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ENHANCING EFFICIENCY AND USER ENGAGEMENT IN RECYCLING COLLECTION POINTS: A COMPREHENSIVE FRAMEWORK FOR DESIGN AND LAYOUT IN IPOH

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ABSTRACT

Ipoh's recycling collection points face inefficiencies due to poor accessibility, unclear signage, and low user participation, limiting their effectiveness in waste management. Despite growing environmental awareness, existing studies often overlook the integration of user-friendly design, technology, and community engagement in optimising collection points. Addressing this gap, this study aims to enhance recycling infrastructure by identifying key design elements that influence user engagement and efficiency. A qualitative approach was adopted, involving literature reviews, case studies, and direct observations of selected collection points. The findings reveal that accessibility, technological integration, spatial organisation, and user incentives significantly impact participation. Smart bins, interactive displays, and clear signage improve usability, while community involvement fosters long-term engagement. Future research should explore the real-world implementation of smart technologies and conduct large-scale behavioural studies to validate proposed solutions. By refining design strategies and integrating digital solutions, Ipoh can establish a more efficient, inclusive, and sustainable recycling system.

Keywords: *Recycling, Waste management, User engagement, Sustainable practice, Ipoh infrastructure*

INTRODUCTION

Sustainable waste management is an increasing priority for urban areas worldwide, with recycling infrastructure playing a pivotal role in achieving this goal. In Ipoh, a city in Malaysia's Perak state, the urgency for efficient recycling systems is highlighted by the daily production of 2,942 tonnes of waste and limited disposal facilities, including 16 landfill sites and a single incinerator in Pulau Pangkor (Kementerian Pembangunan Kerajaan Tempatan, 2022). The situation underscores the necessity for robust recycling collection points to reduce landfill dependency and improve waste management systems (Bukhari & G. Sivapragasam, 2012). Recent research reveals growing environmental awareness in Ipoh, accompanied by efforts such as the Trash4Cash kiosk, which offers automated waste collection (Loh, 2023). However, existing recycling infrastructure faces challenges in design efficiency, user engagement, and accessibility (Salleh, 2023). Studies suggest that the strategic design of recycling collection points. Through optimised layouts, clear signage, and inclusive access, the strategic designcan significantly enhance user participation and satisfaction (Engkvist et al., 2016; Ibrahim, 2020).

Despite these insights, a critical research gap remains in adapting global best practices to the specific socio-cultural, logistical, and spatial contexts of cities like Ipoh. Current studies often lack a grounded, location-specific approach that considers community behaviour, local infrastructure limitations, and environmental education strategies within the design of recycling collection points (Rozaimy et al., 2017).

This study aims to bridge these gaps by focusing on the spatial design and functionality of recycling collection points in Ipoh. By examining the factors influencing user engagement, evaluating current infrastructure, and proposing innovative design frameworks, the research seeks to create user-centric, efficient systems. Objectives include identifying barriers to participation, analysing existing layouts, and recommending adaptive design solutions tailored to Ipoh's sociocultural and logistical characteristics.

Addressing these issues is essential not only for achieving higher recycling rates but also for fostering a community-driven approach to sustainability (Taraz et al., 2020). By integrating spatial planning principles with practical waste management needs, this research envisions an enhanced recycling landscape in Ipoh, one that aligns with global sustainability goals while addressing local challenges. This study's outcomes could serve as a model for other cities seeking to advance their recycling infrastructure and promote environmental stewardship.

Recycling and Waste Management

Recycling centres are pivotal to effective waste management systems, functioning as hubs for collecting, sorting, and processing recyclable materials. These facilities aim to divert waste from landfills and channel it into productive reuse, contributing to resource conservation and environmental sustainability (Mathew et al., 2023). Optimal design and functionality of the recycling centre are vital for achieving these goals. For instance, in Figure 1, features such as efficient traffic flow, intuitive layout designs, and safe operating environments ensure the smooth handling of materials and user satisfaction (Engkvist et al., 2016). International best practices further emphasize advanced technologies, such as automated sorting and waste-to-energy systems, which enhance operational efficiency while reducing environmental impact (Kim & Mauborgne, 2022). Despite these advancements, many urban recycling centres face challenges in adapting to growing demands and addressing local infrastructural limitations.

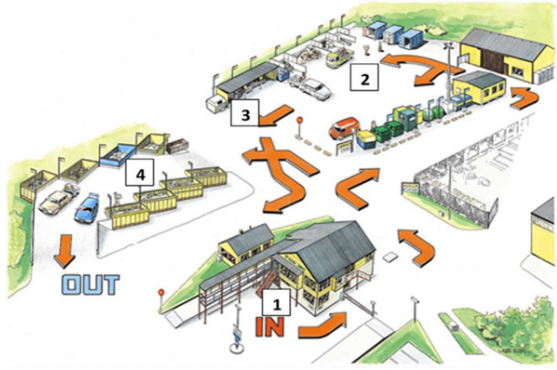


Figure 1. An Example of a Spread-out Recycling Centre
Source: Engkvist et al. (2016)

User Engagement in Recycling

User engagement is a cornerstone of successful recycling initiatives. Studies reveal that user-friendly designs, clear signage, and accessible facilities significantly enhance participation rates (Eklund et al., 2010). Behavioural factors, such as awareness, convenience, and incentives, play critical roles in influencing recycling habits (Johari et al., 2014). In Ipoh, innovations like the Trash4Cash drive-through kiosk have highlighted the importance of convenience and rewards in fostering user participation (Loh, 2023). However, barriers such as inadequate public awareness and complex recycling procedures often deter broader community involvement (Zuraida et al., 2021). Addressing these gaps requires a holistic approach, integrating user feedback and behavioural insights into the design and operation of recycling centres.

Sustainable Practices in Waste Management

As shown in Figure 2, sustainability in waste management encompasses reducing landfill dependence, minimising carbon emissions, and promoting resource recovery. Practices such as composting, recycling, and waste-to-energy technologies align with the United Nations Sustainable Development Goals, emphasising environmental responsibility and circular economy principles (Hannan, Begum et al., 2020). Cities like Ipoh have the potential to embed these principles by focusing on scalable and adaptable recycling solutions tailored to local needs.

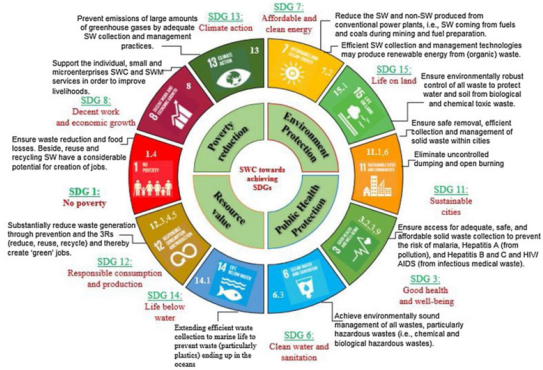


Figure 2. Linkages of the Solid Waste Collection Optimisation to Achieve Sustainable Development Goals

Source: Hannan, Begum, et al. (2020)

Sustainability also demands active community engagement and policy support to ensure long-term success. Integrating technology, such as Geographic Information Systems (GIS) for route optimization and smart waste bins for real-time monitoring, further bolsters sustainable waste management (Malakahmad & Khalil, 2011).

Ipoh's Waste Management Infrastructure

Ipoh's waste management infrastructure struggles to keep pace with the city's growing demands. Key challenges include insufficient collection points, inefficient logistics, and over-reliance on landfills (Moustairas et al., 2022). The absence of comprehensive source-separated waste systems exacerbates inefficiencies. Expanding recycling facilities and addressing infrastructure bottlenecks are crucial for improving waste management. Geographic factors and socio-economic conditions in Ipoh present unique challenges, necessitating localized strategies that incorporate urban integration and accessibility. For example, strategically located sorting stations and pedestrian-friendly recycling centres can enhance user participation and operational efficiency (Engkvist et al., 2016).

Lessons from International Best Practices

International case studies offer valuable insights for improving Ipoh's recycling systems. Sweden's advanced waste-to-energy technologies and Germany's efficient waste separation models serve as benchmarks for sustainable practices (Kim & Mauborgne, 2022). As illustrated in Figure 3, Japan's rigorous source-sorting and Singapore's resource recovery systems demonstrate the effectiveness of integrating technology and legislation into waste management frameworks. These models underscore the importance of robust infrastructure, public awareness, and government support in achieving high recycling rates.

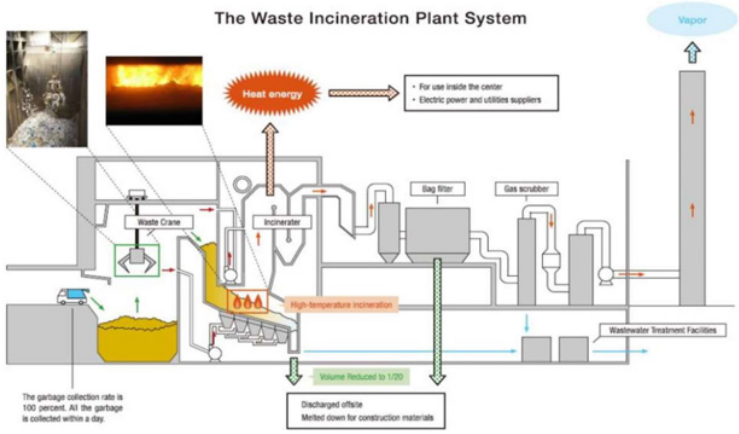


Figure 3. Waste Incineration Plant System in Japan
Source: Government of Japan (2015)

Adapting these lessons to Ipoh involves aligning innovative solutions with the city's socio-cultural and economic context, ensuring scalability and inclusivity in its recycling efforts.

RESEARCH METHODOLOGY

This study employs a systematic, multi-phase methodology to explore and enhance the design and efficiency of recycling collection points in Ipoh, with the broader aim of supporting sustainable waste management practices. The approach consists of three key phases: a literature review and content validation, qualitative data collection and analysis through case studies, and the development of a design framework—culminating in comprehensive documentation and reporting.

A qualitative approach was selected over a quantitative one due to the exploratory nature of the research questions. The study seeks to understand user experiences, spatial interactions, and design perceptions—elements best captured through in-depth, contextual, and interpretive methods rather than statistical generalizations. This approach allows for richer insights into behaviours and perceptions that directly influence recycling participation, particularly within the unique socio-cultural setting of Ipoh.

The first phase involves an in-depth review of the literature to identify key factors affecting user engagement at recycling points. Elements such as accessibility, signage, and layout are extracted and validated using relevance and quality criteria, aligned with Ipoh's local conditions. This phase addresses the first research objective: evaluating engagement factors.

The second phase employs a qualitative case study strategy, using stratified sampling to ensure a diverse representation of sites based on location, facility size, and user demographics. Standardisation of qualitative observations was ensured through the use of structured observation checklists, photographic documentation, and predefined criteria derived from the literature review. Observations focused on layout functionality, user navigation, and accessibility. Interviews with stakeholders and informal feedback from users were triangulated to ensure data reliability and thematic consistency.

The third phase focuses on developing a practical framework for design enhancement. Using insights from earlier phases, the framework emphasises accessibility, spatial logic, user experience, and technological integration. Collaborative feedback from stakeholders informed the final recommendations, ensuring contextual fit and feasibility.

The study concludes with detailed documentation of findings, design principles, and implementation strategies. This final phase ensures transparency, replicability, and practical application of the proposed solutions, contributing to policy development and sustainable urban planning efforts.

Overall, this structured methodology was grounded in qualitative inquiry and design analysis. This method provides an effective pathway for identifying actionable improvements in Ipoh's recycling infrastructure.

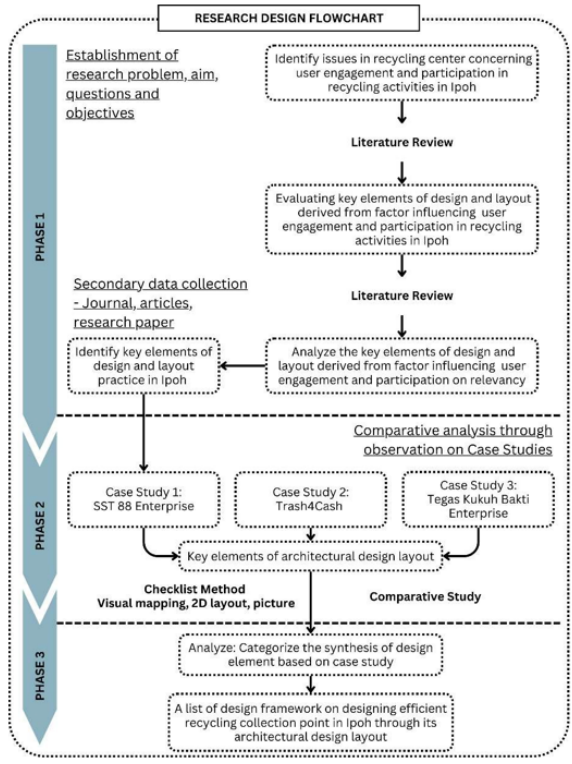


Figure 4. Research Design Flowchart

Source: Faiz, (2024)

FINDING ANALYSIS AND DISCUSSION

This chapter analyses the research findings aimed at improving the efficiency and user engagement of recycling collection points in Ipoh. Key factors influencing participation, such as accessibility, signage, and user behaviour, were identified through a comprehensive literature review and case studies. The current design and layout of collection points were evaluated, revealing inefficiencies and opportunities for enhancement. Using these insights, a framework for improved design was proposed, emphasizing user-friendly layouts and efficiency. The findings provide actionable recommendations to address challenges in Ipoh's recycling infrastructure, aiming to foster sustainable practices and enhance the city's waste management system.

Phase 1: Literature Review on Factors Influencing User Engagement and Participation and Key Elements of Design and Layout Derived from These Factors

This chapter explores factors influencing user engagement and participation at recycling collection points in Ipoh and identifies key design and layout elements derived from these factors. A literature review revealed the most impactful factors as Accessibility andConvenience (cited in 23 studies) and Technological Innovation, in (11 studies). These findings emphasize the need for easily accessible facilities and technology-driven solutions, such as automated systems, to encourage participation.

Other influential factors include Financial Incentives (9 studies) and Environmental Awareness and Education (5 studies), both play a significant role in motivating users. Strategic Location Planning emerged as another crucial factor, referenced in 10 papers, emphasizing the importance of optimal placement of collection points to enhance convenience. Other considerations include Efficient Logistics (7 studies) and the influence of Community Engagement and Trust (5 studies combined), though these were less emphasized compared to primary factors.

Secondary factors such as Design and Ergonomics, Gamification, and Economic Benefits were mentioned less frequently, suggesting they complement primary motivators rather than serve as standalone solutions.

These findings support a multidimensional approach to enhancing recycling participation in Ipoh. Prioritizing accessibility, technological integration, financial incentives, and educational initiatives can address barriers, foster engagement, and establish a sustainable recycling culture in the city.

As shown in Tables 1 and 2, the highlights key design and layout elements influencing user engagement at recycling collection points in Ipoh, emphasizing factors crucial to promoting effective participation. Accessibility and Convenience, cited 10 times, emerges as the most critical element, encompassing user-friendly design, layout optimization, and space utilization. These features demonstrate that tailored designs significantly enhance participation.

Environmental and Educational Impact and Public Education Campaigns, referenced 2 and 4 times respectively, underscore the role of awareness programs and effective communication in encouraging recycling behaviours. Elements such as community involvement, feedback, and clear signage reinforce the need for strong educational efforts.

Table 1. Factor Influencing User Engagement and Participation in Recycling Activities (Faiz, 2024)

fluencing	Accessibility & Convenience	Financial Incentives	Environmental Awareness & Education	Public Education Campaigns	Community Engagements & Social Influence	Design & Ergonomics	Strategic Location Planning	Technological Innovation	Trust & Transparency	Efficient Transport Systems	Gamification & Technological Integration
The Representation of User Access te Recycling Centres novese, A., & Piccolo, C. (2021)	✓						✓	✓		✓	
s in the Determination of Organic ling Center Location: A Sample n for Turkiye ndogan, M. (2023)	✓						✓			✓	
on System In Ipoh City & Khalil, N. D. (2011)	✓						✓			✓	
nent and potential revenue from in Malaysia H., Ahmed, S. I., & Mat, R. (2014)	✓	✓						✓			
ion and entrepreneurship through g center operations ood, N. A., Basri, H., Yaacob, M., & M. (2013)	✓		✓	✓				✓			
Waste Management for Sustainable Malaysian Cities Y., Koo, A. C., & Sharji, E. A. (2022)	✓	✓	✓	✓			✓			✓	
it Needs a Boost F. (2023)	✓	✓	✓	✓	✓		✓	✓			
blic acceptance of establishing an cation and recycling center avouras, S., Salvati, L., & Zorpas, A. 2022)	✓		✓	✓					✓		
e at Recycling Centres - A Users pective L., & Engkvist, I. L. (2010)	✓				✓	✓					
at recycling centres R, A., & Eklund, J. (2010)	✓					✓					
gies in Waste Management towards le Development rghe, F. F. (2014)	✓							✓			
ecycling centers and treatment ilities sporte, G. (2022)	✓									✓	
ecycling kiosk opens in Manjoi l. (2023)	✓						✓	✓			✓
ld city imaging in Ipoh tai. (2022)	✓	✓		✓			✓	✓			✓
ntres and future developments , Björkman, M., & Sundin, E. (2016)	✓			✓		✓					
ironmental Services and Waste gement S. (2023)	✓							✓			✓
tion model for linking cost saving ve sustainable development goals Shetwal, A. Q., Kar, P. J., Al Mamun, H., & Mahlia, T. M. I. (2020)	✓						✓			✓	
at recycling centres R, A., & Eklund, J. (2010)	✓										
s towards the disposal, collection,											

Table 2. Key Elements of Design and Layout Derived from Factor Influencing User Engagement and Participation (Faiz, 2024)

Key Elements of Design & Layout	Accessibility & Convenience	Financial Incentives	Environmental Awareness & Education	Public Education Campaigns	Community Engagements & Social Influence	Design & Ergonomics	Strategic Location Planning	Technological Innovation	Trust & Transparency	Efficient Transport Systems	Gamification & Technological Integration	Economic Benefits	References
User- Friendly Design	✓					✓							Eklund et al. (2010), Engkvist et al. (2016)
Signage and Information	✓		✓	✓				✓					Zain et al. (2013)
Lighting and Safety	✓												Hemphälä et al. (2010)
Layout and Space Utilization	✓					✓	✓						Eklund et al. (2010), Hannan et al. (2020), Mahayuddin et al. (2008)
Accessibility	✓						✓			✓			Ayyildiz & Erdogan (2023), Chee (2022), Cheng et al. (2022), Engkvist et al. (2016), Gowri (2023), Hannan et al. (2020), Mahayuddin et al. (2008), Ng et al. (2023), Traven & Široka (2023), Wahlk & Laporte (2022), Yang et al. (2024), Zaharudin et al. (2021), Zain et al. (2013), Zainal (2023)
Technological Integration	✓							✓			✓		Gowri (2023), Ion & Gheorghe (2014), Johari et al. (2014), Loh (2023), Traven & Široka (2023), Yang et al. (2024), Zaharudin et al. (2021), Zain et al. (2013)
Environmental and Educational Impact	✓		✓	✓									Cheng et al. (2022), Moustairas et al. (2022), Zain et al. (2013), Zainal (2023)
Incentives and User Engagement	✓	✓		✓				✓			✓	✓	Chee (2022), Cheng et al. (2022), Johari et al. (2014), Loh (2023), Mathew et al. (2023), Yang et al. (2024), Zainal (2023)
Community Involvement and Feedback	✓			✓	✓								Eklund et al. (2010), Chee (2022)
Maintenance and Upkeep	✓												Malakahmad & Khalil (2011)
Frequency	10	1	2	4	1	2	2	3	0	1	2	1	

Technological Innovation, mentioned in three studies, highlights the importance of integrating user-friendly technologies to simplify recycling processes. While Financial Incentives and Design & Ergonomics received less emphasis, their inclusion supports a comprehensive approach. Strategic Location Planning, cited twice, underscores the importance of situating recycling points for maximum accessibility and convenience.

These findings advocate for a holistic strategy that integrates accessibility, technology, education, and strategic planning. This user-centred approach ensures practical design, effective communication, and innovative solutions, contributing to a sustainable culture of recycling in Ipoh. The next sections provide recommendations to address these findings and enhance the city's recycling infrastructure.

Phase 2: Case Study to Identify the Existing Design and Layout of the Recycling Collection Point

This chapter presents findings from three case studies, each evaluating the design and functionality of selected recycling collection points in Ipoh. The analysis builds upon the factors identified in Phase 1 - Accessibility and Convenience, Technological Innovation, Financial Incentives, Environmental Awareness & Education, Strategic Location Planning, and Design andErgonomics. Each site was assessed to understand how these elements affect user engagement and system efficiency.

The selection of SST 88 Enterprise (Jalan Pasar Tambun), Trash4Cash (Padang Lintau, Manjoi), and Tegas Kukuh Bakti Enterprise (Taman Jade) was intentional and strategic. These sites were chosen based on three key criteria:

1. Location Diversity - The sites represent different urban typologies: a central market hub, a residential-based recycling kiosk, and a suburban roadside facility. This ensures a geographically and functionally varied sample within Ipoh.
2. Operational Models - The case studies range from conventional manual collection systems to semi-automated incentive-based kiosks, allowing a comparison of traditional versus modern approaches.
3. Community Reach and User Demographics - Each site caters to distinct user groups (e.g., daily market-goers, neighbourhood households,

and broader suburban residents), providing insights into how design affects different segments of the population.

This diversity supports a comparative analysis that not only highlights performance variations but also reveals context-specific design implications relevant to Ipoh's broader recycling strategy.

SST 88 Enterprise – Jalan Pasar Tambun

Located in a low-traffic market zone (Figure 5), SST 88 Enterprise is a typical example of a conventional urban recycling collection point. Its strategic location aligns with Phase 1 findings on the importance of Strategic Location Planning, cited in 10 studies. However, spatial inefficiencies and disorganised layouts limit its effectiveness.

The site suffers from poor Accessibility and Convenience, identified as the most critical engagement factor in Phase 1 (23 mentions). Walkways are cluttered and narrow, with no accommodations for disabled users. There is a lack of visual or directional signage, impairing navigation and participation, contrary to best practices in Design and Ergonomics.

No Technological Innovation was observed. The site lacks even basic tracking or automation features, which Phase 1 literature (11 mentions) associates with improved user engagement and operational efficiency. There are Financial Incentives, but no Educational Materials, further missing key motivators. Overall, SST 88 highlights the gap between location advantage and actual design execution.

Figure 5. SST 88 Enterprise in Tambun

Source: Faiz, (2024)

Trash4Cash – Padang Lintau, Manjoi

The second case study, Trash4Cash (Figure 6) represents an emerging model that integrates incentives and semi-digital systems. Its presence in a residential area reflects thoughtful Strategic Location Planning, facilitating access for nearby residents.

The site scores moderately on Accessibility and Convenience, with defined waste zones and relatively open layout, supporting findings from Phase 1 about layout optimisation and space utilisation. However, the signage is inconsistent and faded, which limits the site's potential for Environmental Education.

Similar to SST 88, Trash4Cash incorporates a rudimentary financial incentive system, in which users earn cash based on the recyclables submitted. This aligns with the Phase 1 finding that financial motivation, though mentioned in fewer studies (5 mentions), plays a meaningful role in influencing recycling behaviours. Nevertheless, Technological Innovation is limited, with no automation or mobile user interface present. Feedback systems and interactive features are also absent, leaving room for growth.

Trash4Cash performs best among the three, but it still underutilises its potential in education and user-driven design.

Figure 6. Trash4Cash in Padang Lintau

Source: Faiz, (2024)

Tegas Kukuh Bakti Enterprise – Taman Jade

The third case study, Tegas Kukuh Bakti (Figure 7), is situated along a major arterial road and benefits from strong location visibility, but its layout and infrastructure fall short of best practices.

Design-wise, the facility incorporates dedicated zones for storage, dismantling, and weighing, suggesting some awareness of space efficiency. However, these zones are poorly organised, causing congestion, an issue tied to weak Ergonomic Planning, a concern highlighted in Phase 1.

Signage and Informational Materials were largely absent or inconsistent, undermining Environmental Education and Awareness (5 mentions in Phase 1). No digital systems, smart tools, or real-time tracking were observed, indicating a lack of Technological Integration.

Incentive programs were also missing, weakening community motivation. Additionally, the site lacks proper lighting, safety measures, and accessible pathways, directly contradicting Phase 1 recommendations on user safety and inclusive design.

Tegas Kukuh illustrates how operational zoning alone does not guarantee user engagement without supporting design, education, and feedback systems.

Figure 7. Tegas Kukuh Bakti Enterprise in Ipoh

Source: Faiz, (2024)

Table 3. Analysis on the Existing Design and Layout of Recycling Collection Point According to the Key Elements

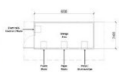
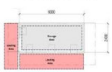
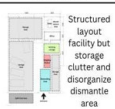
Key Elements	User-Friendly Design	Signage & Information	Incentives & User Engagement	Community Feedback	Accessibility	Lighting & Safety	Layout & Space Utilization	Environmental & Educational	Technological Integration	Maintenance & Upkeep
 Case Study 1: SST 88 Enterprise	 Congested space and clutter storage area	 Signage of business only available outside	No incentives available but user are mostly local and financially motivated	 Direct contact with the owner	 Conveniently located along Jln Pasar Tambun, cluttered pathway pose accessibility challenges for users	Recycling during day only, no safety consideration for user	 Inefficient space utilization, unplanned zoning	No visible educational material or signs promoting awareness	Weighing Station are the only machinery inside the facility	 No information on maintenance schedule
 Case Study 2: Trash4Cash	 Straightforward and functional layout	 Informative but worn out signage	No incentives available but user are mostly local and financially motivated	 Direct contact with the on-duty staff	 Basic accessibility located in Padang Lintau compound a community nodes	Recycling day & night, only one source of lighting and camera for safety	 Compact design with clear loading & storage area	No visible educational material but signs promoting awareness are available	Safety camera are the only technology available	 Routine maintenance schedule is available
 Case Study 3: Tegas Kukuh Bakti Enterprise	 Ease of use, accessible but cluttered storage area	 Signage of business only available outside	No incentives available but user are mostly local and financially motivated	 Direct contact with the owner	 Conveniently located along Jln Temenggong (Main road) cluttered pathway pose accessibility challenges for users	Recycling during day only, no safety consideration for user	 Structured layout facility but storage clutter and disorganize dismantle area	No visible educational material or signs promoting awareness	Weighing Station are the only machinery inside the facility	 No information on maintenance schedule

Table 4. A Cross-Case Synthesis Against Key Phase 1 Elements

Design Factor (Phase 1)	SST 88	Trash4Cash	Tegas Kukuh Bakti
Accessibility & Convenience	Poor	Moderate	Moderate
Technological Innovation	Minimal (Weighing Only)	Minimal (Recording Only)	Minimal (Weighing Only)
Financial Incentives	Present (Cash Based)	Present (Cash Based)	Present (Cash Based)
Environmental Education	None	None	None
Strategic Location Planning	Strong	Strong	Strong
Signage & Information	None	Present (Faded)	None
Design & Ergonomics	Poor	Moderate	Functional (Cluttered)

Source: Faiz, (2024)

As shown in Tables 3 and 4, the comparative analysis confirms the need for multidimensional solutions. While location is a strength across all sites, it alone does not ensure usability or engagement. As emphasised in Phase 1, technological support, educational tools, and inclusive layout design are essential in building effective and user-centred recycling points.

The analysis, as shown in Table 3, discusses the effectiveness of recycling collection points, which is closely tied to their design and layout. SST 88 Enterprise suffers from poor space utilisation and cluttered storage areas, hampering accessibility and operational efficiency. Tegas Kukuh Bakti Enterprise, while featuring structured zones, faces similar challenges with overcrowded storage. In contrast, Trash4Cash stands out with its compact, well-defined layout and improved accessibility, showcasing the benefits of strategic space planning.

Signage remains inconsistent across all sites, with SST 88 and Tegas Kukuh lacking clear guidance for users. Trash4Cash, despite some worn signage, demonstrates the importance of clear and visible information for user navigation and operational flow.

None of the sites offer formal engagement programs but provide users with incentives, limiting user participation. Trash4Cash integrates safety features such as cameras and lighting, contrasting with the day-only operations of the other facilities. Routine maintenance, as seen at

Trash4Cash, underscores its role in sustaining efficiency. Addressing these gaps is key to enhancing user experience and operational performance.

While the case study approach offers rich qualitative insights, it also presents certain limitations. Observations were time-limited and context-specific, potentially missing seasonal or peak usage patterns. Although standardised observation checklists and triangulated interviews were employed, the absence of quantitative behavioural data (e.g., user frequency, waste volume) limits generalizability. In addition, the lack of longitudinal tracking prevents assessment of how design changes influence long-term behaviour.

Future research should incorporate quantitative tools (e.g., surveys, digital sensors), longitudinal tracking, and experimental design testing to measure the actual impact of proposed interventions.

These case studies reinforce the findings from Phase 1: enhancing recycling collection point performance requires more than strategic placement. Sites must prioritise accessibility, user-friendly layout, educational content, financial and technological incentives, and ongoing community feedback mechanisms. While Trash4Cash shows emerging promise, SST 88 and Tegas Kukuh reveal significant gaps between intent and implementation. These insights guide the development of the proposed framework in the following chapter.

Phase 3: Framework for Efficient Recycling Collection Points Based on Case Study Design Enhancement

This chapter presents targeted design and layout improvements for three recycling collection points: SST 88 Enterprise, Trash4Cash, and Tegas Kukuh Bakti Enterprise. These recommendations address key elements such as accessibility, user engagement, and operational efficiency, based on the analysis of current conditions.

For SST 88 Enterprise, optimising spatial layoutand improving accessibility are essential to enhance user-friendliness. Trash4Cash requires better signage, improved information systems, and technology integration. Tegas Kukuh Bakti Enterprise requires enhanced organisation, regular

maintenance, and increased community involvement. Implementing these changes will strengthen the functionality of these facilities, promote user participation, and contribute to sustainable waste management practices.

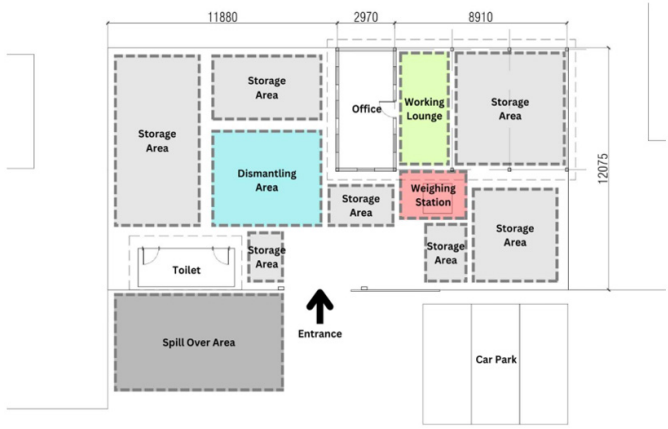


Figure 9. The Original Layout of the Collection Point

Source: Faiz, (2024)

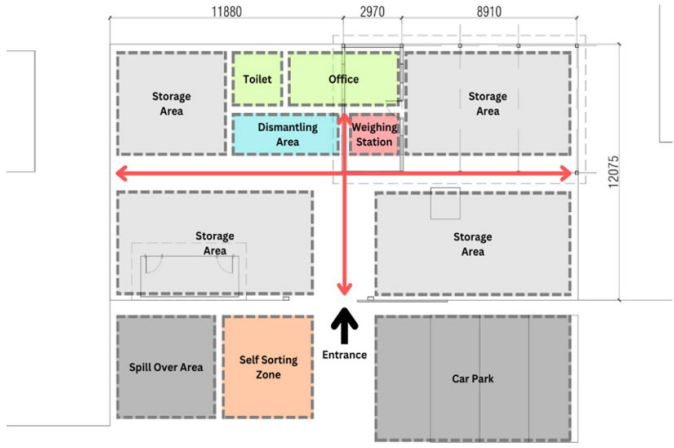


Figure 10. The Enhanced Layout Proposal

Source: Faiz, (2024)

SST 88 Enterprise, located in Tambun, plays a vital role in recycling but faces challenges in design and layout, as shown in Figure 8, reducing its efficiency and user-friendliness. Addressing these issues is key to improving operations and encouraging community participation.

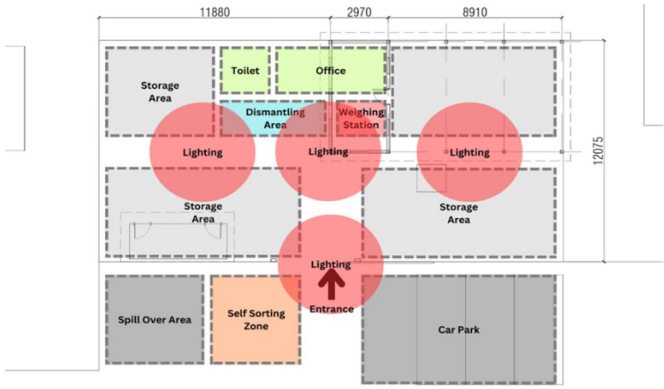


Figure 11. The Proposed Lighting Area for Safety and Efficiency

Source: Faiz, (2024)

Proposed enhancements in Figures 9,10, and 11 include decluttering and reorganising the layout, adding clear signage, and installing proper lighting to improve navigation and safety. Additional features like ramps and vertical storage solutions will boost accessibility and optimise space usage.

Technological upgrades, such as automated sorting systems and digital signage, can streamline operations and modernise the facility. Educational materials, incentive programs, and community feedback mechanisms will engage users and foster a stronger commitment to recycling.

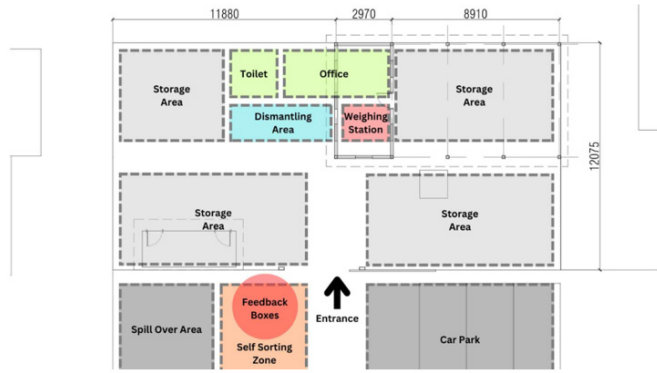


Figure 12. Location of Feedback Mechanism for Community

Source: Faiz, (2024)

Regular maintenance schedules will ensure cleanliness and operational reliability. These targeted improvements aim to create a user-friendly, efficient, and sustainable recycling environment that supports broader community involvement.

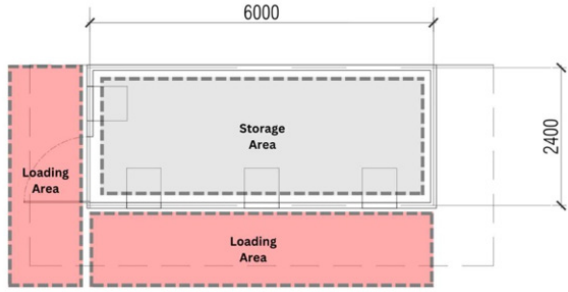


Figure 13. The Original Layout of the Collection Point
Source: Faiz, (2024)

Located in Manjoi, Trash4Cash is a recycling collection point with significant potential to drive environmental sustainability. However, inefficiencies in design and layout hinder its effectiveness, as shown in Figure 13.

The enhancements proposed in Figures 14 and 15 focus on decluttering, organising spaces, and adding clear signage to improve navigation. In Figure 16, improved lighting and safety measures, including better visibility and accessible safety equipment, will ensure a secure environment. Technological integration in Figure 17, such as automated sorting and real-time updates, will modernise operations, while educational materials will promote recycling awareness. Introducing incentive programs and community feedback, as in Figure 18, platforms will increase engagement and participation. Regular maintenance will ensure cleanliness and operational efficiency, creating a user-friendly, impactful facility.

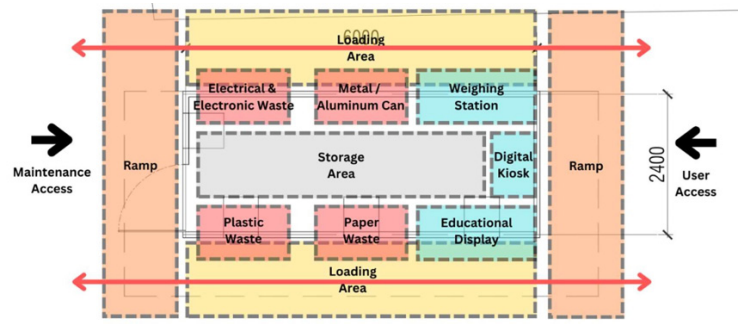


Figure 14. The Enhanced Layout Proposal

Source: Faiz, (2024)

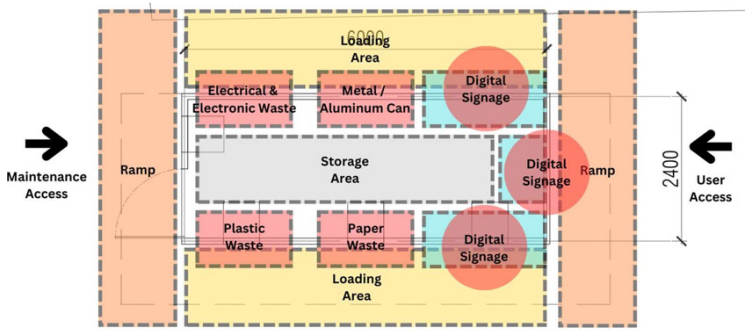


Figure 15. Location of the Signage

Source: Faiz, (2024)

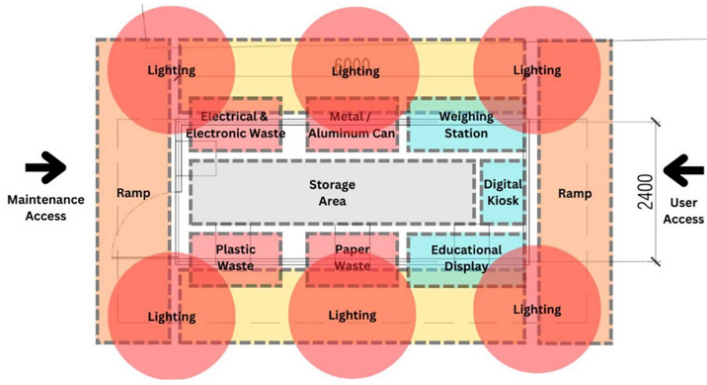


Figure 16. The Coverage for Lighting Area

Source: Faiz, (2024)

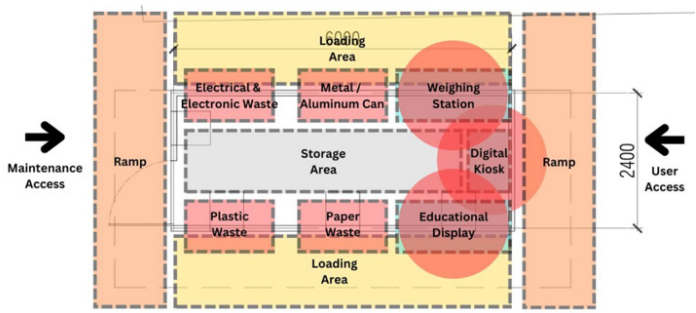


Figure 17. Technological Integration on the Facility

Source: Faiz, (2024)

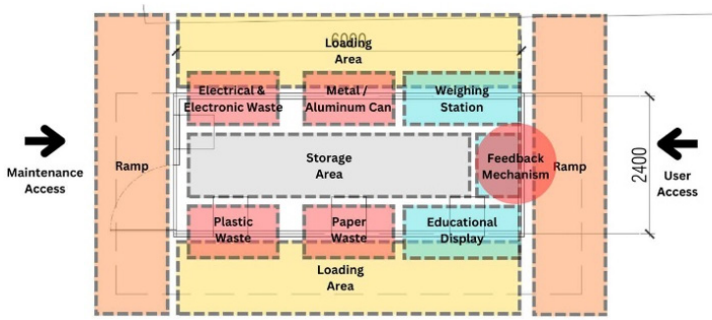


Figure 18. Location of the Feedback Mechanism for Community

Source: Faiz, (2024)

Figure 19. The Original Layout of the Collection Point

Source: Faiz, (2024)

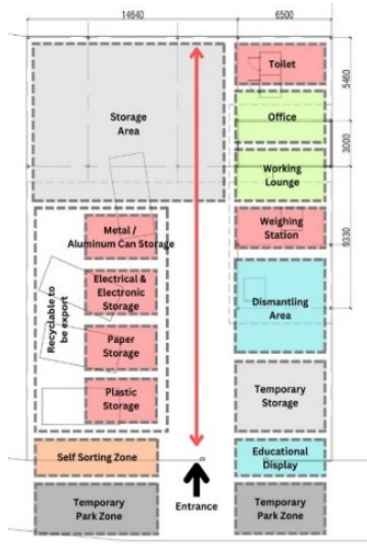


Figure 20. The Enhanced Layout Proposal

Source: Faiz, (2024)

Tegas Kukuh Bakti Enterprise plays a key role in Ipoh's recycling ecosystem but faces challenges in design and layout that hinder efficiency and user satisfaction, as shown in Figure 18. Improvements as in Figure 20 such as decluttering and reorganizing space will enhance usability, while better signage as shown in Figure 21 and lighting in Figure 22 will improve navigation and safety. Integrating modern technologies as shown in Figure 24 like automated sorting and digital signage will streamline operations and create a user-friendly experience. Community engagement through educational efforts, incentive programs, and feedback systems, as in Figure 23, will foster greater participation. Regular maintenance will ensure the facility remains clean and operational, boosting its functionality and contribution to environmental sustainability.

Figure 21. Location of Signage

Source: Faiz, (2024)

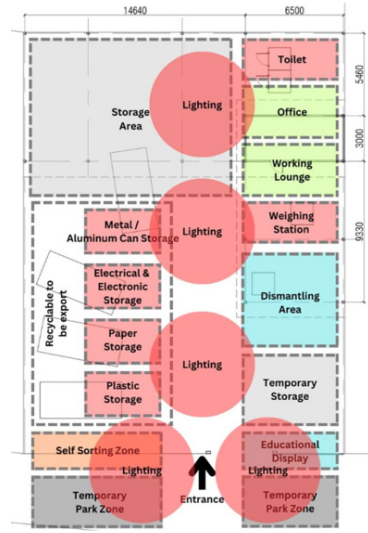


Figure 22. Location of Lighting

Source: Faiz, (2024)

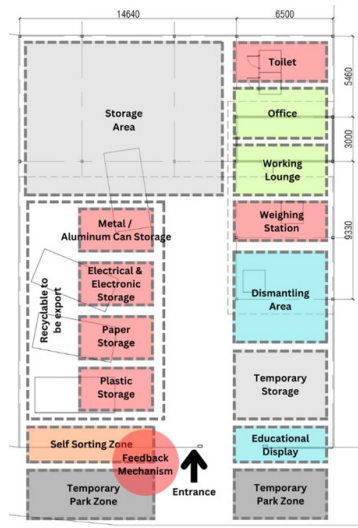


Figure 23. Location of the Feedback Mechanism for Community

Source: Faiz, (2024)

Figure 24. Technological Integration on the Facility

Source: Faiz, (2024)

The analysis of the Enhanced Design and Layout of the case study, as shown in Table 5, discusses the design and layout of recycling collection points, prioritising user-friendly features, effective navigation, and operational efficiency. Clear signage and self-sorting machines improve user engagement and sorting accuracy, as seen in Trash4Cash and Tegas Kukuh Bakti Enterprise.

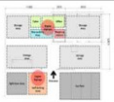
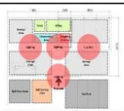
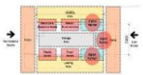
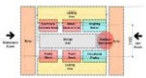
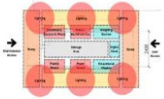
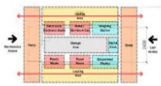
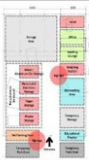
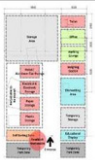
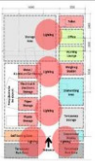
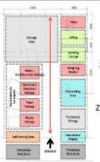
Accessible pathways and spatial organisation enable better navigation, though cluttered areas detract from efficiency in some cases. Incentive systems, such as rewards and feedback mechanisms, boost user motivation and participation. Enhanced safety measures, including well-lit pathways and visible fire extinguishers, improve user confidence.

Technological integration, such as smart bins and real-time tracking, fosters engagement while supporting operational efficiency. Environmental education, through workshops and interactive displays, raises awareness, complementing technical solutions. Consistent maintenance, with staff oversight and app-based reporting, ensures functionality and cleanliness.

Adhering to these strategies can transform recycling collection points into user-centric, efficient hubs, enhancing sustainability efforts and waste management outcomes.

The proposed framework, as shown in Figure 25, integrates critical elements to enhance the design and functionality of recycling collection points, supporting sustainable waste management. Technology integration is key, utilising smart bins with sensors for real-time monitoring, optimised collection routes, and reduced operational costs. Interactive displays provide users with live updates on recycling processes, promoting awareness and good practices.

Table 5. Analysis on the Enhanced Design and Layout of the Case Study According to the Key Elements Evaluated

Thematic Key Elements	User Experience & Interaction				Safety & Accessibility		Spatial Organization	Technical		
Case Study	User-Friendly Design	Signage & Information	Incentives & User Engagement	Community Feedback	Accessibility	Lighting & Safety	Layout & Space Utilization	Environmental & Educational	Technological Integration	Maintenance & Operations
 Case Study 1: SST 88 Enterprise	 Clear guidance and self sorting machine location available for user		 Location of suggestion box or rewards for incentives for user usage		 Conveniently located along Jln Pasar Tambun, cluttered pathway pose accessibility challenges for users	 Visible pathway and safety measures like fire extinguisher location	 Clear organization and pathway for user navigation	Initiatives like interactive displays on recycling processes, workshops for the community, and partnerships with local schools for educational programs	Recommend integrating smart bins with sensors, real-time tracking of bin status, and user apps for information and incentives	Suggestion for regular maintenance schedules, dedicated staff for cleaning and repairs, and real-time reporting of issues through a mobile app
 Case Study 2: Trash4Cash	 Zoning for access to information and the recycle materials for self sorting		 Location of suggestion box or rewards for incentives for user usage		 Basic accessibility located in Padang Lintau compound a community nodes	 Ensuring safety & visibility for user at night	 Improve functionality and access for OKU			
 Case Study 3: Tegas Kukuh Bakti Enterprise	 Clear visible signage outside & inside and self sorting machine for self recycling		 Location of suggestion box or rewards for incentives for user usage		 Conveniently located along Jln Temenggong (Main road) cluttered pathway pose accessibility challenges for users	 Visible pathway and safety measures like fire extinguisher location	 Clear organization and pathway for user navigation, zoning storage area by material			

Source: Faiz, (2024)

Safety and accessibility are addressed through well-lit areas, reducing vandalism and enabling nighttime usage. Accessible pathways, ergonomic bins, and clear signage ensure inclusivity, accommodating all users, including those with disabilities. Educational initiatives, such as workshops and interactive displays, foster sustainability awareness and behavioural change, instilling a culture of recycling. User-friendly designs improve participation through intuitive layouts, ergonomic features, and detailed signage that minimise waste contamination. Spatial organisation prioritises

strategic placement of collection points and efficient use of space to enhance accessibility and functionality.

A mobile application enhances user interaction, offering alerts, issue reporting, and training materials. Regular maintenance ensures cleanliness and functionality, preventing technical issues. Finally, incentives and user engagement boost participation. Rewards, recognition programs, and community feedback mechanisms foster long-term commitment. This comprehensive framework combines technology, education, design, and community involvement to create sustainable, efficient, and inclusive recycling systems.

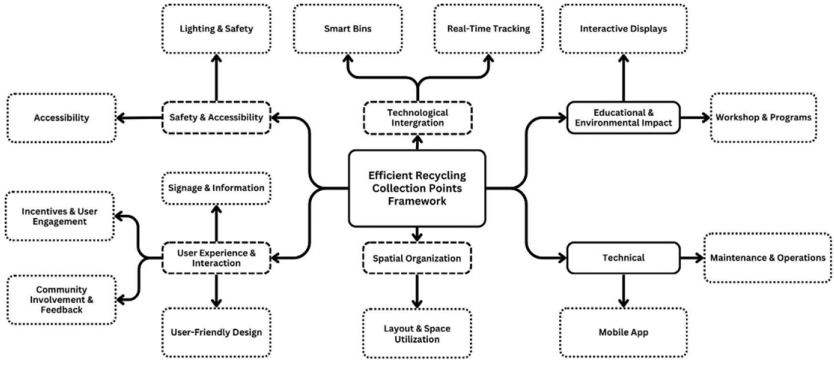


Figure 25. Proposed Framework for Efficient Recycling Collection Points Based on Case Study Design Enhancement

Source: Faiz, (2024)

CONCLUSION

This research investigated the efficient design of recycling collection points in Ipoh, focusing on how spatial planning and user-centred design can improve recycling participation and operational effectiveness. Through a structured, three-phase methodology - comprising a comprehensive literature review, detailed case studies, and a framework development process - the study identified and analysed the key design, behavioural, and infrastructural factors shaping user engagement at recycling sites.

From Phase 1, the literature review highlighted Accessibility & Convenience, Technological Innovation, Financial Incentives, and

Environmental Awareness & Education as the most significant contributors to recycling participation. These factors were used to structure the analysis in Phase 2, where three distinct case studies (SST 88, Trash4Cash, and Tegas Kukuh Bakti) revealed consistent gaps: cluttered or inefficient layouts, poor signage, limited technology use, and inadequate incentive schemes or educational components. These findings directly informed Phase 3, where a design framework was proposed that integrates user-friendly features, smart infrastructure, clear signage, and inclusive design standards to encourage sustainable behaviour.

Compared to global models, such as Japan's neighbourhood-sorted collection zones and South Korea's RFID-based smart bin systems, Ipoh's facilities lack scalability, data integration, and participatory features. However, this study contributes a context-specific framework that can serve as a scalable prototype for Malaysian secondary cities, balancing local constraints with internationally inspired best practices. By localising global principles through case-based insights, this research offers a uniquely adaptable and cost-effective solution for medium-sized urban settings.

Policy and Planning Implications

The study offers several key implications for urban policy and municipal planning:

- Standardised design guidelines should be developed for collection points, incorporating principles of universal accessibility, spatial clarity, and smart technologies.
- Public-private partnerships could be encouraged to fund and maintain smart bins, interactive signage, and incentive mechanisms.
- Community-based monitoring and feedback systems should be formalised to keep infrastructure user-driven and responsive.
- Regulatory frameworks must be updated to mandate design compliance in future recycling initiatives.

Additionally, city councils and waste authorities could pilot the proposed framework in select neighbourhoods, tracking performance via digital tools before scaling city-wide.

LIMITATIONS AND FUTURE RESEARCH

While the research provides grounded design insights, it is not without limitations. The findings are based on a qualitative, location-specific analysis, which, though rich in context, limits generalizability. The absence of large-scale user surveys or real-time operational data restricts behavioural insights. Technological recommendations, such as smart bins and interactive displays, remain theoretical; real-world testing was beyond the study's scope.

Future research should expand to additional case sites, incorporate quantitative methods (e.g., usage tracking, perception surveys), and pilot smart design interventions to measure their direct impact on participation rates. A mixed-methods approach, combining design audits with behavioural studies, would yield more robust, scalable findings.

RECOMMENDATIONS

Based on the integrated findings from all three phases, the following actions are recommended:

- Technology Integration: Introduce smart bins with fill-level sensors and real-time data systems.
- Safety and Accessibility: Ensure safe, well-lit paths and inclusive features such as ramps and handrails.
- Environmental Education: Incorporate educational signage, interactive displays, and local recycling workshops.
- User Experience: Standardise signage and improve ergonomic features of bins and pathways.
- Spatial Organization: Prioritise placement in high-footfall areas and optimise internal zoning.
- Community Engagement: Launch reward-based incentives, feedback systems, and participatory planning tools.

Ipoh stands at a pivotal point where thoughtful urban design can translate awareness into action. By integrating evidence-based spatial planning, technological solutions, and human-centred design, the city has the opportunity to transform its recycling infrastructure into a model

of sustainable, scalable, and inclusive waste management. This study's framework - while grounded locally - holds potential relevance for similar mid-sized cities across Southeast Asia seeking to balance cost, community, and environmental performance.

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DECLARATION OF AI-GENERATED CONTENT

AI tools (e.g, ChatGPT, Grammarly) were used for drafting, assistance, paraphrasing and grammar checking. All content was critically reviewed and edited by researcher.

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AUTHOR CONTRIBUTIONS

All authors contributed to the design of the research, the case study guide, and the write-up. The survey, data cleaning and tabulation was undertaken by main author. All authors have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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