sustainability-related initiatives. Leadership support determines strategic priorities, resource allocation, and organisational culture, all of which are essential for integrating sustainable hazardous waste management into core operations (Rahman et al., 2023; Ahsan & Khawaja, 2024).

Rahman et al. (2023) argue that strong leadership drives the adoption of green initiatives, ensuring consistent investment in sustainable waste management practices. For instance, in Indonesia, leadership-driven approaches have

successfully enhanced production waste management (Rahman et al., 2023). Studies also demonstrate that organisations with strong leadership commitment are more likely to invest in sustainable technologies, employee training, and continuous improvement initiatives, leading to superior environmental performance (Leonidou et al., 2017).

2.3.7 Incentives and rewards

Economic incentives, including subsidies, tax reductions, and rewards, play a critical role in offsetting the financial burden of sustainable waste management investments (Calvo et al., 2015; Cheng et al., 2022). Financial viability is particularly important for encouraging SMEs to adopt sustainable practices.

Calvo et al. (2015) demonstrate that public incentives in Spain significantly improved construction and demolition waste management by encouraging green technologies (Calvo et al., 2015). Studies also show that when sustainability initiatives deliver tangible economic benefits, such as cost savings, resource recovery, or revenue generation, organisations are more likely to sustain long-term commitment (Danish et al., 2022).

CHAPTER 3.0

RESEARCH METHODOLOGY

3.1 Overview of research design

This study adopted a mixed-methods research design, integrating qualitative exploratory methods and quantitative statistical analysis to systematically investigate the barriers and critical success factors (CSFs) influencing sustainable hazardous waste management in Malaysia.

The rationale for employing a mixed-methods approach lies in the complex and multidimensional nature of hazardous waste management, which involves regulatory, technical, organizational, economic, and behavioural dimensions. Qualitative methods were first used to establish contextual understanding and informed instrument development, while quantitative methods were subsequently applied to empirically validate and structure of the identified factors. This sequential design enhances methodological robustness by ensuring that survey instruments are theory-driven, context-specific, and empirically verifiable.

3.2 Research process flow

To improve clarity and transparency, the overall research methodology is structured into three sequential phases, as illustrated in Figure 3.1.

Phase 1: Preliminary research and questionnaire development

Phase 2: Pilot study, data collection, and statistical analysis

Phase 3: Data validation and formulation of recommendations

This structured flow ensures logical progression from conceptual exploration to empirical validation and practical interpretation.

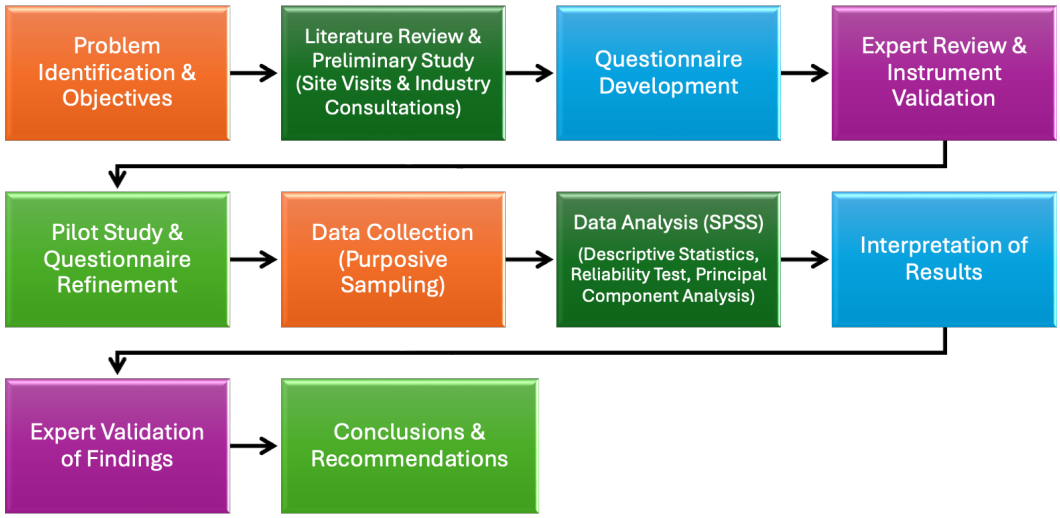

Figure 3.1: Research Process Flow

3.3 Phase 1: Preliminary research and questionnaire development

3.3.1 Preliminary Research

The preliminary phase aimed to establish theoretical grounding and practical relevance for the research instruments. Three complementary methods were employed:

a) Systematic literature review

Peer-reviewed journal articles, conference proceedings, international reports, and Malaysian regulatory documents related to hazardous waste

management and sustainability were reviewed. This process identified recurring barriers and CSFs, which formed the conceptual basis for the study variables.

b) Site visits and informal industry consultations

Preliminary site visits and informal discussions were conducted with competent personnel, including environmental officers, scheduled waste generators, licensed contractors, and individuals familiar with Department of Environment (DOE) requirements. These engagements provided practical insights into actual operational constraints, decision-making processes, and industry perceptions, ensuring contextual alignment with Malaysian industrial practices.

c) Integration of theory and practice

Findings from literature and field observations were triangulated to ensure that the study variables reflected both academic consensus and real-world conditions.

The use of preliminary qualitative exploration is justified as it reduces construct omission and improves content validity in survey-based sustainability research.

3.3.2 Questionnaire Development

Based on the preliminary research, a structured questionnaire was developed to measure perceived barriers and CSFs influencing sustainable hazardous waste management.

b) Questionnaire structure:

- Section A: Demographic information
- Section B: Barriers to sustainable hazardous waste management
- Section C: Critical success factors

c) Item formulation:

Questionnaire items were derived directly from the literature review and preliminary consultations. Each item represents a specific observable indicator of broader latent constructs (e.g., awareness, regulatory complexity, organizational commitment).

d) Measurement scale:

A five-point Likert scale was used to capture respondents' level of agreement. This scale is widely accepted for attitudinal and perception-based research and is compatible with multivariate statistical techniques such as factor analysis.

3.3.3 Instrument validation (Expert Review)

Prior to pilot testing, the draft questionnaire underwent expert validation to enhance clarity, relevance, and content accuracy.

a) Expert selection criteria:

Experts were selected based on:

- Professional certification in scheduled waste management
- More than 5 years of relevant industry experience
- Direct involvement in hazardous waste compliance, treatment, or sustainability initiatives

b) Number and method of engagement:

The draft instrument was reviewed through direct consultation, focusing on:

- Relevance of questionnaire items
- Clarity of wording
- Practical applicability to Malaysian industrial settings

Feedback from experts was incorporated to refine item phrasing, eliminate ambiguity, and ensure alignment with industry terminology and regulatory practice.

3.4 Phase 2: Pilot study, data collection, and statistical analysis

3.4.1 Pilot study

A pilot study was conducted to test the reliability and clarity of the questionnaire before full-scale deployment. Its purpose is to identify ambiguous or redundant items and assess internal consistency of measurement scales. Pilot responses were analysed using IBM SPSS Statistics, with Cronbach's Alpha applied to test internal consistency. Items with unclear wording or weak reliability indicators were revised or removed. Conducting a pilot study strengthens methodological rigour by minimizing measurement error.

3.4.2 Sample technique and data collection

A purposive sampling technique was employed. The study specifically targeted respondents with direct knowledge and responsibility for hazardous waste management. Random sampling would risk including respondents lacking relevant expertise, thereby weakening data validity. Target population: scheduled waste

competent persons, environmental, safety and health (ESH) officers, environmental managers and regulatory-related practitioners.

The finalized questionnaire was distributed using Google Forms. A total of 103 valid responses were collected, exceeding the commonly recommended minimum sample size of 100 for exploratory factor analysis. The online survey approach was necessary due to logistical constraints and ensured wide geographic coverage across Malaysian industrial regions.

3.4.3 Data processing and statistical analysis

All collected data were analysed using IBM SPSS Statistics. Responses were checked for completeness and consistency prior to analysis. Cronbach's Alpha was used to assess internal consistency for both barrier and CSF scales. Values exceeding 0.90 indicate excellent reliability. Mean ranking analysis was used to identify the relative importance of individual barriers and CSFs. Principal Component Analysis (PCA) was employed to deduce data dimensionality, identify latent constructs underlying observed variables and group related variables into interpretable components. PCA is appropriate for exploratory studies aiming to uncover underlying factor structures in perception-based survey data.

3.5 Phase 3: Data validation and recommendation

3.5.1 Expert validation of findings

To enhance credibility and practical relevance, the extracted components and interpretations were reviewed by an industry expert certified in scheduled waste

management. The scope of validation includes: appropriateness of identified components, practical relevance of rankings and consistency with current industry practice.

3.5.2 Development of recommendations

Validated results were synthesized to formulate practical, evidence-based recommendations aimed at reducing key barriers, strengthening critical success factors and supporting policy and industry decision-making.

3.6 Methodological alignment with research objectives

This research methodology demonstrates rigor through systematic literature-driven instrument development, expert-validated questionnaire design, purposeful sampling of competent professionals, robust statistical analysis using SPSS and PCA and Industry validation of findings. The methodology is therefore aligned with the research objectives 1 - to analyze the common barriers and critical success factors affecting the adoption of sustainable hazardous waste management through a systematic review of existing literature, site visits, and interviews with competent personnel.

CHAPTER 4.0

RESULTS AND DISCUSSION

4.1 Response rate of survey questionnaire

This chapter presents and discusses the findings of the study in direct relation to the research objectives 2 - to identify the actual barriers and critical success factors for sustainable hazardous waste management as perceived by competent personnel within industries in Malaysia through surveys, factor analysis using statistical software, and validation of findings through expert review.

The discussion goes beyond descriptive reporting by interpreting the statistical results, examining their practical implications, and comparing them with prior empirical studies and established sustainability and organizational theories. Unexpected or counterintuitive findings are also highlighted and critically examined to provide a balanced and reflective analysis.

The target respondents for this study are those competent person, environmental practitioners and law enforcer who are well-verse about the legal aspects and practicability of managing scheduled wastes in a sustainable manner. The survey questionnaire (in “google form” format) was shared to the target respondents via the contact details obtained from several channels such as

Malaysian Society for Occupational Safety & Health (MSOSH), Perak Organization of Safety,Health & Environment (POSHE), Environment Institute of Malaysia (EiMAS), Nothern Region Group of Safety, Health and Environment (NRG-SHE) and personal connection. Due to the Movement Control Order (MCO) following Covid-19 pandemic, distributing the questionnaire physically to increase the response rate was nearly impossible. However, out of 410 requests sent via WhatsApp with constant follow up, a total of 103 completed questionnaires was collected throughout 2020-2022. All 103 responses collected were complete and valid, thus giving an overall response rate of 25% (103/410) which is consider acceptable (SurveyLab, 2023).

4.2 Demographic data

The demographic profile indicates that the respondents are predominantly experienced, well-educated professionals holding senior technical or managerial positions. This strengthens the credibility and relevance of the findings, as perceptions were obtained from individuals directly responsible for scheduled waste compliance and decision-making.

The dominance of respondents aged above 40 with more than six years of service suggests that the findings reflect established industry practices rather than theoretical assumptions. This is particularly important when interpreting barriers such as awareness and regulatory complexity, as these perceptions are shaped by long-term exposure to Malaysia’s hazardous waste management framework rather than limited operational experience.

4.2.1 Gender of respondents

Majority of respondents (80%) who took part in this survey were male, while the remaining 20% of the respondents were female. Gender distribution of the respondents are shown in Figure 4.1 and Table 4.1. From the total of 103 respondents, 82 of them were male while the rest of 21 people were female.

Such phenomenon could be due to the common perception that tasks related to hazardous waste management is physical demanding and dangerous, thus, it discourages female to take up such role due to its challenging job nature.

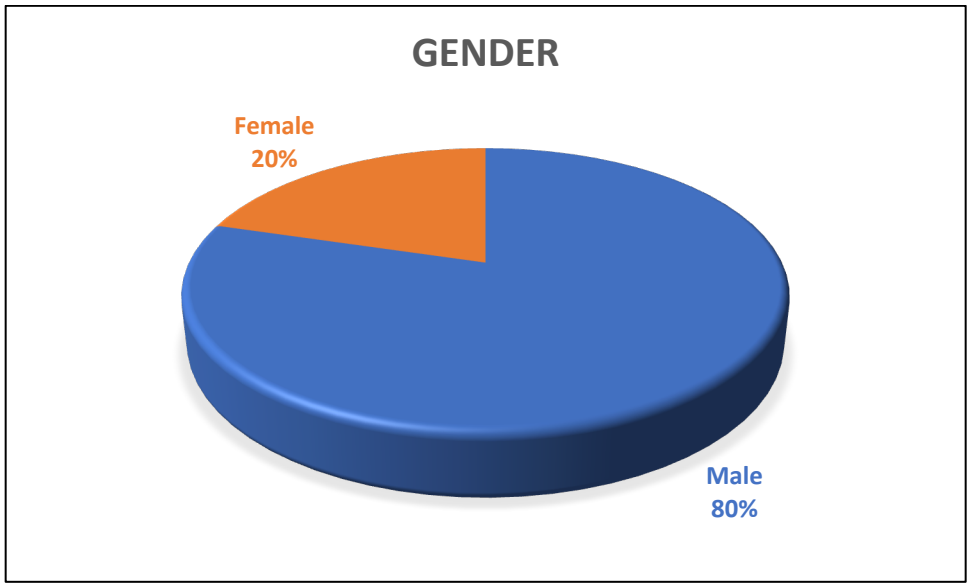

Figure 4.1: Distribution of respondents by gender

Table 4.1: Gender of respondents

Gender	N	%
Male	82	80%
Female	21	20%
Total	103	100%

Note: N = number of respondents, % = percentage

4.2.2 Age of respondents

Based on Figure 4.2 and Table 4.2, 45% (47) of the respondents were between the ages of 30-39, followed by 32% (33) respondents between the ages of 40-49, 11% (11) respondents between the ages of 20-29, 9% (9) respondents between the ages of 50-59 and the remaining 3% (3) respondents were between the ages of 50-59. It was found that majority (77%) of the respondents were aged 40 and above, which also corresponds to the years of service data that indicates 45% of the respondents had served their respective organization for 6 years or more.

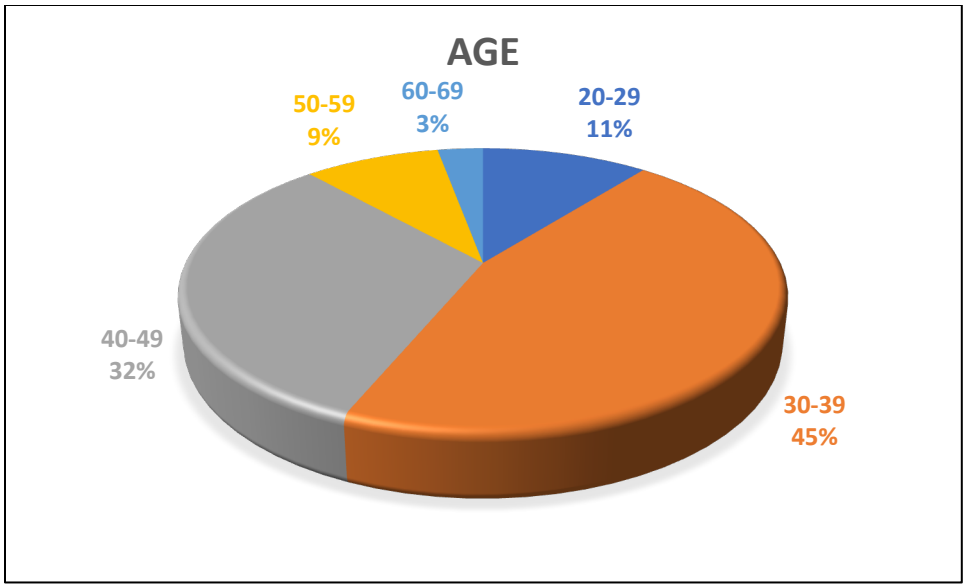

Figure 4.2: Distribution of respondents by age

Table 4.2: Age of respondents

Age	N	%
20-29	11	11%
30-39	47	45%
40-49	33	32%
50-59	9	9%
60-69	3	3%
Total	103	100%

Note: N = number of respondents, % = percentage

4.2.3 Educational qualification of the respondents

The educational qualification of the 103 respondents were shown in Figure 4.3 and Table 4.3. Among the 103 who responded to the survey, 53% (55) of them were degree holder, 24% (25) of them were masters holder, 17% (17) of them were

diploma holder, 5% (5) of them were PhD holder and the remaining 1% (1) was SPM certificate holder. It shows that majority of the respondents were considered well educated.

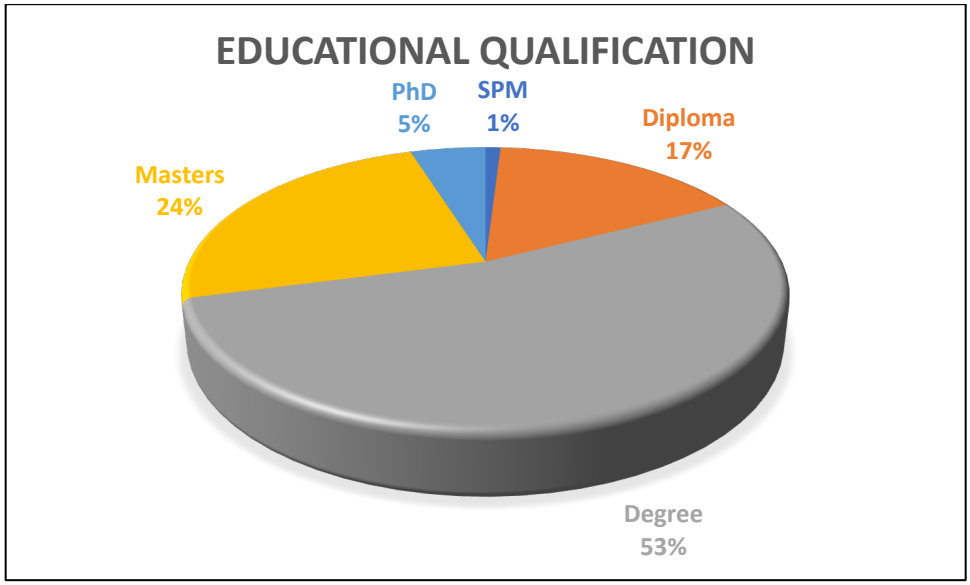

Figure 4.3: Distribution of respondents by educational qualification

Table 4.3: Educational qualification of respondents

Educational Qualification	N	%
SPM	1	1%
Diploma	17	17%
Degree	55	53%
Masters	25	24%
PhD	5	5%
Total	103	100%

Note: N = number of respondents, % = percentage

4.2.4 Type of organization of the respondents

Majority of respondents (89%, 92 people) who took part in this survey worked in privately owned organization, while the remaining 11% (11) of the respondents were working in government-owned organization. Type of organization distribution of the respondents are shown in Figure 4.4 and Table 4.4.

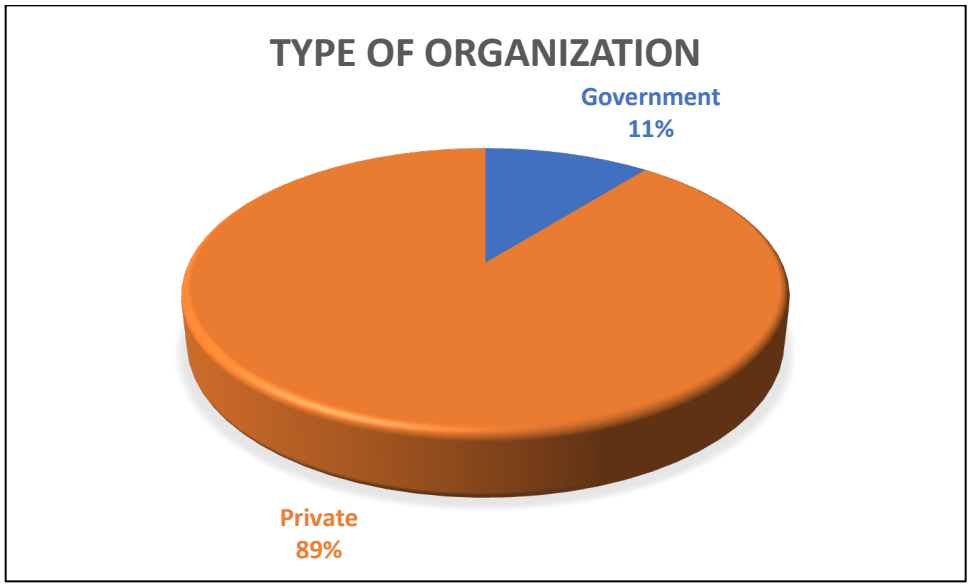

Figure 4.4: Distribution of respondents by type of organization

Table 4.4: Type of organization of respondents

Organization	N	%
Government	11	11%
Private	92	89%
Total	103	100%

Note: N = number of respondents, % = percentage

4.2.5 Organization's location of the respondents

Based on Figure 4.5 and Table 4.5, 39% (40) of the respondents' organization were located in Perak, followed by 24% (25) located in Selangor, 14% (14) located Kuala Lumpur, 13% (13) located in Penang, 3% (3) located in Johor, 2% (2) located in Kedah and the remaining 4% (4) were located in other states within Malaysia.

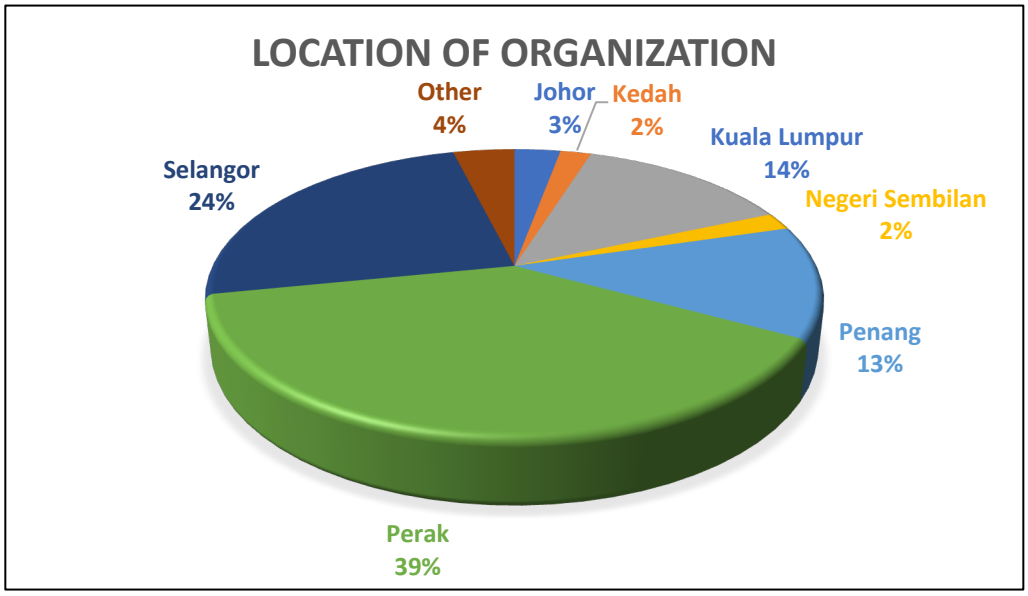

Figure 4.5: Distribution of respondents by location of organization

Table 4.5: Organization's location of respondents

Location of organization	N	%
Johor	3	3%
Kedah	2	2%
Kuala Lumpur	14	14%
Negeri Sembilan	2	2%
Penang	13	13%
Perak	40	39%
Selangor	25	24%
Other	4	4%
Total	103	100%

Note: N = number of respondents, % = percentage

4.2.6 Years of service of respondents

The years of service of the 103 respondents were shown in Figure 4.6 and Table 4.6. From the data obtained, it was found that 40% (41) of the respondents had served their organization for 1-5 years, 23% (24) had served their organization for more than 10 years, 22% (23) had served their organization for 6-10 years, and the remaining 15% (15) had served their organization for less than 1 year.

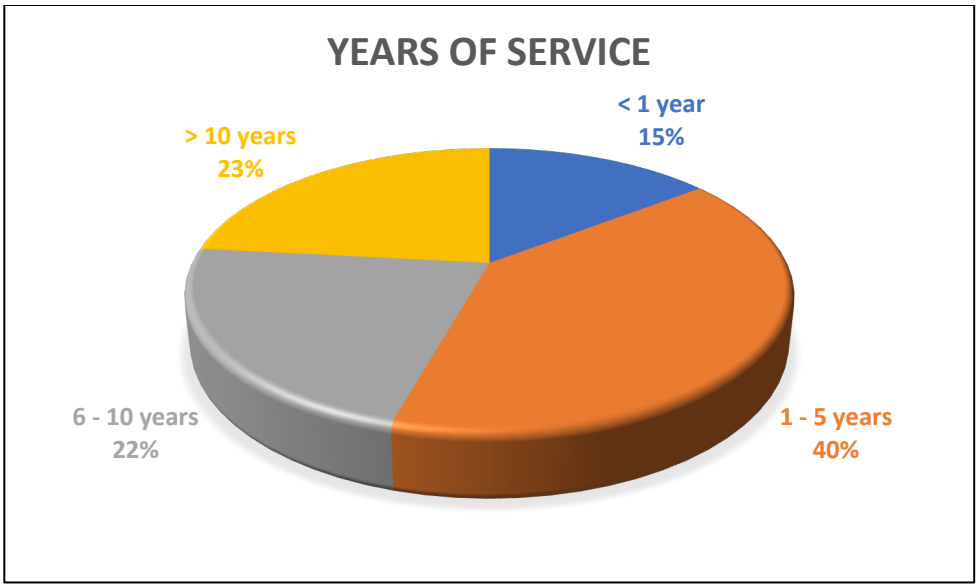

Figure 4.6: Distribution of respondents by years of service

Table 4.6: Years of service of respondents

Years of Service	N	%
< 1 year	15	15%
1 - 5 years	41	40%
6 - 10 years	23	22%
> 10 years	24	23%
Total	103	100%

Note: N = number of respondents, % = percentage

4.2.7 Position of respondents

The positions of the 103 respondents were shown in Figure 4.7 and Table 4.7. They are all actively involved in the scheduled waste management within their respective organization and thus they have been invited to take part in this survey. Among the 103 who responded to the survey, 38% (39) of them were senior executive/engineer,

36% (37) of them were in management position, 17% (18) of them were junior executive/engineer, and the remaining 9% (9) of them were in senior management position. Such distribution showed that majority of the respondents were holding senior position which is considered experienced and knowledgeable professionals.

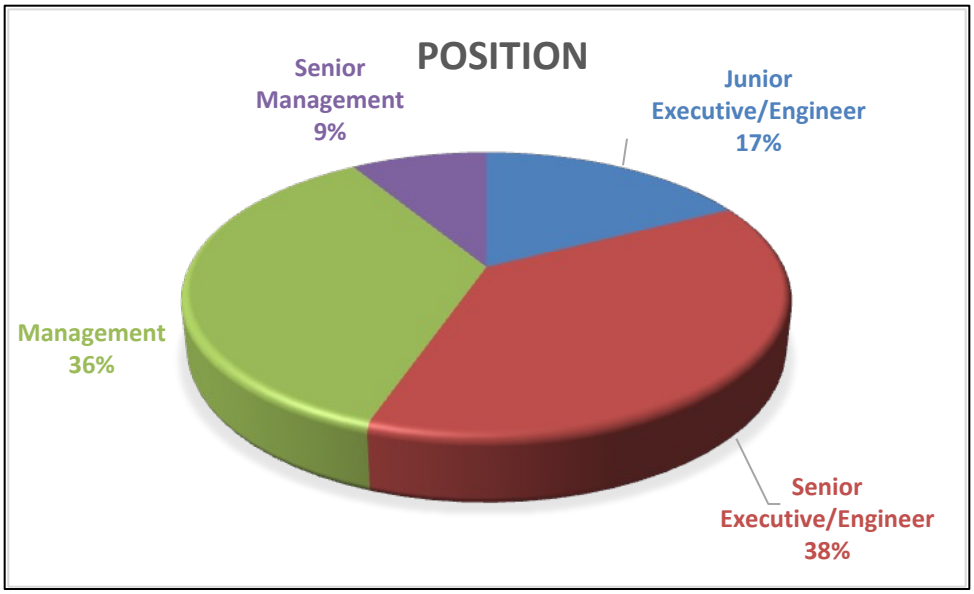

Figure 4.7: Distribution of respondents by position

Table 4.7: Position of respondents

Position	N	%
Junior Executive/Engineer	18	17%
Senior Executive/Engineer	39	38%
Management	37	36%
Senior Management	9	9%
Total	103	100%

Note: N = number of respondents, % = percentage

4.3 Reliability test

Cronbach's alpha is a measure of internal consistency reliability. It assesses the degree to which different items in a scale or questionnaire are measuring the same construct. It is calculated by measuring the correlation between each item and the overall score, and then averaging those correlations. The resulting score ranges from 0 to 1, with higher values indicating greater internal consistency.

There are different reports about the acceptable values of alpha, ranging from 0.70 to 0.95 (DeVellis, 2021). In this study, reliability test was conducted separately for barriers and critical success factors (CSFs). The SPSS output indicated that Cronbach's Alpha for barriers and critical success factors were 0.924 and 0.938 respectively as shown in Table 4.8. The high Cronbach's alpha values confirm strong internal consistency and validate the robustness of the survey instrument. These values exceed commonly accepted thresholds, indicating that the items reliably measure underlying latent constructs. This supports the suitability of subsequent factor analysis and strengthens confidence in the extracted components.

Table 4.8: Cronbach's Alpha for barriers and critical success factors

Reliability Statistics			
Scale	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Barriers	0.924	0.924	30
CSFs	0.938	0.941	21

4.4 Descriptive statistic

Descriptive statistics can be applied to both quantitative and categorical data, and can be used to summarize both large and small datasets. It is the first step in data analysis, providing an initial understanding of the data before more complex statistical methods are applied. The descriptive statistic techniques used in this study was mean ranking. Mean ranking is a method of ordinal data analysis, which is used to determine the relative standing or position of different items within a group or sample. It is a way to rank items based on their mean score.

4.5 Mean ranking of barriers

The mean values of each barrier was calculated and ranked in descending order. The mean values ranking will provide an overview of the level of importance of each factors as perceived by the respondents. As shown in Table 4.9, the mean values for barriers were ranging from 2.63 to 3.82. The mean ranking analysis reveals that awareness-related barriers dominate the top positions, this finding suggests that the principal challenge in Malaysia is not technological infeasibility, but cognitive and organizational readiness. Financial investment was ranked as a significant but secondary barrier. This implies that cost concerns are amplified by uncertainty and lack of awareness, rather than by absolute financial incapacity alone.

From the data, it is clear that lack of awareness about the benefits and possibility of sustainable hazardous waste management is a significant barrier. The top two barriers in the ranking are related to employee awareness of sustainable

hazardous waste management. Another significant barrier identified in the survey is financial investment, which was ranked fourth. The survey also identifies legal and regulatory barriers to sustainable hazardous waste management, including the extensive and hard-to-comply laws related to hazardous waste management.

In contrast, some barriers related to the characteristics and quantity of the hazardous wastes generated were ranked lower, such as the quantity being insufficient or low, or the hazardous wastes being too dangerous to be reused. This suggests that the company may not perceive these factors as significant barriers to sustainable hazardous waste management.

Overall, the identified barriers to sustainable hazardous waste management in the company can be explained by several factors. Firstly, lack of awareness among employees about the benefits and possibilities of sustainable hazardous waste management may be due to a lack of training and education provided by the company. Companies may prioritize other business functions over sustainable practices, and therefore may not allocate sufficient resources for employee education and training.

Secondly, the financial investment barrier may be due to the perception that sustainable hazardous waste management is a costly initiative that may not yield immediate financial returns. This could be due to the fact that sustainable practices may require the use of more expensive technology, processes, or equipment. Companies may also be more focused on meeting their financial targets in the short term, rather than investing in long-term sustainability efforts.

Thirdly, legal and regulatory barriers to sustainable hazardous waste management may be due to the complexity and ambiguity of the regulations, making it difficult for companies to comply with them. This could be because regulations related to hazardous waste management may be subject to frequent changes and updates, making it difficult for companies to keep up with the latest requirements.

In addition, the lack of proper channels to identify potential beneficiaries of hazardous wastes, as well as uncertainty about the technologies used to manage hazardous wastes in a sustainable manner, may be due to a lack of collaboration and communication between the company and potential beneficiaries or waste management service providers.

Overall, these barriers may be due to a combination of factors, including a lack of awareness and education, financial constraints, complex and evolving regulations, and inadequate communication and collaboration between the company and relevant stakeholders. Addressing these barriers will require a multifaceted approach that involves improving education and training, incentivizing sustainable practices, simplifying regulations, and enhancing communication and collaboration.

Table 4.9: Mean ranking of barriers

Barriers	N	Std. Deviation	Mean	Rank
Majority of employees do not aware of the benefits of managing hazardous wastes in sustainable manner	103	0.86	3.82	1
Majority of employees do not aware that hazardous wastes can be managed in a sustainable manner	103	0.866	3.77	2
There was no proper channel to identify the potential beneficiary of our hazardous wastes	103	0.877	3.61	3
Sustainability efforts are impossible without financial investment	103	1.089	3.59	4
Majority of employees do not aware of the environmental impact caused by hazardous wastes	103	1.043	3.58	5
There was no effort in identifying potential beneficiary of our hazardous wastes	103	0.998	3.47	6
We are uncertain about how others can benefit from our hazardous wastes	103	0.957	3.44	7
We are uncertain about the technologies used to manage hazardous wastes in sustainable manner	103	0.967	3.44	7
No one had ever showed interest on our hazardous wastes	103	0.948	3.36	9
Public opinion affects the company's decision	103	0.997	3.21	10

The hazardous wastes generated are not suitable to be reused for other purposes	103	1.03	3.17	11
Company worry about public's protest against sustainable hazardous wastes management	103	1.064	3.16	12
The law(s) related to sustainable hazardous waste management is too extensive	103	1.024	3.1	13
Company worry about the negative perception of public about sustainable hazardous wastes management	103	1.037	3.06	14
Company not willing to invest on sustainability efforts	103	1.166	3.05	15
The quantity of hazardous wastes generated is insufficient to be reused by others	103	1.163	3.04	16
It takes very long to accumulate the quantity of hazardous wastes needed by others	103	1.15	3.03	17
The content of hazardous wastes generated are inconsistent	103	1.014	2.97	18
Company does not have the necessary technologies to manage the hazardous wastes in sustainable manner	103	1.163	2.96	19
The law(s) related to sustainable hazardous waste management is hard to comply with	103	0.994	2.95	20
Company not willing to allocate resources for sustainable hazardous wastes management	103	1.187	2.94	21

Company does not have the necessary facilities to manage the hazardous wastes in sustainable manner	103	1.167	2.9	22
The quantity of hazardous wastes generated is low	103	1.167	2.9	22
The hazardous wastes generated are too dangerous to be reused	103	1.007	2.87	24
Company does not have budget allocation to support sustainability efforts	103	1.082	2.87	24
We are uncertain about the characteristics of our hazardous wastes	103	1.1	2.87	24
Company does not have the necessary system to manage the hazardous wastes in sustainable manner	103	1.107	2.76	27
There is no dedicated personnel responsible for hazardous wastes management	103	1.175	2.72	28
There is no individual who is knowledgeable about sustainable hazardous wastes management	103	1.085	2.69	29
The law(s) related to sustainable hazardous waste management is hard to understand	103	1	2.63	30

4.6 Mean ranking of CSFs

The mean values of each CSF were calculated and ranked in descending order. The mean values ranking will provide an overview of the level of importance of each factor as perceived by the respondents. The CSF analysis clearly identifies top

management commitment as the most influential success factor. The top three ranked items are all leadership-related, emphasizing that sustainability adoption is fundamentally a strategic and governance issue. This supports upper-echelon theory, which posits that organizational outcomes are shaped by leadership values, priorities, and resource allocation decisions.

As shown in Table 4.10, the mean values for CSFs were ranging from 3.64 to 4.49. From the data, it can be observed that the top three CSFs identified by the participants are related to the role of top management in promoting and supporting sustainability efforts. These CSFs are: "Top management should provide necessary resources to support the sustainability efforts" (mean=4.49), "Top management should promote sustainability efforts" (mean=4.41), and "Top management should encourage sustainability efforts" (mean=4.38).

The next two CSFs with similar mean scores are related to incentives and rewards that could motivate industries to participate in sustainability efforts. These are "Incentive or reward could motivate more industries to participate in sustainability effort" (mean=4.32) and "Incentive from government could improve the sustainability efforts" (mean=4.27), followed by "Reward from government could improve sustainability efforts" (mean=4.27).

Other CSFs identified by the participants include pressure from authority (mean=4.16), building a good company image (mean=4.12), ISO14001 certification (mean=4.07), benefits gained affecting the company's aggressiveness (mean=4.01), popularity gained (mean=4.00), economic gain (mean=3.97),

environmental benefits (mean=3.96), customer pressure (mean=3.95), and gaining trust from customers (mean=3.84).

Lastly, the CSFs related to the success of sustainability efforts, which are the financial capabilities of hazardous wastes beneficiaries and consistent demand from beneficiaries, had similar mean scores (mean=3.85). The technology stability of hazardous wastes beneficiaries (mean=3.82) and public pressure (mean=3.64) were ranked as the lowest among the CSFs identified.

The pattern of the above data indicates that top management support is perceived as the most important critical success factor (CSF) for sustainability efforts, as reflected by the highest mean and rank score. This is likely because the leadership of an organization plays a crucial role in setting the tone for sustainability initiatives and providing the necessary resources, budget, and guidelines to implement such programs. When top management prioritizes sustainability efforts, it sends a message to employees, customers, and stakeholders that sustainability is a core value of the organization. Studies have revealed that top management commitment is crucial in improving the environmental management processes, as well as enhancing the overall path of sustainability management in the organization as a whole (Sreenivasan Jayashree et al., 2015). Another study by Laura M. Graves et al. (2019) also found that the immediate manager's active environmental leadership was positively related to employees' pro-environmental behaviours (PEBs).

In addition to top management support, other factors that are ranked highly as CSFs include incentives or rewards, pressure from government, and pressure

from customers. These factors can motivate companies to invest in sustainability efforts, as they can result in economic benefits, improved reputation, and increased trust from stakeholders. Financial incentives have been assumed to encourage behaviour change in employees, including environmental sustainability related behaviours according to Paillé et al. (2022). Cheng et al. (2022) also suggested that financial incentives may motivate employees to reduce unnecessary waste in construction materials on site.

On the other hand, factors such as technology stability of hazardous waste beneficiaries and the financial capabilities of beneficiaries have lower mean and rank scores, indicating that they are perceived as less critical CSFs for sustainability efforts. This is likely because these factors are more specific to certain industries or situations and may not be applicable or relevant to all organizations.

Table 4.10: Mean ranking of CSFs

CSFs	N	Std. Deviation	Mean	Rank
Top management should provide necessary resources to support the sustainability efforts	103	0.712	4.49	1
Top management should promote sustainability efforts	103	0.733	4.41	2
Top management should encourage sustainability efforts	103	0.716	4.38	3
Incentive or reward could motivate more industries to participate in sustainability effort	103	0.843	4.32	4

Incentive from government could improve the sustainability efforts	103	0.865	4.27	5
Reward from government could improve sustainability efforts	103	0.888	4.27	5
Authority's pressure is one of the key factor driving the sustainability efforts	103	0.837	4.16	7
Sustainability efforts can build good company image	103	0.771	4.12	8
Sustainability efforts is part of the requirements under ISO14001	103	0.820	4.07	9
ISO14001 certification is one of the key factor driving the sustainability efforts	103	0.895	4.06	10
The benefits gained will affects the company's aggressiveness on sustainability efforts	103	0.934	4.01	11
Sustainability efforts can gain popularity for the company	103	0.804	4.00	12
The economic gain is one of the key factor driving the sustainability efforts	103	0.834	3.97	13
The environmental benefits is one of the key factor driving the sustainability efforts	103	0.740	3.96	14
Customer's pressure is one of the key factor driving the sustainability efforts	103	0.974	3.95	15
Company promote sustainability efforts due to ISO14001 certification	103	0.948	3.94	16

The success of sustainability efforts rely on the financial capabilities of hazardous wastes beneficiaries	103	0.733	3.85	17
The success of sustainability efforts rely on the consistent demand from beneficiaries	103	0.733	3.85	17
Sustainability efforts can gain trust from customers	103	0.968	3.84	19
The success of sustainability efforts rely on the technology stability of the hazardous wastes beneficiaries	103	0.711	3.82	20
Public's pressure is one of the key factor driving the sustainability efforts	103	0.979	3.64	21

4.7 Factor Analysis

The specific focus in factor analysis is understanding which variables are associated with which latent constructs. Latent constructs are those constructs which are unobserved, hidden, or latent, from the data we collect on related variables we can observe and directly measure. According to Pallent (2001), there are two components to be considered in determining whether a data set is adequate for factor analysis – the sample size and the strength of the relationship among the factors.

In terms of sample size, there were many recommended sample size for factor analysis which varies from 100 to 500. However, research has demonstrated that the general rule of thumb of the minimum sample size are not valid and useful (MacCallum, Widaman, Zhang, & Hong, 1999; Preacher & MacCallum, 2002). If communalities are high, recovery of population factors in sample data is normally

very good, almost regardless of sample size, level of overdetermination, or the presence of model error (MacCallum, Widaman, Preacher, and Hong, 2001, p. 636). MacCallum, Widaman, Zhang, and Hong (1999) suggested communalities should all greater than 0.6. Item communalities are considered "high" if they are all 0.8 or greater, but this is unlikely to occur in real data (Costello & Osborne, 2005, p. 4).

4.8 Communalities (for Barriers)

For the purpose of this study, total 103 responds were collected which is slightly above the recommended sample size of 100 by Gorsuch (1983) and Kline (1979, p. 40). In addition, the communalities of variables obtained were ranged between 0.591 – 0.900 (Table 4.11) with 96.67% (29/30) of them above 0.6, therefore, the sample size of 103 is considered acceptable for factor analysis.

Table 4.11: Communalities (Barriers)

Barriers	Initial	Extraction
The law(s) related to sustainable hazardous waste management is hard to understand	1.000	.681
The law(s) related to sustainable hazardous waste management is hard to comply with	1.000	.755
The law(s) related to sustainable hazardous waste management is too extensive	1.000	.662
Company does not have the necessary system to manage the hazardous wastes in sustainable manner	1.000	.780
Company does not have the necessary technologies to manage the hazardous wastes in sustainable manner	1.000	.854

Company does not have the necessary facilities to manage the hazardous wastes in sustainable manner	1.000	.883
The quantity of hazardous wastes generated is low	1.000	.668
The quantity of hazardous wastes generated is insufficient to be reused by others	1.000	.836
It takes very long to accumulate the quantity of hazardous wastes needed by others	1.000	.794
The content of hazardous wastes generated are inconsistent	1.000	.642
The hazardous wastes generated are not suitable to be reused for other purposes	1.000	.723
The hazardous wastes generated are too dangerous to be reused	1.000	.604
Majority of employees do not aware of the environmental impact caused by hazardous wastes	1.000	.816
Majority of employees do not aware that hazardous wastes can be managed in a sustainable manner	1.000	.863
Majority of employees do not aware of the benefits of managing hazardous wastes in sustainable manner	1.000	.821
There was no effort in identifying potential beneficiary of our hazardous wastes	1.000	.682
There was no proper channel to identify the potential beneficiary of our hazardous wastes	1.000	.629
No one had ever showed interest on our hazardous wastes	1.000	.667
Company worry about the negative perception of public about sustainable hazardous wastes management	1.000	.878
Company worry about public's protest against sustainable hazardous wastes management	1.000	.900
Public opinion affects the company's decision	1.000	.724

Company does not have budget allocation to support sustainability efforts	1.000	.623
Company not willing to invest on sustainability efforts	1.000	.758
Sustainability efforts are impossible without financial investment	1.000	.591
We are uncertain about the characteristics of our hazardous wastes	1.000	.689
We are uncertain about how others can benefit from our hazardous wastes	1.000	.892
We are uncertain about the technologies used to manage hazardous wastes in sustainable manner	1.000	.846
There is no individual who is knowledgeable about sustainable hazardous wastes management	1.000	.728
There is no dedicated personnel responsible for hazardous wastes management	1.000	.666
Company not willing to allocate resources for sustainable hazardous wastes management	1.000	.687

4.8.1 KMO and Bartlett's test (for Barriers)

To determine the strength of the relationship among the factors, Kaiser-Meyer-Olkin (KMO) test were used. Table 4.12 provides results from a Kaiser-Meyer-Olkin (KMO) test, KMO values closer to 1.0 are consider ideal while values less than 0.5 are unacceptable. The KMO measure of sampling adequacy obtained is 0.797, which indicates that a high proportion (79.7%) of the variance in the data can be attributed to the underlying factors. This result suggests that the data is appropriate for factor analysis.

The table also provides results for the approximate chi-square test, which is used to assess the overall fit of the factor analysis solution. The test statistic is 2410.052, the degrees of freedom (df) are 435, and the significance (Sig) is 0.000. The low significance value indicates that the factor analysis solution is a good fit for the data, with a high degree of statistical confidence.

Table 4.12: KMO and Bartlett's test (Barriers)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.797
Bartlett's Test of Sphericity	Approx. Chi-Square	2410.052
	df	435
	Sig.	0.000

4.8.3 Principal component analysis (Barriers)

For Principal Component Analysis (PCA), the eigenvalue was set at 1, therefore components with eigenvalues greater than 1 are retained while those component with lower eigenvalues are discarded (Wai et al., 2012). After extracting principal components, Varimax rotation are applied to improve interpretability. The factor loading value was set at 0.5, ensuring that each variable has a higher loading on one principal component while minimizing its loadings on others.

Table 4.13 data represent the output of a principal component analysis with 7 components. The table shows the amount of variance explained by each component, both before and after rotation. The first component explains the most variance (32.375%), followed by the second (10.266%) and third (8.856%). These

three components together explain almost 52% of the variance. The fourth through sixth components each explain around 5-7% of the variance, while the seventh component explains 4.031%. The remaining components each explain a smaller proportion of the variance, with the last component explaining only 0.128%. The cumulative percentage of variance explained have to be more than 50% to be considered as acceptable (Meyers et al., 2006). In this case, the cumulative percentage of variance explained was 74.47%, which is acceptable.

Table 4.14 displays the rotated component matrix resulting from a principal component analysis with varimax rotation and Kaiser normalization. It includes 7 components which associated with 28 barriers related to sustainable hazardous waste management.

Each cell in the matrix shows the correlation between a specific barrier and a specific component. The higher the correlation coefficient, the stronger the relationship between the barrier and the component. The components are not labeled, but they represent underlying factors that explain the common variance among the barriers.

Table 4.13: Principal component analysis (Barriers)

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.712	32.375	32.375	9.712	32.375	32.375	3.904	13.014	13.014
2	3.08	10.266	42.641	3.08	10.266	42.641	3.894	12.981	25.995
3	2.657	8.856	51.497	2.657	8.856	51.497	3.587	11.957	37.952
4	2.141	7.137	58.634	2.141	7.137	58.634	2.989	9.962	47.914
5	2.021	6.738	65.371	2.021	6.738	65.371	2.702	9.007	56.921
6	1.52	5.068	70.44	1.52	5.068	70.44	2.648	8.825	65.746
7	1.209	4.031	74.47	1.209	4.031	74.47	2.617	8.724	74.47
8	0.944	3.147	77.617						
9	0.833	2.777	80.394						
10	0.697	2.322	82.716						
11	0.665	2.218	84.934						
12	0.58	1.934	86.868						
13	0.48	1.599	88.467						
14	0.453	1.51	89.977						
15	0.424	1.413	91.39						
16	0.362	1.207	92.597						
17	0.295	0.983	93.58						
18	0.258	0.861	94.441						
19	0.238	0.794	95.235						
20	0.225	0.751	95.986						
21	0.212	0.707	96.693						
22	0.186	0.621	97.314						
23	0.171	0.571	97.885						
24	0.146	0.488	98.373						
25	0.123	0.41	98.783						
26	0.111	0.37	99.153						
27	0.085	0.285	99.438						
28	0.078	0.259	99.697						
29	0.053	0.175	99.872						
30	0.038	0.128	100						

Table 4.14: Rotated component matrix (Barriers)

Rotated Component Matrix*								
Barriers		Component						
		1	2	3	4	5	6	7
B1	The law(s) related to sustainable hazardous waste management is hard to understand					0.802		
B2	The law(s) related to sustainable hazardous waste management is hard to comply with					0.816		
B3	The law(s) related to sustainable hazardous waste management is too extensive					0.794		
B4	Company does not have the necessary system to manage the hazardous wastes in sustainable manner						0.687	
B5	Company does not have the necessary technologies to manage the hazardous wastes in sustainable manner						0.821	
B6	Company does not have the necessary facilities to manage the hazardous wastes in sustainable manner						0.788	
B7	The quantity of hazardous wastes generated is low		0.771					
B8	The quantity of hazardous wastes generated is insufficient to be reused by others		0.886					
B9	It takes very long to accumulate the quantity of hazardous wastes needed by others		0.851					
B10	The content of hazardous wastes generated are inconsistent		0.643					
B11	The hazardous wastes generated are not suitable to be reused for other purposes		0.65					
B12	The hazardous wastes generated are too dangerous to be reused							
B13	Majority of employees do not aware of the environmental impact caused by hazardous wastes	0.866						
B14	Majority of employees do not aware that hazardous wastes can be managed in a sustainable manner	0.874						
B15	Majority of employees do not aware of the benefits of managing hazardous wastes in sustainable manner	0.833						
B16	There was no effort in identifying potential beneficiary of our hazardous wastes	0.69						
B17	There was no proper channel to identify the potential beneficiary of our hazardous wastes	0.64						
B18	No one had ever showed interest on our hazardous wastes	0.579						
B19	Company worry about the negative perception of public about sustainable hazardous wastes management				0.909			
B20	Company worry about public's protest against sustainable hazardous wastes management				0.932			
B21	Public opinion affects the company's decision				0.794			
B22	Company does not have budget allocation to support sustainability efforts			0.693				
B23	Company not willing to invest on sustainability efforts			0.753				
B24	Sustainability efforts are impossible without financial investment			0.674				
B25	We are uncertain about the characteristics of our hazardous wastes							0.59
B26	We are uncertain about how others can benefit from our hazardous wastes							0.906
B27	We are uncertain about the technologies used to manage hazardous wastes in sustainable manner							0.838
B28	There is no individual who is knowledgeable about sustainable hazardous wastes management							
B29	There is no dedicated personnel responsible for hazardous wastes management			0.54				
B30	Company not willing to allocate resources for sustainable hazardous wastes management			0.601				

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.*

* Rotation converged in 15 iterations.

4.8.2 Barriers to sustainable hazardous waste management

Based on the findings derived from the principal component analysis (Table 4.13) and the rotated component matrix (Table 4.14), it can be inferred that:

Component 1 is associated with barriers related to “awareness and outreach”;

Component 2 is associated with barriers related to “quantity and quality constraints”; Component 3 is associated with barriers related to “lack of resources”;

Component 4 is associated with barriers related to “public perception”;

Component 5 is associated with barriers related to “complex regulations”;

Component 6 is associated with barriers related to “lack of infrastructure”;

Component 7 is associated with barriers related to “uncertainty about hazardous waste”

Component 1: Awareness and outreach

This component consists of six barriers which were B13, B14, B15, B16, B17 and B18. This component explains the largest proportion of variance (32.375%), confirming that awareness-related issues are the primary limiting factor. This finding aligns with organizational learning theory, which emphasizes that knowledge gaps and limited absorptive capacity inhibit innovation adoption.

While awareness and outreach efforts can be instrumental in promoting sustainable waste management practices, they also present challenges that can hinder the achievement of sustainability goals. One significant issue is the lack of awareness among industries about the environmental and social impacts of their waste management practices (Ferronato, 2019). This includes insufficient

understanding of the volume and types of waste generated, the hazards posed by waste, and its effects on the environment and human health, which can discourage investment in sustainable solutions. Additionally, the perception of high costs associated with sustainable practices, particularly for small and medium-sized enterprises (SMEs), acts as a barrier, as industries may be deterred by the upfront and ongoing expenses of implementing new technologies and processes (Tumpa, 2019).

Furthermore, the complexity of waste management regulations adds to the challenge, with industries often struggling to navigate and comply with these rules. This complexity may lead to a focus on regulatory compliance rather than proactive adoption of sustainable practices (Derhab and Elkhwesky, 2023). Resistance to change is another obstacle, as industries may fear negative impacts on operations, workforce, or profitability, coupled with concerns about the reliability of new technologies and availability of trained personnel. Lastly, limited access to reliable information on sustainable waste management further complicates decision-making, leaving industries ill-equipped to adopt effective solutions (Lozano, 2023).

Component 2: Quantity and quality constraints

This component consists of five barriers which were B7, B8, B9, B10 and B11. This component explained 10.266% of the total variance. Although frequently cited in international literature, quantity and quality constraints were unexpectedly ranked lower than awareness and financial concerns. This suggests that, contrary to common assumptions, waste characteristics are not perceived as the main obstacle

by practitioners. This can be attributed to the fact that scheduled waste generators in Malaysia have long operated within established regulatory frameworks that require the management of diverse waste streams, thereby normalising such variability as part of routine operations. Consequently, these factors are perceived as less problematic. In contrast, greater difficulty is associated with the identification of technically feasible recovery pathways and appropriate downstream beneficiaries, which remain less developed within the current waste management ecosystem.

Managing hazardous waste is inherently challenging due to its dangerous properties, such as toxicity, flammability, corrosiveness, or reactivity, which can pose significant risks to both human health and the environment if improperly handled. The quantity of hazardous waste generated by industries is a major barrier to sustainable management. If the volume is too high, waste management systems can become overwhelmed, resulting in higher transportation costs, storage issues, and potential environmental hazards. Conversely, when hazardous waste quantities are too low, it may not be cost-effective to invest in specialized equipment or facilities for proper management.

Equally important are the quality and composition of hazardous waste, which can vary significantly depending on the source. This variability creates challenges in managing the waste effectively and efficiently. The inconsistent composition of hazardous waste complicates the application of appropriate treatment or recovery methods, as different types of waste require specific

approaches for safe and sustainable management. This inconsistency can lead to inefficient or ineffective waste management practices (Thakur et al., 2023).

Additionally, the strict regulations governing hazardous waste management, which vary based on waste type and composition, further complicate compliance. Inconsistent waste quality makes it difficult to meet these regulatory requirements, increasing the risk of non-compliance and resulting in potential legal penalties. Addressing both the quantity and variability of hazardous waste is essential for improving sustainable waste management practices and minimizing environmental and health risks.

Component 3: Lack of resources

This component consists of five barriers which were B22, B23, B24, B29 and B30. This component explained 8.856% of the total variance. Resource constraints reflect classical sustainability barriers identified in SMEs and developing economies. However, their moderate variance contribution suggests that resource scarcity interacts with awareness and leadership, rather than acting independently.

Lack of resources, including financial, technical, and human resources, significantly impedes sustainable hazardous waste management (Kumar, 2024). Proper hazardous waste management requires specialized knowledge, infrastructure, and significant funding, all of which are often beyond the reach of many industries. Inadequate infrastructure, such as treatment and disposal facilities, can lead to the accumulation of hazardous waste at industrial sites, creating serious environmental and health risks. Without the proper technical knowledge and

expertise, industries may struggle with waste characterization, treatment, and disposal, resulting in improper practices that can harm both the environment and public health.

Additionally, insufficient financial resources make it difficult to invest in necessary equipment, maintain facilities, or comply with regulatory standards. This lack of funding can further exacerbate the problem by leading to suboptimal waste management practices, which in turn result in negative environmental and health impacts. Addressing resource limitations is essential for improving hazardous waste management and reducing associated risks.

Component 4: Public perception

This component consists of three barriers which were B19, B20 and B21. This component explained 7.137% of the total variance. Public resistance and negative perception form a distinct component, supporting NIMBY theory and stakeholder theory. The implication is that social acceptance remains a necessary condition for sustainable hazardous waste initiatives, especially for recovery or treatment facilities.

Public perception serves as a significant barrier to sustainable hazardous waste management by influencing both community support and the successful implementation of appropriate practices (Bui and Tseng, 2022). A lack of trust between the public and industry often fosters skepticism, leading to resistance and opposition toward hazardous waste management initiatives. This mistrust can hinder the development of new facilities or the adoption of new practices, even

when they are environmentally responsible. Misconceptions about hazardous waste management also contribute to negative perceptions. For example, the public may not fully understand the benefits of certain waste management technologies, such as incineration, or may incorrectly associate hazardous waste facilities with health risks.

Additionally, the "Not In My Backyard" (NIMBY) phenomenon further complicates efforts to establish necessary facilities (Eguchi, 2020). Communities may oppose the placement of hazardous waste management sites near them, making it difficult to find suitable locations and delaying or preventing the implementation of sustainable waste management solutions. Addressing these perception challenges is crucial for advancing effective and environmentally responsible hazardous waste management.

Component 5: Complex regulations

This component consists of three barriers which were B1, B2 and B3. This component explained 6.738% of the total variance. Regulatory complexity remains a recognized barrier, particularly for SMEs. However, its lower variance contribution suggests that regulation alone does not prevent sustainability adoption, but rather interacts with organizational capability and clarity of guidance.

Complex regulations pose a considerable challenge to sustainable hazardous waste management across industries, particularly affecting small and medium-sized enterprises (SMEs). These regulations often create confusion and uncertainty about legal requirements, which can lead to unintentional non-

compliance and adverse environmental and health consequences. SMEs, in particular, struggle with understanding these intricate rules due to limited access to expertise and resources. Additionally, the high costs associated with compliance, such as investments in proper waste management systems, training, and legal consultation, can strain their budgets, further discouraging adherence.

The significant regulatory burden, including administrative tasks and detailed reporting requirements, can overwhelm smaller organizations, diverting attention and resources from adopting more sustainable practices. This combination of factors hinders progress in achieving effective and environmentally responsible hazardous waste management (Caldera et al., 2019).

Component 6: Lack of infrastructure

This component consists of three barriers which were B4, B5 and B6. This component explained 5.068% of the total variance. Infrastructure limitations were significant but not dominant. This challenges the conventional assumption that infrastructure scarcity is the primary barrier in developing countries.

A lack of infrastructure presents a significant challenge to sustainable hazardous waste management, as it undermines the ability of industries to handle waste effectively and safely. One key issue is the limited availability of collection services, which often fail to adequately support industries, particularly those located far from treatment or recovery facilities. This can result in excessive on-site storage of hazardous waste, increasing the risk of environmental contamination and health hazards.

Additionally, the scarcity of specialized treatment or recovery facilities complicates sustainable waste management efforts (Kumar et al., 2023).. Many facilities are equipped to handle only specific types of hazardous waste, which becomes problematic for industries that generate diverse waste streams. Managing such a variety often requires navigating complex arrangements with multiple facilities, consuming significant time and resources. These infrastructure gaps impede the adoption of efficient and sustainable hazardous waste management practices, exacerbating risks to both the environment and human health.

Component 7: Uncertainty about hazardous waste

This component consists of three barriers which were B25, B26 and B27. This component explained 4.031% of the total variance. This component highlights uncertainty regarding waste characteristics and recovery technologies. It reinforces the argument that information asymmetry and risk perception discourage sustainability investments.

Uncertainty about hazardous waste significantly hinders sustainable waste management by creating challenges in compliance, risk management, reputation, and financial planning. When industries lack clear knowledge about the types of hazardous waste they generate or the sustainable technologies available to manage it, they face difficulty in adhering to environmental regulations (Raeisi & Ghoushchi, 2022). This uncertainty can result in unintentional non-compliance, leading to legal penalties and fines. Additionally, it impairs effective risk

management, as industries struggle to identify and mitigate potential threats to human health and the environment, increasing the likelihood of accidents and spills.

From a reputational standpoint, unclear waste management practices can damage a company's image, as they may appear negligent in their handling of hazardous materials. Financially, the ambiguity complicates budgeting and resource allocation for proper waste management, potentially leading to inadequate or inefficient practices that incur greater costs over time (Moktadir & Ren, 2023). Addressing this uncertainty is critical for industries to adopt effective, safe, and sustainable hazardous waste management practices.

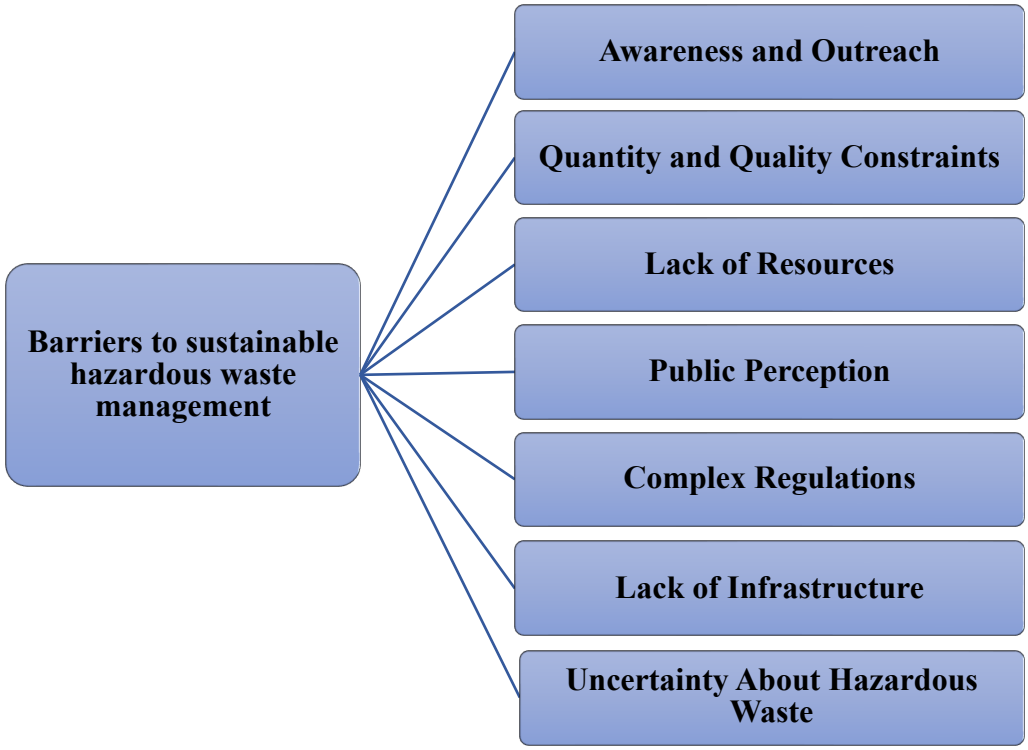

Figure 4.8: Barriers to sustainable hazardous waste management

4.9 Communalities (for CSFs)

For the purpose of this study, total 103 responds were collected which is slightly above the recommended sample size of 100 by Gorsuch (1983) and Kline (1979, p. 40). In addition, the communalities of variables obtained were ranged between 0.591 – 0.900 (Table 4.15) with 96.67% (29/30) of them above 0.6, therefore, the sample size of 103 is considered acceptable for factor analysis.

Table 4.15: Communalities (CSFs)

Critical Success Factors	Initial	Extraction
Technology stability of the hazardous wastes beneficiaries	1.000	.799
Financial capabilities of hazardous wastes beneficiaries	1.000	.729
Consistent demand from beneficiaries	1.000	.657
The economic gain	1.000	.635
The environmental benefits	1.000	.535
The benefits gained	1.000	.747
Customer's pressure	1.000	.765
Authority's pressure	1.000	.650
Public's pressure	1.000	.553
ISO14001 certification	1.000	.855
Sustainability efforts is part of the requirements under ISO14001]	1.000	.884
Company promote sustainability efforts due to ISO14001 certification	1.000	.823

Sustainability efforts can build good company image	1.000	.879
Sustainability efforts can gain popularity for the company	1.000	.838
Sustainability efforts can gain trust from customers	1.000	.857
Top management should encourage sustainability efforts	1.000	.705
Top management should promote sustainability efforts	1.000	.767
Top management should provide necessary resources to support the sustainability efforts	1.000	.779
Incentive from government	1.000	.905
Reward from government	1.000	.884
Incentive or reward	1.000	.897

4.9.1 KMO and Bartlett's test (for CSFs)

To determine the strength of the relationship among the factors, Kaiser-Meyer-Olkin (KMO) test were used. Table 4.16 provides results from a Kaiser-Meyer-Olkin (KMO) test, KMO values closer to 1.0 are consider ideal while values less than 0.5 are unacceptable. The KMO measure of sampling adequacy obtained is 0.884, which indicates that a high proportion (88.4%) of the variance in the data can be attributed to the underlying factors. This result suggests that the data is appropriate for factor analysis.

The table also provides results for the approximate chi-square test, which is used to assess the overall fit of the factor analysis solution. The test statistic is 1992.190, the degrees of freedom (df) are 210, and the significance (Sig) is 0.000. The low significance value indicates that the factor analysis solution is a good fit for the data, with a high degree of statistical confidence.

Table 4.16: KMO and Bartlett's test (CSFs)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.884
Bartlett's Test of Sphericity	Approx. Chi-Square	1992.190
	df	210
	Sig.	.000

4.9.2 Principal component analysis (CSFs)

For Principal Component Analysis (PCA), the eigenvalue was set at 1, therefore components with eigenvalues greater than 1 are retained while those component with lower eigenvalues are discarded (Wai et al., 2012). After extracting principal components, Varimax rotation are applied to improve interpretability. The factor loading value was set at 0.5, ensuring that each variable has a higher loading on one principal component while minimizing its loadings on others.

Table 4.17 data represent the output of a principal component analysis with 5 components. The table shows the amount of variance explained by each component, both before and after rotation. The first component explains the most variance (46.467%), followed by the second (12.159%) and third (7.501%). These three components together explain almost 52% of the variance. The fourth and fifth

components each explain around 5-6% of the variance. The cumulative percentage of variance explained have to be more than 50% to be considered as acceptable (Meyers et al., 2006). In this case, the cumulative percentage of variance explained was 76.883%, which is acceptable.

Table 4.18 displays the rotated component matrix resulting from a principal component analysis with varimax rotation and Kaiser normalization. It includes 5 components which associated with 21 critical success factors (CSF) related to sustainable hazardous waste management.

Each cell in the matrix shows the correlation between a specific CSF and a specific component. The higher the correlation coefficient, the stronger the relationship between the CSF and the component. The components are not labeled, but they represent underlying factors that explain the common variance among the CSFs.

Table 4.17: Principal component analysis (CSFs)

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.758	46.467	46.467	9.758	46.467	46.467	4.447	21.174	21.174
2	2.553	12.159	58.626	2.553	12.159	58.626	3.307	15.75	36.924
3	1.575	7.501	66.127	1.575	7.501	66.127	3.118	14.846	51.770
4	1.226	5.839	71.965	1.226	5.839	71.965	2.755	13.119	64.889
5	1.033	4.917	76.883	1.033	4.917	76.883	2.519	11.994	76.883
6	0.959	4.569	81.452						
7	0.694	3.305	84.757						
8	0.589	2.806	87.563						
9	0.492	2.341	89.904						
10	0.414	1.969	91.874						
11	0.302	1.436	93.31						
12	0.252	1.2	94.51						
13	0.246	1.169	95.68						
14	0.216	1.028	96.708						
15	0.182	0.869	97.577						
16	0.146	0.696	98.272						
17	0.105	0.498	98.77						
18	0.097	0.46	99.23						
19	0.061	0.29	99.521						
20	0.058	0.277	99.798						
21	0.043	0.202	100						

Table 4.18: Rotated component matrix (CSFs)

Rotated Component Matrix*						
Critical Success Factors		Component				
		1	2	3	4	5
C1	The success of sustainability efforts rely on the technology stability of the hazardous wastes beneficiaries			0.777		
C2	The success of sustainability efforts rely on the financial capabilities of hazardous wastes beneficiaries			0.802		
C3	The success of sustainability efforts rely on the consistent demand from beneficiaries			0.734		
C4	The economic gain is one of the key factor driving the sustainability efforts					0.547
C5	The environmental benefits is one of the key factor driving the sustainability efforts					
C6	The benefits gained will affects the company's aggressiveness on sustainability efforts					0.815
C7	Customer's pressure is one of the key factor driving the sustainability efforts		0.63			
C8	Authority's pressure is one of the key factor driving the sustainability efforts					0.598
C9	Public's pressure is one of the key factor driving the sustainability efforts					
C10	ISO14001 certification is one of the key factor driving the sustainability efforts		0.821			
C11	Sustainability efforts is part of the requirements under ISO14001		0.843			
C12	Company promote sustainability efforts due to ISO14001 certification		0.825			
C13	Sustainability efforts can build good company image				0.747	
C14	Sustainability efforts can gain popularity for the company				0.802	
C15	Sustainability efforts can gain trust from customers				0.839	
C16	Top management should encourage sustainability efforts	0.558				
C17	Top management should promote sustainability efforts	0.597				
C18	Top management should provide necessary resources to support the sustainability efforts	0.635				
C19	Incentive from government could improve the sustainability efforts	0.916				
C20	Reward from government could improve sustainability efforts	0.902				
C21	Incentive or reward could motivate more industries to participate in sustainability effort	0.912				
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.* * Rotation converged in 6 iterations.						

4.9.3 Critical success factors for sustainable hazardous waste management

Based on the result of principal component analysis (Table 4.17) and rotated component matrix (Table 4.18), it can be inferred that:

Component 1 is associated with CSF related to “organizational drivers”;

Component 2 is associated with CSF related to “external obligations”;

Component 3 is associated with CSF related to “beneficiary’s capabilities ”;

Component 4 is associated with CSF related to “positive reputation”;

Component 5 is associated with CSF related to “organizational imperatives”.

Component 1: Organizational drivers

This component consists of six barriers which were C16, C17, C18, C19, C20 and C21. This component explained 21.174% of the total variance. This component confirms that leadership support, internal commitment, and organizational culture are decisive enablers. This finding strongly aligns with prior studies that identify management commitment as a prerequisite for environmental performance improvement.

Organizational drivers significantly influence sustainable hazardous waste management by shaping an organization's priorities, strategies, and operations. These drivers encompass both internal and external forces that steer organizations toward adopting responsible waste management practices (Leonidou et al., 2017).

Leadership commitment plays a vital role, as top management's dedication ensures sustainability becomes a strategic focus through resource allocation, measurable goals, and fostering a culture of environmental responsibility (Ahsan, 2024). Regulatory compliance serves as a critical external driver, motivating organizations to adhere to laws and standards, thus avoiding penalties while adopting best practices in waste handling.

Corporate Social Responsibility (CSR) initiatives further encourage businesses to reduce hazardous waste, enhancing their reputation and fulfilling societal expectations. Technological advancements enable organizations to innovate in waste treatment and tracking, minimizing environmental impact and reducing costs. Additionally, growing pressure from customers and stakeholders demands environmentally responsible practices, compelling organizations to adopt sustainable waste management to maintain a positive image and align with market and societal values (Hajam et al., 2023).

Component 2: External obligations

This component consists of four barriers which were C7, C10, C11 and C12. This component explained 15.75% of the total variance. Regulatory and customer pressure act as external motivators. However, their secondary position suggests that compliance pressure alone is insufficient without internal leadership commitment.

External obligations play a pivotal role in enhancing sustainable hazardous waste management by guiding organizations toward adopting environmentally responsible practices. Regulatory requirements imposed by governments ensure strict adherence to hazardous waste disposal guidelines, which mitigate environmental harm and promote sustainability (Sigman, 2021).

Similarly, growing customer awareness and demand for eco-friendly practices compel businesses to adopt sustainable waste management to preserve their market reputation. These external pressures also encourage innovation, driving companies to invest in advanced technologies for safer waste disposal and

recycling, ultimately reducing long-term environmental impact (Creadore & Castaldi, 2022). Furthermore, external obligations foster accountability and transparency in waste management reporting, enabling better monitoring and continual improvement.

Component 3: Beneficiary's capabilities

This component consists of three barriers which were C1, C2 and C3. This component explained 14.846% of the total variance. This component highlights the role of waste receivers and recovery partners. Its moderate importance indicates that sustainability depends on ecosystem readiness, not solely on waste generators.

Beneficiaries' capabilities, encompassing their skills, resources, and expertise, play a crucial role in advancing sustainable hazardous waste management. Strengthening these capabilities enables more effective practices, as beneficiaries with enhanced technical knowledge can implement safer handling, treatment, and disposal methods, reducing environmental impact (Mmereki et al., 2014).

A strong understanding of regulatory requirements ensures better compliance with laws and standards, minimizing legal risks and violations. Advanced capabilities also foster innovation, allowing beneficiaries to develop and adopt sustainable technologies for waste reduction and recycling. Improved education and training heighten awareness, promoting informed decision-making and greater community involvement. Moreover, beneficiaries with strong organizational skills can allocate resources more efficiently, ensuring cost-effective and impactful waste management. Enhanced risk assessment abilities further

support robust strategies to prevent accidents and environmental harm, contributing to overall sustainability (Simbolon et al., 2017).

Component 4: Positive reputation

This component consists of three barriers which were C13, C14 and C15. This component explained 13.119% of the total variance. Reputation-driven sustainability supports stakeholder theory, where companies pursue sustainability to gain legitimacy, trust, and competitive advantage.

A positive reputation plays a vital role in advancing sustainable hazardous waste management by fostering trust, collaboration, and support from key stakeholders. It builds confidence among customers, regulators, and local communities, encouraging cooperation and backing for waste management initiatives (Scott et al., 2023).

Reputable organizations are more likely to form partnerships with other businesses, environmental groups, and government agencies, facilitating the exchange of best practices and resources. Such a reputation also attracts investment, as environmentally responsible companies appeal to investors focused on sustainability, enabling access to funds for advanced waste management technologies.

Regulatory processes can become more streamlined for organizations with a strong environmental track record, easing compliance efforts. Moreover, customer loyalty increases as consumers prefer companies that prioritize sustainability, providing additional revenue that can be reinvested in waste

management improvements. Lastly, a positive reputation enhances employee morale, promoting satisfaction and retention, which further supports the organization's sustainable practices (Karim & Rabiul, 2022).

Component 5: Organizational imperatives

This component consists of three barriers which were C4, C6 and C8. This component explained 11.994% of the total variance. This component reflects the integration of sustainability into operational efficiency and long-term competitiveness. It indicates that organizations are more likely to sustain initiatives when environmental benefits align with economic and operational objectives.

Organizational imperatives, encompassing both compliance obligations and operational benefits, are fundamental to advancing sustainable hazardous waste management. Compliance with legal requirements and adherence to industry standards ensure that organizations operate within regulatory frameworks, avoid penalties, and implement best practices for safety and environmental protection.

Beyond compliance, these imperatives enable organizations to leverage significant benefits, such as improved operational efficiency through waste reduction, enhanced recycling, and cost-effective disposal (Werimon et al., 2023). A commitment to responsible waste management strengthens an organization's reputation, attracting customers and investors who prioritize environmental responsibility, while fostering innovation in waste reduction technologies provides a competitive market advantage. By integrating sustainability into core operations, organizations embed environmental considerations into strategic decision-making

and promote employee engagement, cultivating a culture of accountability and responsibility that drives effective and sustainable waste management practices (Pekaar & Demerouti, 2023).

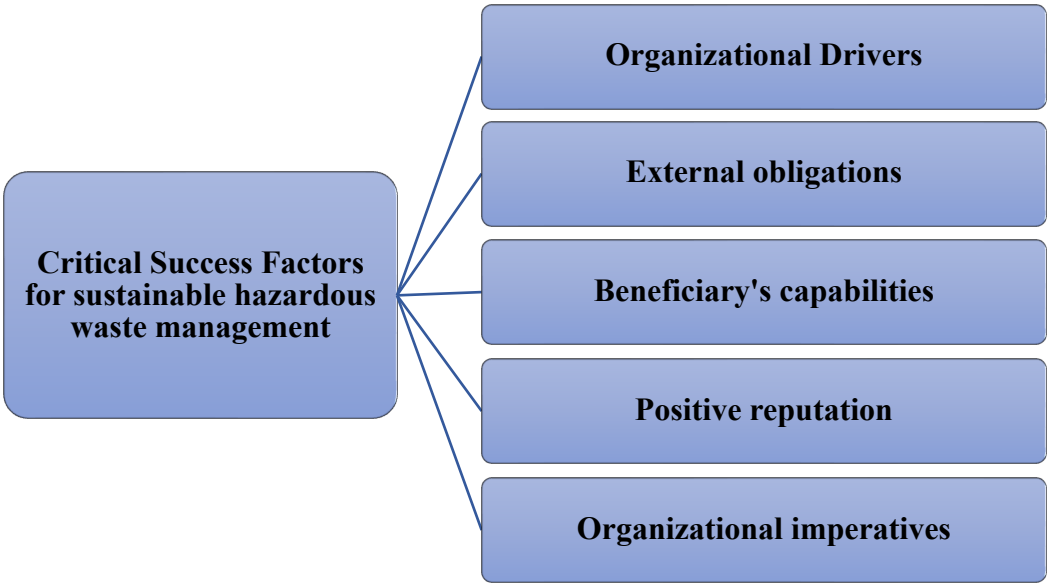

Figure 4.9: Critical success factors for sustainable hazardous waste management

4.10 Data validation by industry expert

The gathered responses and findings were reviewed by an industry expert for validation (Appendix C). Ms. Siti ‘Aisyah Binti Tajudin, a Certified Environmental Professional in Scheduled Waste Management (CePSWaM) at MEMC Electronic Materials Sdn. Bhd., confirmed that the data is relevant and accurately reflects current industry trends and realities. She noted that cost-effectiveness is a pivotal factor in scheduled waste management and emphasized the necessity of close

collaboration with scheduled waste contractors to enhance understanding of the overall waste management framework.

4.11 Discussion of noteworthy findings

Two notable unexpected findings emerge:

a) Waste quantity and quality were not dominant barriers, contradicting common assumptions in hazardous waste literature.
b) Infrastructure limitations were less critical than awareness and leadership, suggesting that sustainability challenges are more organizational than technical.

These findings indicate that Malaysia's challenge lies less in capacity building and more in mindset transformation, leadership alignment, and institutional learning.

4.12 Implications for practice and policy

The findings suggest that effective sustainable hazardous waste management requires a dual strategy:

a) Barrier reduction through awareness programmes, regulatory clarification, and information sharing.
b) CSF reinforcement through leadership engagement, incentives, and reputational drivers.

This integrated approach bridges the gap between regulatory intent and industrial practice.

4.13 Chapter summary

This chapter has systematically linked empirical findings to the research objectives, interpreted statistical outcomes, compared results with prior studies and theories, and examined unexpected findings. The results confirm that sustainable hazardous waste management in Malaysia is primarily constrained by organizational and cognitive barriers, while success is driven by leadership commitment and strategic alignment rather than technical feasibility alone.

CHAPTER 5.0

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study was undertaken to systematically examine the barriers and critical success factors (CSFs) influencing the adoption of sustainable hazardous waste management practices in Malaysia. Guided by clearly defined research objectives and supported by empirical evidence, the study has successfully fulfilled its intended aims and contributes meaningful insights to both academic literature and industry practice.

5.2 Achievement of Research Objective 1

The first objective sought to analyze the common barriers and critical success factors affecting sustainable hazardous waste management through a systematic review of literature, site visits, and engagement with competent personnel. This objective was achieved by synthesizing global and local studies with contextual industry observations. The literature review established that challenges such as regulatory complexity, lack of infrastructure, financial constraints, limited awareness, and stakeholder resistance are consistently reported in developing and emerging economies, including Malaysia. Similarly, success factors such as

leadership commitment, regulatory pressure, economic incentives, and reputational benefits were identified as key drivers of sustainability adoption.

By integrating literature findings with preliminary industry engagement, the study ensured that the conceptual framing of barriers and CSFs was grounded not only in theory but also in practical realities. This provided a robust foundation for subsequent empirical investigation and ensured strong alignment between theory and practice.

5.3 Achievement of Research Objective 2

The second objective aimed to identify the actual barriers and CSFs as perceived by competent personnel within Malaysian industries using survey data, statistical analysis, and expert validation. This objective was fully achieved through a structured survey administered to 103 experienced environmental professionals, followed by reliability testing and Principal Component Analysis (PCA).

Empirical results revealed seven key barrier components, with awareness and outreach emerging as the most dominant barrier. This finding indicates that limited understanding of sustainable hazardous waste management options, benefits, and recovery pathways poses a greater constraint than technical feasibility or waste characteristics. Financial constraints, regulatory complexity, lack of infrastructure, public perception, resource limitations, and uncertainty regarding waste characteristics were also identified as significant but secondary barriers.

Conversely, five CSF components were extracted, with organizational drivers—particularly top management commitment, leadership support, and

resource allocation—ranked as the most influential enablers. External obligations, including regulatory and customer pressure, as well as incentives, corporate reputation, and beneficiary capabilities, were also found to play critical roles. Importantly, expert validation confirmed that these findings accurately reflect current industry practices and decision-making considerations, thereby strengthening the credibility and applicability of the results.

5.4 Achievement of Research Objective 3

The third objective focused on proposing recommendations to enhance sustainable hazardous waste management. Based on the empirical findings, the study demonstrates that effective improvement requires a dual and integrated strategy: reducing key barriers while simultaneously strengthening critical success factors.

The recommendations emphasize targeted awareness and training programmes, clearer regulatory guidance, financial incentives, infrastructure development, and stronger collaboration between waste generators, contractors, and beneficiaries. These recommendations are directly derived from validated findings, ensuring their relevance and feasibility for real-world implementation.

5.5 Novelty and key contributions of the study

The primary novelty of this research lies in its integrated empirical framework that simultaneously examines barriers and critical success factors within the specific regulatory and industrial context of Malaysia. Unlike many prior studies that focus on either barriers or success factors in isolation, this study provides a holistic, data-

driven understanding of how these elements interact to influence sustainability adoption.

Methodologically, the use of PCA to extract latent components, combined with expert validation, represents a significant contribution by strengthening both statistical robustness and practical relevance. Conceptually, the study advances existing knowledge by demonstrating that awareness, leadership commitment, and organizational drivers outweigh purely technical considerations in determining sustainability outcomes. Practically, the findings bridge the gap between regulatory intent and industrial practice by offering actionable insights tailored to Malaysian industries.

Overall, this study contributes to the body of knowledge on sustainable hazardous waste management by providing empirically validated, context-specific evidence that supports Malaysia's transition toward circular economy principles, improved environmental performance, and long-term sustainability. The findings are valuable for policymakers, regulators, and industry practitioners seeking to design more effective strategies for sustainable hazardous waste management.

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APPENDICES

APPENDIX A: Survey questionnaire

Barriers and critical success factors towards sustainable hazardous waste management

Dear Professor/Doctor/Sir/Madam,

Greetings. I'm a candidate currently pursuing a Master's degree in Universiti Tunku Abdul Rahman (UTAR). I'm currently conducting research to identify the factors affecting sustainable hazardous waste management efforts.

Hazardous wastes (also known as 'Scheduled Wastes' in Malaysia) are wastes with properties that make them dangerous or potentially harmful to human health or the environment. Managing hazardous wastes in a sustainable manner could significantly reduce the volume of wastes going to the landfill site and therefore reduce the burden to the environment. This is achievable via efforts such as waste recovery, waste-to-energy, and waste-to-raw material. Despite the potential economic and environmental benefits, sustainable hazardous waste management efforts among industries still relatively weak. Therefore, this study is aimed to identify the underlying factors contributing to the low sustainability efforts in managing the hazardous wastes.

In order to ensure the success of the comprehensive analysis, I, therefore, seek your kind support to complete this survey questionnaire. Rest assured, all the data collected will be kept confidential and anonymous.

Thank you.

Yours sincerely,
Chin Yik Heng

* Indicates required question

1. I hereby consent on my voluntary participation in this survey which will be conducted anonymously. (As proposed accordingly by Personal Data Protection Statement - UTAR) *

   Mark only one oval.

   - ◯ Yes - proceed to the next section
   - ◯ No - responses will be discarded

Section A: Demographic Information

2. Gender *

   Mark only one oval.

   - ◯ Male
   - ◯ Female

3. Age group *

   Mark only one oval.

   - ◯ 20 - 29
   - ◯ 30 - 39
   - ◯ 40 - 49
   - ◯ 50 - 59
   - ◯ 60 - 69

4. Year(s) of service in the current organization *

Mark only one oval.

- ◯ < 1 year
- ◯ 1 - 5 years
- ◯ 6 - 10 years
- ◯ > 10 years

5. Position level

Mark only one oval.

- ◯ Junior Executive/Engineer
- ◯ Senior Executive/Engineer
- ◯ Management
- ◯ Senior Management

6. Educational qualification *

Mark only one oval.

- ◯ PhD
- ◯ Masters
- ◯ Degree
- ◯ Diploma
- ◯ STPM
- ◯ SPM

7. Location of organization *

Mark only one oval.

- ◯ Kedah
- ◯ Penang
- ◯ Perak
- ◯ Selangor
- ◯ Kuala Lumpur
- ◯ Negeri Sembilan
- ◯ Melaka
- ◯ Johor
- ◯ Other

8. Type of organization *

Mark only one oval.

- ◯ Government
- ◯ Semi-government
- ◯ Private
- ◯ Non-profit Organisation

Section B: Barriers

This section outline the barriers affecting the sustainable hazardous waste management efforts. Please rate the degree to which you agree or disagree with each of the following statements.

9. B1. Complexity of legislation *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
The law(s) related to sustainable hazardous waste management is hard to understand	◯	◯	◯	◯	◯
The law(s) related to sustainable hazardous waste management is hard to comply with	◯	◯	◯	◯	◯
The law(s) related to sustainable hazardous waste management is too extensive	◯	◯	◯	◯	◯

10. B2. Lack of infrastructure *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Company does not have the necessary system to manage the hazardous wastes in sustainable manner	◯	◯	◯	◯	◯
Company does not have the necessary technologies to manage the hazardous wastes in sustainable manner	◯	◯	◯	◯	◯
Company does not have the necessary facilities to manage the hazardous wastes in sustainable manner	◯	◯	◯	◯	◯

11. B3. Hazardous waste quantity *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
The quantity of hazardous wastes generated is low	◯	◯	◯	◯	◯
The quantity of hazardous wastes generated is insufficient to be reused by others	◯	◯	◯	◯	◯
It takes very long to accumulate the quantity of hazardous wastes needed by others	◯	◯	◯	◯	◯

12. B4. Hazardous waste quality *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
The content of hazardous wastes generated are inconsistent	◯	◯	◯	◯	◯
The hazardous wastes generated are not suitable to be reused for other purposes	◯	◯	◯	◯	◯
The hazardous wastes generated are too dangerous to be reused	◯	◯	◯	◯	◯

13. B5. Lack of awareness about environmental sustainability *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Majority of employees do not aware of the environmental impact caused by hazardous wastes	◯	◯	◯	◯	◯
Majority of employees do not aware that hazardous wastes can be managed in a sustainable manner	◯	◯	◯	◯	◯
Majority of employees do not aware of the benefits of managing hazardous wastes in sustainable manner	◯	◯	◯	◯	◯

14. B6. Poor networking *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
There was no effort in identifying potential beneficiary of our hazardous wastes					
There was no proper channel to identify the potential beneficiary of our hazardous wastes					
No one had ever showed interest on our hazardous wastes					

15. B7. Public resistance *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Company worry about the negative perception of public about sustainable hazardous wastes management					
Company worry about public's protest against sustainable hazardous wastes management					
Public opinion affects the company's decision					

16. B8. Financial constraints *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Company does not have budget allocation to support sustainability efforts					
Company not willing to invest on sustainability efforts					
Sustainability efforts are impossible without financial investment					

17. B9. Lack of information *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
We are uncertain about the characteristics of our hazardous wastes	⬭	⬭	⬭	⬭	⬭
We are uncertain about how others can benefit from our hazardous wastes	⬭	⬭	⬭	⬭	⬭
We are uncertain about the technologies used to manage hazardous wastes in sustainable manner	⬭	⬭	⬭	⬭	⬭

18. B10. Insufficient resources *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
There is no individual who is knowledgeable about sustainable hazardous wastes management	⬭	⬭	⬭	⬭	⬭
There is no dedicated personnel responsible for hazardous wastes management	⬭	⬭	⬭	⬭	⬭
Company not willing to allocate resources for sustainable hazardous wastes management	⬭	⬭	⬭	⬭	⬭

Section C: Critical Success Factors

This section outline the critical success factors affecting the sustainable hazardous waste management efforts. Please rate the degree to which you agree or disagree with each of the following statements.

19. C1. The readiness of the hazardous waste beneficiary *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
The success of sustainability efforts rely on the technology stability of the hazardous wastes beneficiaries	◯	◯	◯	◯	◯
The success of sustainability efforts rely on the financial capabilities of hazardous wastes beneficiaries	◯	◯	◯	◯	◯
The success of sustainability efforts rely on the consistent demand from beneficiaries	◯	◯	◯	◯	◯

20. C2. Benefits gained from sustainability efforts *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
The economic gain is one of the key factor driving the sustainability efforts					
The environmental benefits is one of the key factor driving the sustainability efforts					
The benefits gained will affects the company's aggressiveness on sustainability efforts					

21. C3. Stakeholder's pressure *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Customer's pressure is one of the key factor driving the sustainability efforts					
Authority's pressure is one of the key factor driving the sustainability efforts					
Public's pressure is one of the key factor driving the sustainability efforts					

22. C4. Adoption of ISO14001 *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
ISO14001 certification is one of the key factor driving the sustainability efforts					
Sustainability efforts is part of the requirements under ISO14001					
Company promote sustainability efforts due to ISO14001 certification					

23. C5. Effects on corporate image *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Sustainability efforts can build good company image					
Sustainability efforts can gain popularity for the company					
Sustainability efforts can gain trust from customers					

24. C6. Commitment from top management *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Top management should encourage sustainability efforts					
Top management should promote sustainability efforts					
Top management should provide necessary resources to support the sustainability efforts					

25. C7. Incentives and reward *

Mark only one oval per row.

	strongly disagree	disagree	neither agree nor disagree	agree	strongly agree
Incentive from government could improve the sustainability efforts					
Reward from government could improve sustainability efforts					
Incentive or reward could motivate more industries to participate in sustainability					

26. Are there other barriers or critical success factors which are not listed above? *

APPENDIX B: Summary of responses

Barriers and critical success factors towards sustainable hazardous waste management

103 responses

Publish analytics

I hereby consent on my voluntary participation in this survey which will be conducted anonymously. (As proposed accordingly by Personal Data Protection Statement - UTAR)

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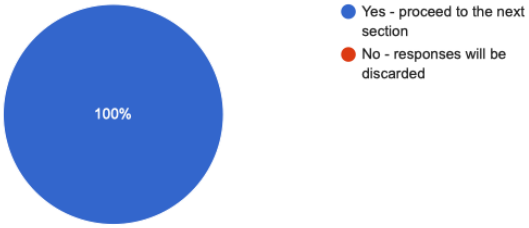
103 responses



Section A: Demographic Information

Gender

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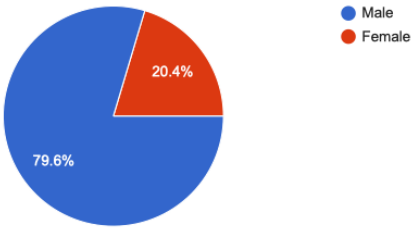
103 responses



Age group

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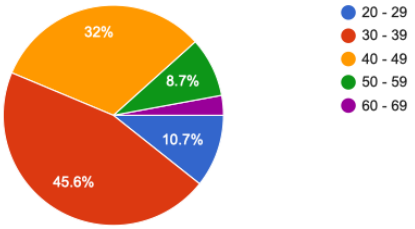
103 responses



Year(s) of service in the current organization

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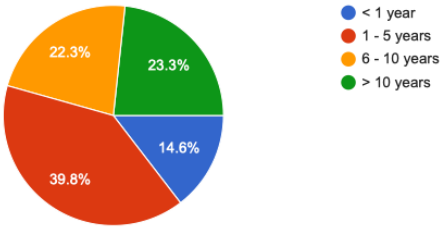
103 responses



Position level

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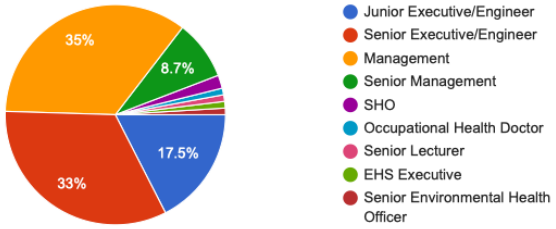
103 responses



Educational qualification

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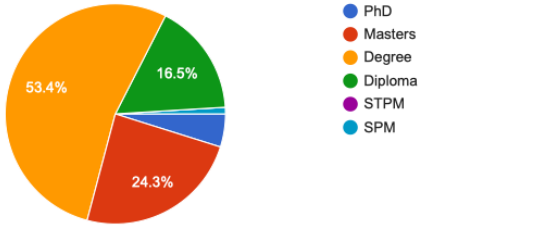
103 responses



Location of organization

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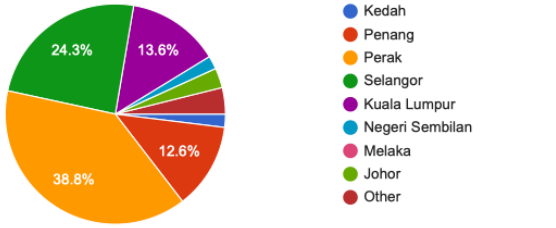
103 responses



Type of organization

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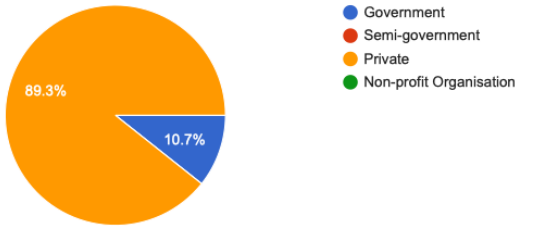
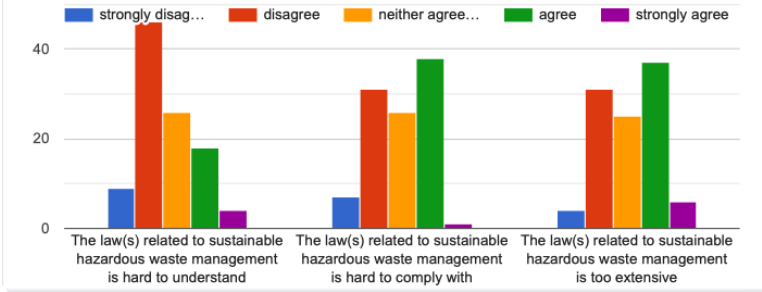
103 responses

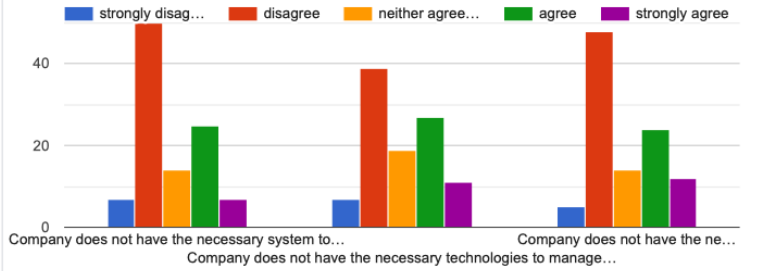


Section B: Barriers

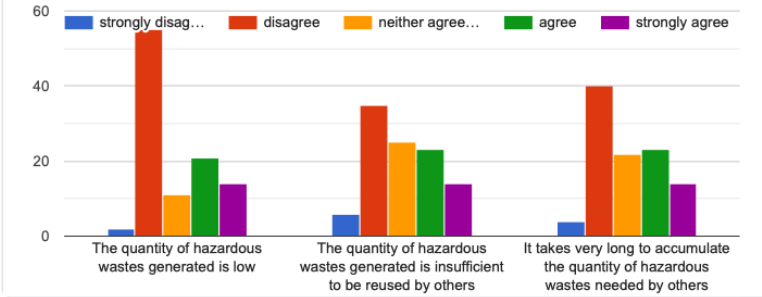
B1. Complexity of legislation



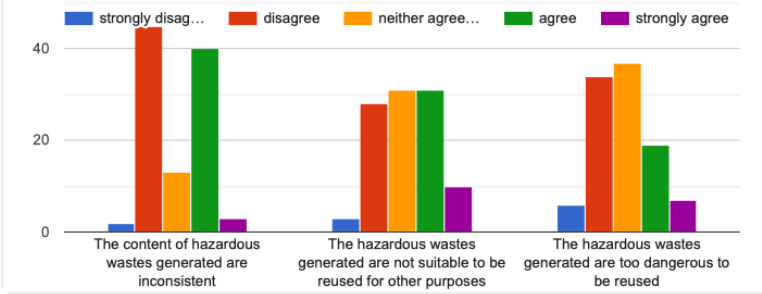
B2. Lack of infrastructure



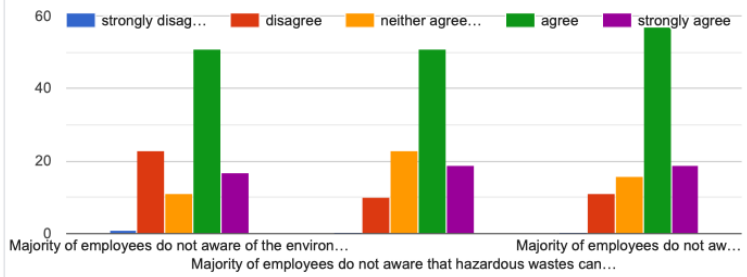
B3. Hazardous waste quantity



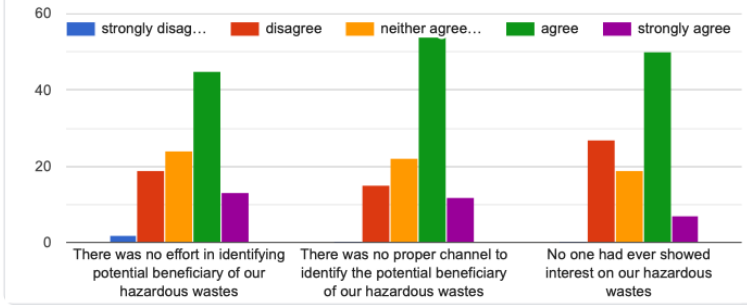
B4. Hazardous waste quality



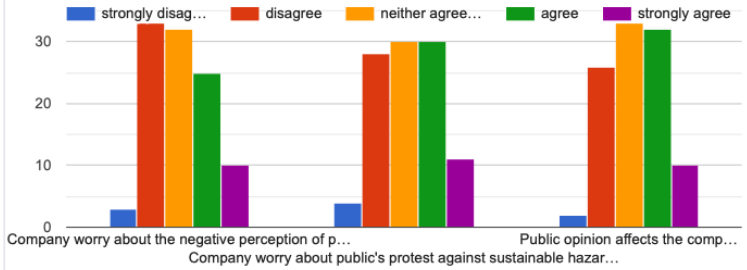
B5. Lack of awareness about environmental sustainability



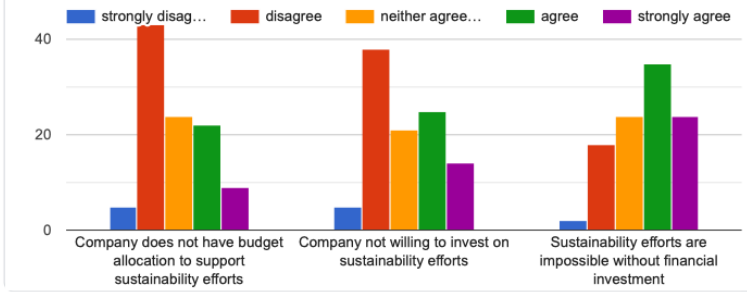
B6. Poor networking



B7. Public resistance

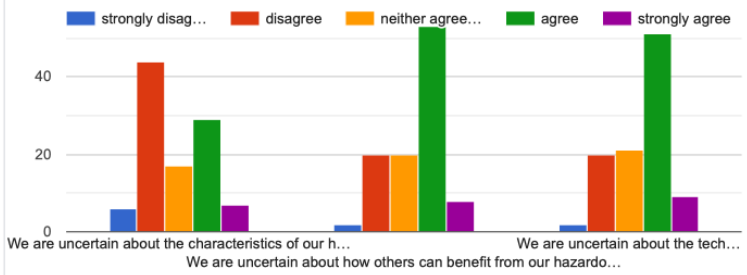


B8. Financial constraints



B9. Lack of information

Copy



B10. Insufficient resources

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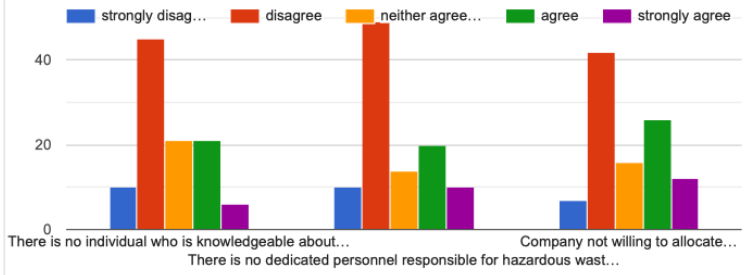
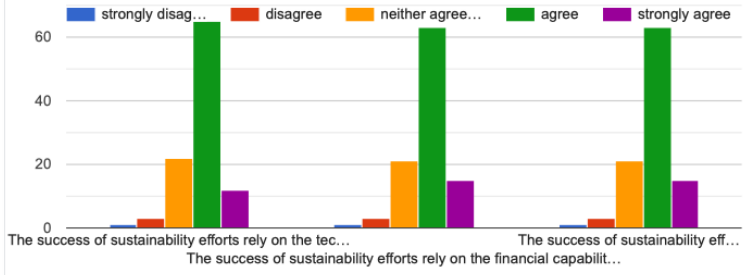


Section C: Critical Success Factors

C1. The readiness of the hazardous waste beneficiary

Copy



C2. Benefits gained from sustainability efforts

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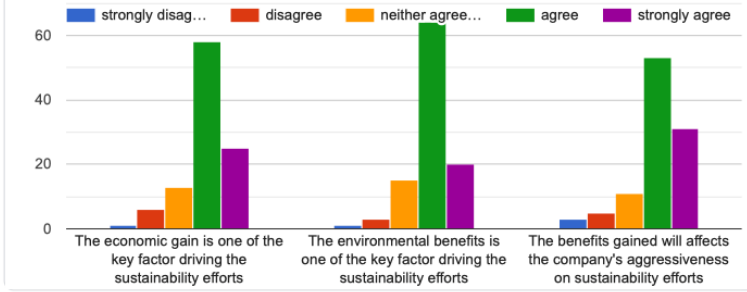
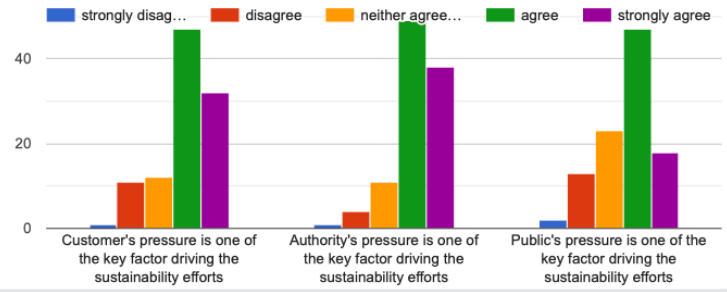


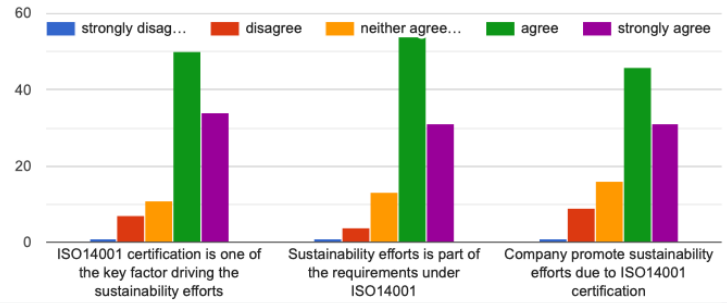
C3. Stakeholder's pressure

Copy



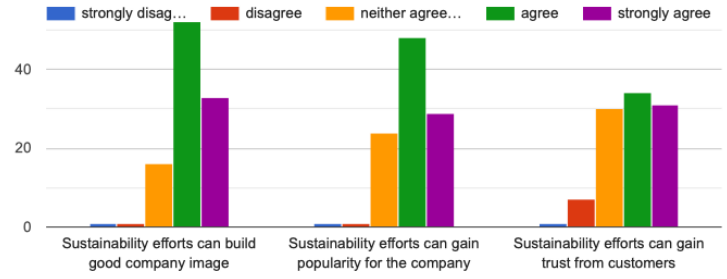
C4. Adoption of ISO14001

Copy



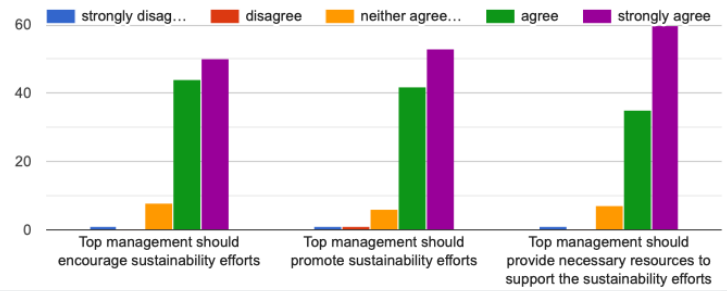
C5. Effects on corporate image

Copy



C6. Commitment from top management

Copy



C7. Incentives and reward

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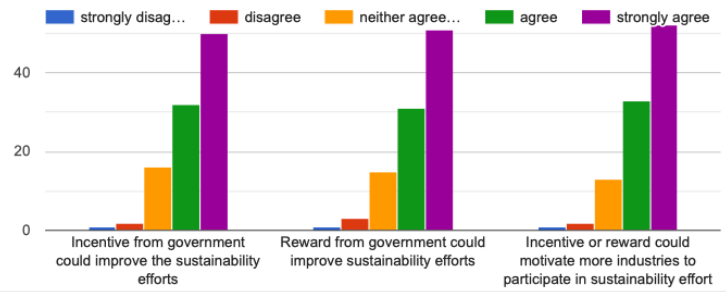

Are there other barriers or critical success factors which are not listed above?

103 responses

No

no

Nil

None

N/A

Not sure

Insufficient Licensed Contractor across Malaysia in managing the long list of SW.

1.The price to dispose for scheduled waste was very expensive.2.vendor not take for disposal for small quantity less than 1 tonne.

3R services is ineduquate

No

Development of resource compentency

Medical surveillqnce

Allocate budget for SDG for better tomorrow

Industries should invest financially to the universities/ research centres to work together on research in this issue.

practice are the main importance for sustainability

Language barrier between employees and management makes very hard to train employees on sustainable effort. Lack of general knowledge in foreign and local employees.

Language barrier with foreign workers may affect sustainability efforts as they may not truly understand the importance of sustainability.

nil

Na

No other barriers

Promotion and strighten the legal requirements

.

-

No.

N.A

Rewards from company to staff to encourage them to improve sustainability efforts

NO

Political redtapes and flip flop on enforcement

Availability of facility i.e there is NO waste treatment plant for SW403 and SW404 at Sabah and

Labuan

NIL

none

suggest dont use the colum neither agree or disagree

bureaucracy

Not enough facility in each state to do waste recovery

Nope

The supply and demand for hazardous waste is an important criteria to ensure the continuity of sustainability efforts

Debatable

No.

DOE SHALL STRICTLY ENSURE THAT ALL INDUSTRY PLAYER'S TO COMPLY WITH ALL THE LAW AS STIPULATED IN EQA 1974

Government enforcement need to be stepped up.

Nothing

NA

Politician and cronies always win and never get any punishment. For e.g Selangor water pollution and Johor. Still happen even news viral

Please look at Singapore how with Chinese, Malays & Indians , foreingers,, Rulers, Politicians, Local authorities Employers, Employees to mangage the environment well. there is fish in rivers, but we have repeated pollution of Sg Kim-Kim with fitting of school children. Is it in Keeping with Rukun Negara? .Allah /God is watching us. We have the EQA & know exactly the barriers or critical success factors & what to but we are not doing it . Our future is stolen. Can you please reply to me how your paper work can contribute to Malaysian Environmental Sustainability?. I pray to God there will be some change ? I went to Japan 35 years aoa to see the Minimata Bay with mercury poisoning. They told me please take care of Malaysia do not repeat Japanese mistake. Our river are constantly polluted. Allah/ God have mercy on us. Help us

process engineer who knows better about the hazardous waste characteristics should actively involved in evaluating the potential use of the waste to other waste beneficiary

Attitude of individual or organization.

N/a

Ni comments

How to improve knowledge hazardous waste management and environmental sustainability among employee and public.

Unlicensed operation and big time corruption is a major factor too.

Yes....some services monopoly by some organisation where you have to used it no matter what is the charges.

APPENDIX C: Industry expert validation

Subject: Request for Expert Validation of Survey Data

Dear Sir/Madam,

I hope this message finds you well. I am reaching out to seek your expertise in validating the data collected from a recent survey conducted as part of our ongoing research project. Given your extensive knowledge and experience in Scheduled Waste Management, your insights would be invaluable in ensuring the accuracy and relevance of our findings.

The survey aims to evaluate the barriers and critical success factors to sustainable hazardous waste management. We have compiled the preliminary data and are at a stage where expert evaluation can significantly enhance the reliability and applicability of the results.

We would greatly appreciate if you could review the attached survey data and provide your feedback on the following aspects:

1. **Relevance and Accuracy:** Are the gathered responses and findings relevant and accurately reflective of industry trends and realities?
2. **Comments and Suggestions:** Are there any data that are considered irrelevant or not accurately reflective of industry trends and realities? Are there any suggestions to further improve the presentation of the data?

Your feedback will not only contribute to the robustness of our study but also help in steering the subsequent phases of our research.

We are looking forward to your affirmative response and are more than willing to accommodate your schedule for a discussion or provide any additional information you may require.

Thank you very much for considering our request.

Warm regards,

Ts. Chin Yik Heng
Faculty of Engineering and Green Technology (FEGT)
Universiti Tunku Abdul Rahman (UTAR)
Jalan Universiti, Bandar Barat
31900 Kampar, Perak.
Tel: 016-5103011
Email: yhchin@utar.edu.my

REPLY SHEET

1. **Question:** Are the gathered responses and findings relevant and accurately reflective of industry trends and realities?

   Your Answer:

   Yes, the gathered responses and findings are relevant to the industry trends. As the industry player, the critical part on the schedule waste management will be the cost effectiveness.

2. **Question:** Are there any data that are considered irrelevant or not accurately reflective of industry trends and realities?

   Your Answer:

   The survey findings are mostly relevant.

3. **Question:** Are there any suggestions to further improve the presentation of the data?

   Your Answer:

   Suggest to engage with the waste disposal contractor, on how they manage the waste will be helpful to understand on the overall concept of the waste management.

Signature	
Name	Siti 'Aisyah Binti Tajudin
Position	ESH Engineer
CePSWaM Registration No.	CePSWAM/04997