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"Fostering a Culture of Innovation and Entrepreneurial Excellence"

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PTDI, UiTM Cawangan Johor
Kampus Pasir Gudang

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A-ST063: UNDERGROUND SMART WASTE CHUTE IN LANDED RESIDENTIAL AREAS

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ABSTRACT

The Underground Smart Waste Chute (USWC) is an innovative solution designed to revolutionise waste management in landed residential areas. By integrating advanced technologies such as the Internet of Things (IoT), automated sorting, and pneumatic waste collection, USWC offers an efficient and hygienic waste disposal system. Its primary aim is to address challenges in waste segregation and inefficient collection systems while promoting sustainability. USWC features include real-time waste monitoring, automated compaction, and sealed systems to reduce odors and pests. The technology fosters proper waste sorting and minimizes plastic usage, encouraging environmentally conscious behaviors among residents. Its integration with IoT optimises collection routes, reducing operational costs and environmental footprints. USWC has a significant socioeconomic impact because it promotes cleaner living conditions, eases the burden on landfill capacity, and improves public health and safety by reducing waste-related hazards. Economically, the system promotes innovation and reduces waste management expenses, giving local industries the chance to go commercial. USWC is a scalable and economically feasible solution that has the potential to complement urban modernisation initiatives and sustainability goals. It sets the standard for waste management procedures worldwide and helps to build resilient, environmentally friendly communities in addition to addressing waste management issues.

Keywords: Smart Waste Management, Underground Waste Chute, IoT Integration, Sustainability, Waste Segregation

1. Product Description

The Underground Smart Waste Chute (USWC) is an innovative waste management system designed specifically for landed residential areas to streamline waste disposal and enhance sustainability. This system integrates advanced technologies such as the Internet of Things (IoT), automated sorting mechanisms, and pneumatic waste transportation to optimize waste collection and segregation. The USWC consists of user-friendly deposit points connected to underground pipes that transport waste to central collection hubs, reducing the need for traditional garbage trucks and minimizing traffic and emissions. Key features of the USWC include real-time waste level monitoring, automated waste compaction, and sealed systems to prevent odors, pests, and bacterial growth. The system also provides distinct compartments for recyclables and general waste, encouraging environmentally responsible behavior among residents. By reducing dependency on plastic bags and

optimizing waste management logistics, the USWC significantly reduces environmental impact. This innovation improves public health and hygiene, lowers operational costs, and supports modern urban living by aligning with smart city and sustainability initiatives. The USWC is a scalable and commercially viable solution that addresses critical challenges in waste management, offering benefits to residents, local governments, and the environment while promoting a cleaner, more efficient, and sustainable waste management practice.

2. Materials and Methods

To achieve the objectives, the study was divided into 3 phases. Data was collected by applying literature reviews and simulation studies. The analysis used in the study was descriptive analysis, 3D Modeling Design, and Expert Validation. **Table 1** shows the research design of the study.

Table 1. Research Design of the Study.

Phase	***Method***	***Analysis***	***Research Objective***	***Expected Outcome***
Phase 01	Background Study ⬇ Problem Statement	Descriptive Analysis	To identify potential design improvements and technological advancements that can enhance the segregation capabilities of smart waste chutes.	Identification of potential design improvements and technological advancements for smart waste chutes, enabling more efficient sorting of recyclables and general waste.
Phase 02	Literature Review ⬇ Simulation	3D Modeling Design	To develop an underground smart waste collection system to improve the efficiency of solid waste management.	Implementation of a system that improves the operational efficiency of solid waste management, including optimized waste collection routes and reduced environmental impact.
Phase 03	Performance of the Product ⬇ Potential Marketability	Expert Validation	To demonstrate the marketability potential of smart waste chute system in landed residential areas.	Analysis and validation of the commercial viability of smart waste chute systems in landed residential areas, considering aspects like cost, demand, and sustainability benefits.

Table 2. Comparison between the Existing Product and USWC.

Features	***Smart Waste Bin***	***Pneumatic Waste Collection System***	***Underground Smart Waste Chute (USWC)***
Waste Segregation Capability	Limited segregation; primarily measures waste levels.	No segregation; focuses on waste transportation.	Integrated sorting system with features for recycling and composting organic waste.
Technology Integration	Equipped with IoT sensors for real-time fill-level monitoring and notifications.	Uses air pressure to transport waste through underground pipes to central facilities.	Combines IoT, automation, and pneumatic features for waste collection, segregation, and monitoring.
Environmental Impact	Reduces overflow but requires frequent collection trips.	Lowers vehicle emissions but consumes significant energy for operation.	Reduces emissions, optimizes energy use, and minimizes landfill waste with improved sorting.
Collection Efficiency	Limited; depends on user compliance for proper sorting.	Highly efficient in transporting waste but lacks sorting and compacting features.	High efficiency in sorting, compacting, and transporting waste, optimizing collection schedules.
User Interface	Simple; users dispose of waste into labeled smart bins.	No direct user interaction; waste is deposited at centralized chutes.	Easy; User-friendly with real-time feedback and gamification for responsible waste disposal.
Maintenance Requirements	Moderate; sensors and IoT devices need regular upkeep.	High; underground systems require regular inspections and repairs.	Moderate; pneumatic and IoT systems need periodic maintenance but are designed for durability.
Cost of Implementation	Moderate; requires sensors, bins, and connectivity infrastructure.	High; requires extensive underground piping and central collection points.	High initial cost but integrates multiple features, offering long-term savings.
Suitability for Residential Areas	Ideal for smaller communities or individual households.	Suitable for large-scale urban developments.	Designed for landed residential areas, balancing scalability and customization.
Marketability	Suitable for urban areas with budget constraints.	Targeted at large-scale developments or highly urbanized areas.	Ideal for residential areas with a focus on sustainability and advanced technology adoption.

Table 2 demonstrates that the Underground Smart Waste Chute (USWC) outperforms the Smart Waste Bin and Pneumatic Waste Collection System in multiple aspects. It integrates

advanced IoT, automation, and pneumatic technologies, offering efficient sorting, compacting, and transportation capabilities. The USWC minimises environmental impact by reducing emissions and optimizing energy use while enhancing collection efficiency with streamlined processes. It provides a user-friendly interface with real-time feedback and gamification, ensuring responsible waste management. Though it has a high initial cost, its durability and long-term savings make it an ideal solution for residential areas prioritizing sustainability and advanced technology. This makes the USWC a more relevant and innovative choice for modern waste management needs.

3. Novelty and uniqueness

The Underground Smart Waste Chute system introduces a novel approach to waste management by integrating advanced technologies and design enhancements tailored specifically for landed residential areas. Its uniqueness lies in its combination of IoT-enabled real-time monitoring, automated waste segregation, and pneumatic waste collection systems. Unlike conventional smart waste bins that focus solely on waste level notifications or pneumatic systems that lack segregation capabilities, this innovation seamlessly incorporates automated sorting mechanisms to separate recyclables and organic waste at the source. Furthermore, the system features a user-friendly interface with gamified incentives, encouraging responsible waste disposal behavior among residents. The use of optical sorting systems, real-time feedback, and mobile applications sets it apart, fostering active user participation in sustainable practices. This innovation also stands out with its integration of anaerobic digestion technology to process organic waste, reducing landfill dependence while generating biogas and compost. By optimizing waste collection routes and schedules through IoT data, it significantly reduces operational costs and environmental impact. Its adaptability to diverse residential settings and alignment with sustainable development goals make it a unique and transformative solution for modern urban waste management. The system's scalability and long-term cost-effectiveness further reinforce its novelty and market potential.

4. Benefit to mankind

The Underground Smart Waste Chute system offers significant benefits to mankind by addressing critical environmental and social challenges in waste management. By integrating advanced sorting and monitoring technologies, it promotes efficient waste segregation, reducing landfill dependency and enhancing recycling rates. This directly contributes to a cleaner, healthier environment by minimizing pollution and greenhouse gas emissions. For residents, the system simplifies waste disposal, improves hygiene, and reduces exposure to harmful waste, fostering safer and more comfortable living conditions. The automated process eliminates manual labor risks for sanitation workers and reduces operational costs for municipalities. On a larger scale, the system supports sustainable urban development by aligning with global initiatives like the UN Sustainable Development Goals, particularly those focused on responsible consumption, climate action, and sustainable cities. By encouraging eco-friendly behavior through gamification and real-time feedback, it fosters community engagement and long-term environmental stewardship, benefiting both current and future generations.

5. Innovation and Entrepreneurial Impact

The project promotes innovation and contributes to a culture of entrepreneurship by integrating advanced technologies and sustainable practices, particularly through waste segregation awareness initiatives. Educational workshops raise awareness about the importance of waste segregation, empowering local entrepreneurs to develop innovative solutions for waste management. These initiatives encourage collaboration among various stakeholders, including startups, educational institutions, and industry leaders, facilitating the exchange of knowledge and resources. This collaborative environment stimulates creative problem-solving and enhances the overall entrepreneurial ecosystem. By focusing on both innovation and environmental responsibility, the project inspires a new generation of entrepreneurs equipped to drive economic growth and social change while fostering a community that values sustainability and resilience.

6. Potential commercialization

The proposed smart waste chute system has significant commercialization potential in residential areas. By addressing critical urban waste management challenges, this innovation appeals to developers, municipalities, and environmentally conscious communities. Its integration of automated waste segregation, real-time monitoring, and IoT-based optimization ensures operational efficiency and cost savings, making it a viable solution for public and private stakeholders. Targeting landed residential areas, this product aligns with sustainable development goals and can gain traction through governmental incentives and urban planning mandates. Its modular design allows adaptation across diverse housing types, enhancing scalability. Additionally, its ability to foster user engagement via feedback and gamification promotes adoption, while reducing reliance on manual labor provides economic incentives. The smart waste chute system is a forward-thinking product poised to meet the demands of modern waste management, with strong prospects for widespread implementation and market adoption.

7. Acknowledgment

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8. Authors' Biography

Nurul Husna Adila Mohd Famil, a final-year student pursuing a Bachelor of Science (Hons.) in Construction Technology at Universiti Teknologi MARA (UiTM), Seri Iskandar Campus. Academic interests include sustainable construction methods and innovative waste management solutions. Current research focuses on developing an Underground Smart Waste Chute system to enhance waste segregation and promote eco-friendly practices in residential areas. Dedicated to contributing to sustainable urban development through the integration of advanced technologies in construction, with a strong commitment to addressing modern environmental challenges and supporting global sustainability goals.

Dr. Noor Rizallinda Ishak is a highly accomplished Senior Lecturer at Universiti Teknologi MARA, Seri Iskandar Campus, Perak Branch, with over 13 years of expertise in the Built Environment area. She earned her Ph.D. in Design and Built Environment in 2023, demonstrating a profound commitment to academic excellence. A prolific researcher and author, she has made significant contributions to scholarly literature and is renowned for her dynamic presentations at conferences and her leadership in training initiatives. Her unwavering dedication to innovation, education, and professional growth positions her as a visionary in shaping the future of the built environment.