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# DESIGN AND DEVELOPMENT OF PORTABLE 3-IN-1 COLLECTION TROLLEY

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**Abstract:**

The increasing volume of food waste generated in institutional dining facilities presents significant challenges in terms of operational efficiency, hygiene, and environmental sustainability. This study presents the design and development of a portable 3-in-1 collection trolley aimed at improving plate handling and food waste management in university café environments. The proposed system integrates a spring-loaded plate stacking mechanism, a dedicated utensil compartment, and an enclosed waste bin within a single mobile unit. The design adopts a systematic engineering approach, incorporating user-centered design principles, morphological analysis, and mechanical performance evaluation. Experimental validation demonstrates that the trolley can safely support up to 80 plates while maintaining stability and accessibility. In addition, the enclosed waste compartment significantly reduces odour emission and pest attraction compared to conventional open systems. User feedback further indicates improvements in operational efficiency, ergonomics, and

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workplace hygiene. The findings suggest that the proposed design offers a cost-effective and sustainable solution for improving food service operations, with potential applications in institutional and commercial environments.

**Keyword:**

Multipurpose Trolley, Plate Waste Trolley, Multi-Compartment Collection Trolley



## Introduction

The 3-in-1 Collection Trolley is a product designed to improve the efficiency of plate and food waste collection in UTHM cafes. Food waste represents a significant portion of solid waste generated in Malaysia, with improper management leading to hygiene issues, pest problems, and unpleasant odors (Hassan et al., 2020). Conventional trolleys often mix plates, utensils, and food waste in a single compartment, resulting in disorganization and inefficient cleaning processes (Kumar & Singh, 2021).

This project integrates three dedicated compartments for plates, utensils, and food waste into a single mobile unit, equipped with a spring-loaded stacking system for plates and an enclosed bin to contain food waste odors. By combining these features with a durable mild steel frame and easy-to-maneuver swivel caster wheels, the trolley aims to reduce handling time, minimize operator fatigue, and maintain higher hygiene standards (Budynas & Nisbett, 2020). The design, development, and testing of this trolley were carried out to meet the operational needs of UTHM cafe workers while ensuring cost-effectiveness and sustainability.

Food waste has emerged as a critical global issue, contributing significantly to environmental degradation, resource inefficiency, and operational challenges in food service systems (Filimonau & De Coteau, 2019; Papargyropoulou et al., 2014). In institutional settings such as university cafes, inefficient waste handling practices often result in poor hygiene conditions, increased labour requirements, and reduced service quality (Heikkilä et al., 2016).

Conventional plate collection systems typically involve manual segregation of plates, utensils, and food waste, which leads to workflow inefficiencies and ergonomic risks for workers (Karwowski, 2012). Previous studies have highlighted the importance of integrating ergonomic

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design and efficient material handling systems to reduce physical strain and improve productivity (Neumann & Dul, 2010).

Although automated solutions such as conveyor-based systems and sensor-assisted plate return units have been developed, their high cost and infrastructure requirements limit their applicability in small-scale or semi-structured environments (Gu et al., 2007). Therefore, there is a need for a cost-effective, portable, and user-friendly solution that can enhance operational efficiency while maintaining hygiene standards.

This study aims to address these challenges through the design and development of a portable 3-in-1 collection trolley that integrates multiple functions into a single system. The research focuses on improving efficiency, ergonomics, and hygiene through systematic engineering design and performance validation.

***Project Background***

The current process of collecting plates and food waste in UTHM cafes is mostly manual and inefficient, often resulting in congestion at the disposal area and poor waste segregation (Hassan et al., 2020). Workers typically must collect plates, utensils, and food waste together, leading to increased cleaning time, higher physical strain, and reduced hygiene standards.

**Figure 1: Collection of Plates and Food Waste in UTHM Cafes**

Figure 1 shows the current plate and food waste collection practice in UTHM cafes, where customers typically leave used plates, utensils, and leftover food on a shared surface for staff to manually sort. This method is inefficient, as it increases congestion during peak hours and requires additional time for separation and cleaning. Moreover, uncovered food waste often emits unpleasant odours and attracts pests, creating hygiene concerns in dining areas (Hassan et al., 2020; Kumar & Singh, 2021).

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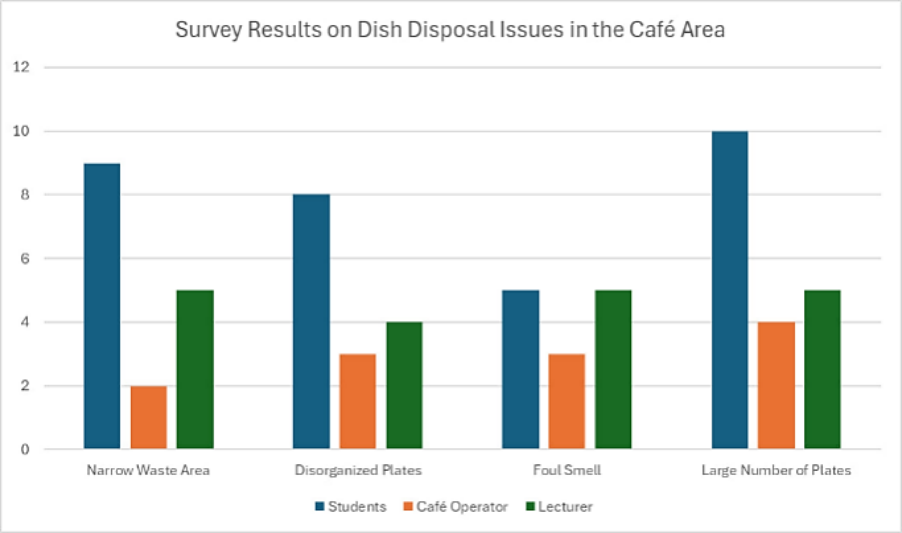


**Figure 2: Survey on Dish Disposal Issues in the Café**

Figure 2 illustrates the findings of a survey conducted among UTHM cafe staff and students to evaluate the challenges of dish and food waste disposal. Survey results revealed frequent issues such as long queues at the dish return area, the mixing of food waste with tableware, and difficulties in maintaining cleanliness during busy hours. These findings highlight inefficiencies in the current dish management process and the need for a more systematic approach (Hassan et al., 2020; Kumar & Singh, 2021).

In addition, respondents expressed concerns over unpleasant odours and pest problems caused by uncovered food waste. Many participants also emphasized the lack of a practical and ergonomic system to facilitate faster collection and transportation of dishes and waste. These insights support the development of an improved trolley design to enhance hygiene and efficiency in cafe operations (Filimonau & De Coteau, 2019).

**Figure 3: Survey on Dish Disposal Issues in the Café**

Various studies and product reviews have examined plate and food waste collection systems, focusing on efficiency, hygiene, and user ergonomics. Traditional methods such as the manual separation of plates and leftover food into open containers require significant labour and time

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and often result in contamination between food waste and reusable utensils (Kumar & Singh, 2021).

As illustrated in Figure 3, in some cases, both food waste and plates are collected in a rubbish bin, causing the mixing of organic waste with tableware, which complicates cleaning. In other instances, workers manually separate food waste from plates before disposal, a method that is slow and increases exposure to unpleasant odours (Hassan et al., 2020).


**Figure 4: Survey on Dish Disposal Issues in the Cafe**

**Figure 5: Survey on Dish Disposal Issues in the Cafe**

Automated systems, such as the Automated Plate Slot (Figure 4), have been implemented in certain restaurants to speed up plate return and initial cleaning. These systems often include sensors to detect plates and guide them into a cleaning channel, reducing manual handling and maintaining better hygiene (Kumar & Singh, 2021).

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Another example is the Conveyor System (Figure 5), which transports used plates directly from the customer area to the kitchen. This design streamlines workflow by continuously moving plates to the washing area, reducing the time spent in public areas (Kumar & Singh, 2021). However, both the automated plate slot and conveyor system require high installation costs, fixed infrastructure, and large operational space, making them unsuitable for smaller facilities like UTHM cafes.

The development of efficient material handling and waste management systems requires a multidisciplinary approach that integrates principles of mechanical engineering, ergonomics, and sustainable design. Fundamental mechanical behaviour and system dynamics play a critical role in ensuring structural reliability and operational stability, particularly in load-bearing mechanisms such as spring-assisted platforms engineering mechanics and dynamics (Meriam & Kraige, 2021). In practical applications, previous studies on trolley-based systems have demonstrated the importance of functional compartmentalization and mobility in improving operational efficiency within food service environments (Abdullah & Hassan, 2020).

From a materials and sustainability perspective, the selection of appropriate materials significantly influences product durability, environmental impact, and lifecycle performance, emphasizing the need for eco-informed design strategies (Ashby, 2012). In line with circular economy principles, modern product development increasingly incorporates resource efficiency, waste minimization, and lifecycle thinking into engineering design processes (Bocken et al., 2016).

Hygiene and food safety considerations are also essential in food handling systems, as improper waste containment can lead to contamination risks and public health concerns (Buccheri et al., 2010). Effective waste management strategies, including optimized collection and segregation systems, have been shown to improve operational efficiency while reducing environmental burdens (Cheng et al., 2020). Additionally, insights from warehouse and logistics system design highlight the importance of efficient flow management, accessibility, and space utilization in improving system performance (De Koster et al., 2007).

The engineering design process itself is guided by systematic methodologies that emphasize iterative development, user centered design, and performance evaluation, ensuring that final products meet both functional and user requirements (Dym et al., 2005). Furthermore, maintaining hygiene standards in food service operations requires structured management systems and proper waste handling protocols to minimize risks and ensure compliance with safety regulations (Griffith, 2006).

Globally, food waste remains a significant challenge, with substantial implications for environmental sustainability and resource utilization (Gustavsson et al., 2011), necessitating the adoption of efficient collection and management systems within institutional settings. Ergonomic assessment tools, such as the Rapid Entire Body Assessment (REBA), have been widely applied to evaluate and reduce physical strain in manual handling tasks (Hignett & McAtamney, 2000), while studies on musculoskeletal disorders emphasize the importance of minimizing repetitive movements and improper postures in workplace design (Marras, 2008). Moreover, research on food waste generation across supply chains highlights inefficiencies in handling and disposal processes, reinforcing the need for improved system design (Parfitt et al., 2010). Advances in food waste management technologies further support the integration of

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innovative, sustainable solutions that enhance both operational performance and environmental outcomes (Thi et al., 2015).

## Methodology

The design and development of the 3-in-1 Collection Trolley followed a systematic engineering design process to ensure functionality, durability, and user-friendliness ((Budynas & Nisbett, 2020); Hassan et al., 2020). The methodology is summarized in Figure 6 as a flow chart.

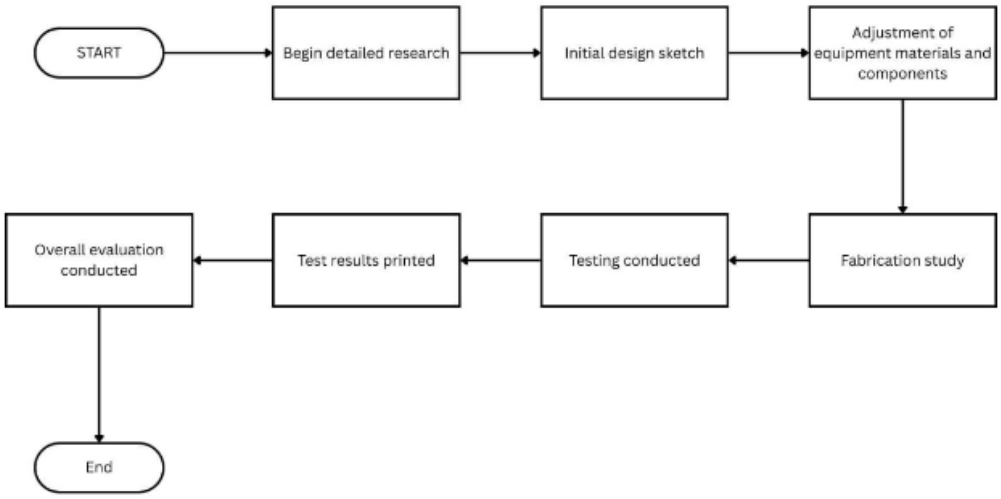


**Figure 6: Flow Chart Of The 3-In-1 Collection Trolley Design And Development Process**

The process began with problem identification through direct observation and surveys conducted among UTHM cafe operators and users. This was followed by data collection on existing products, operational challenges, and user needs. Benchmarking was performed to compare existing plate and food waste collection solutions in terms of capacity, hygiene control, mobility, and cost (Budynas & Nisbett, 2020; Hassan et al., 2020; Kumar & Singh, 2021).

In the concept development stage, multiple design concepts were generated using a morphological chart to explore different frame materials, panel types, wheel types, and waste container options. Each concept was evaluated based on criteria such as functionality, ergonomics, cost, manufacturability, and ease of maintenance. The highest-scoring concept was selected for further development.

The embodiment design phase involved preparing detailed 2D drawings and 3D CAD models of the trolley, specifying materials, dimensions, and component arrangements. Engineering calculations, including spring force analysis based on Hooke's Law (Papargyropoulou et al., 2014), were performed to ensure the plate stacking system could handle the intended load without excessive deformation.

In the fabrication stage, the mild steel frame was cut, welded, and assembled. Plywood panels were cut to size and fixed to the frame, followed by the installation of swivel caster wheels, spring mechanisms, and containers. The testing phase assessed the trolley's performance in

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terms of manoeuvrability, stability under load, odour control, and ease of plate stacking/unstacking.

The development of the 3-in-1 Collection Trolley followed a structured engineering design methodology adapted from established product development frameworks (Ulrich & Eppinger, 2016). The process consisted of five key stages including problem identification, concept generation, design development, prototype fabrication, and performance evaluation. Problem identification was conducted through direct observation and structured surveys among cafe operators and users to identify inefficiencies in existing waste handling practices. Benchmarking analysis was performed to evaluate current solutions based on criteria such as efficiency, hygiene control, ergonomic impact, and cost (Dora et al., 2021).

Concept generation was carried out using a morphological chart to explore alternative design configurations systematically. The evaluation of design alternatives considered multiple criteria, including functionality, manufacturability, durability, and user ergonomics. Engineering analysis was conducted to ensure structural integrity and functional reliability. The spring-loaded mechanism was designed based on Hooke's Law to maintain consistent plate positioning under varying loads. Prototype testing involved experimental evaluation of load capacity, mobility, stability, and waste containment performance. User feedback was also collected to assess usability and acceptance

***Proposed Design***

The proposed 3-in-1 Collection Trolley integrates multiple features aimed at improving operational efficiency and hygiene in UTHM cafes. The design process began with concept generation using a morphological chart to systematically explore combinations of design parameters. Options considered included frame materials (mild steel, stainless steel, aluminium), panel types (plywood, stainless steel sheet, composite board), wheel types (swivel casters with brakes, fixed casters, pneumatic wheels), and waste bin types (open container, enclosed bin, plastic drum).

The morphological chart used in this process is shown in Figure 7.

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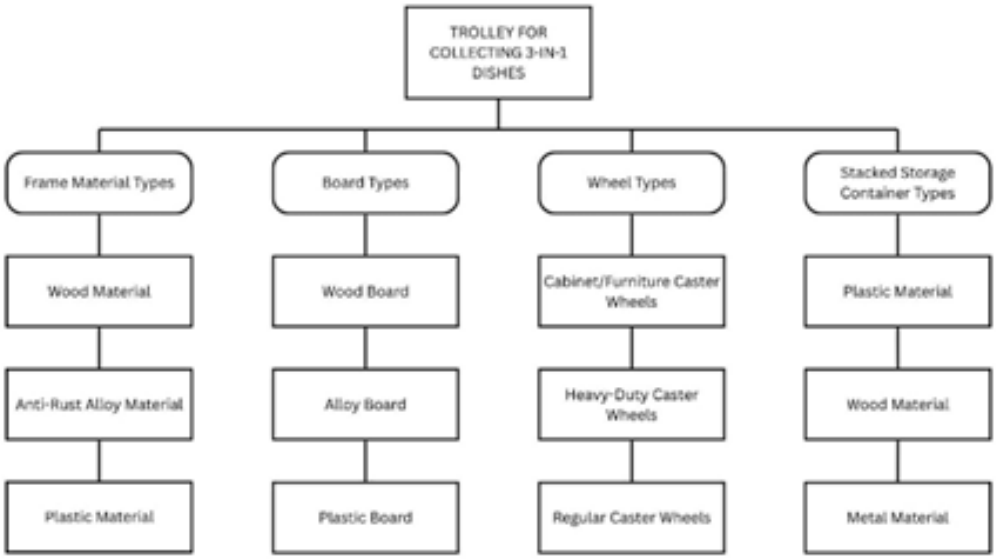


**Figure 7: Morphological Chart for the 3-in-1 Collection Trolley**

After evaluating each combination based on cost, manufacturability, durability, and ease of cleaning, the selected concept used a mild steel frame for structural strength, plywood panels for cost efficiency, 4-inch heavy-duty swivel caster wheels with brakes for manoeuvrability, and an enclosed plastic bin for food waste odour control.

The final conceptual 3D design is presented in Figure 8.

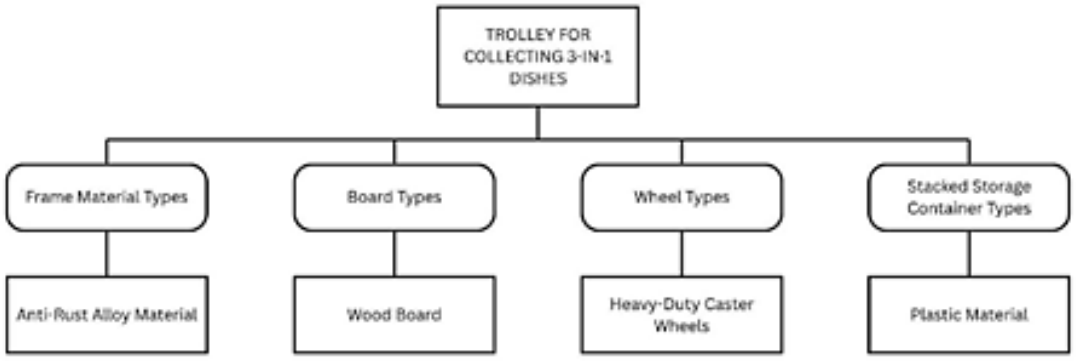


**Figure 8: Conceptual 3D Design of the 3-in-1 Collection Trolley**

This design includes:

- Spring-loaded plate compartment for organised stacking and reduced risk of breakage.
- Enclosed waste bin to trap odours and prevent pest access.
- Separate utensil compartment for forks, spoons, and cups.
- Ergonomic height of 850 mm for comfortable handling by cafe staff.
- Overall dimensions of 1200 mm (L) × 900 mm (W) × 850 mm (H).

The selected design is intended to be both cost-effective and functional, ensuring long-term use in cafe operations while reducing physical strain on workers.

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**Embodiment Design**

The embodiment design stage translated the selected concept into detailed engineering specifications, ensuring manufacturability and structural integrity. The trolley frame is constructed from mild steel hollow sections, chosen for their high strength-to-weight ratio and ease of welding (Budynas & Nisbett, 2020). Plywood panels are used to enclose compartments, providing a smooth surface for cleaning while reducing cost compared to stainless steel.

The trolley consists of three main compartments:

**Plate Compartment** – Equipped with a spring-loaded base to maintain plates at an accessible height as they are stacked. The spring constant was calculated using Hooke's Law (Papargyropoulou et al., 2014) to ensure the force supports up to 80 plates without excessive compression.

**Utensil Compartment** – An open-top container for forks, spoons, and cups, located adjacent to the plate entry slot.

**Food Waste Bin** – A sealed, high-capacity plastic bin positioned at the center, designed to contain odours and prevent pest access.

The overall structure measures 1200 mm (L) × 900 mm (W) × 850 mm (H), allowing easy manoeuvrability in confined cafe spaces while maintaining sufficient storage capacity. Four 4-inch swivel caster wheels with brakes ensure stability during stationary use and smooth movement when transporting the trolley.

The exploded view of the trolley is shown in Figure 9, highlighting the arrangement of the frame, panels, compartments, and wheel assembly.

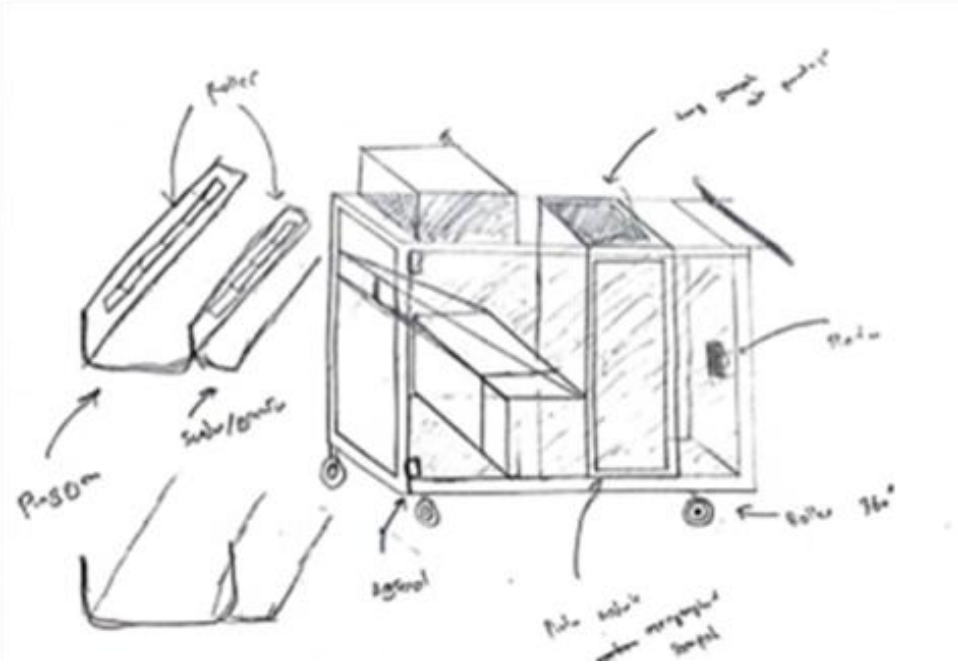

**Figure 9: Labelled 3D internal layout**

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***Details Design***

The detailed design phase finalized all dimensions, materials, and component specifications for fabrication. The trolley structure is fabricated from 25 mm × 25 mm mild steel hollow sections, joined by arc welding to ensure durability under frequent use. All mild steel components are coated with anti-rust paint to prolong service life.

Panels are made from 9 mm plywood for the frame enclosure and 3 mm plywood for internal compartment divisions, selected for their lightweight, smooth finish, and ease of cleaning.
The plate compartment is equipped with a spring mechanism mounted beneath the base plate. The spring constant (k) was calculated using Hooke's Law.

$$F = kx$$

where F is the maximum load from stacked plates (approx. 20 kg), and x is the maximum compression distance (0.15 m). The calculated spring constant ensures smooth compression without sudden drops, protecting plates from damage (Papargyropoulou et al., 2014).

The food waste bin is a 77 L high-density polyethene (HDPE) container with a hinged lid that contains odours and prevents contamination. It is mounted centrally for balanced weight distribution. Caster wheels are 4-inch, 360° swivel-type with dual locking brakes, enabling easy manoeuvrability and stable positioning during loading/unloading. Each wheel is rated for a load capacity of at least 80 kg, exceeding the estimated maximum operational load.

The detailed engineering drawing with dimensions is presented in Figure 10, while the component list and specifications are summarized in Table 1.

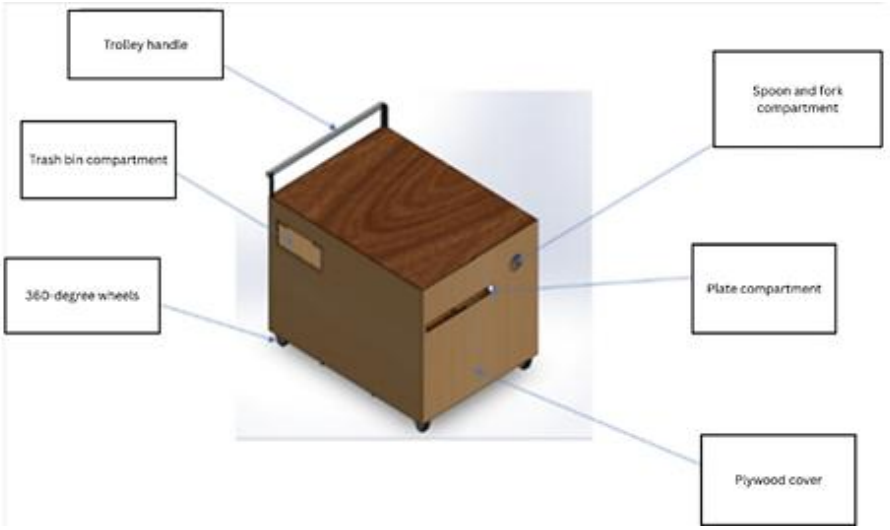


**Figure 10: Isometric Dimensioned Drawing**

***Prototype Development***

The fabrication of the 3-in-1 Collection Trolley was carried out following the detailed engineering design specifications. The process began with the cutting and welding of 25 mm × 25 mm mild steel hollow sections to form the trolley frame. After assembly, all metal parts were coated with anti-rust paint for corrosion resistance.

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Panels made of 9 mm plywood were cut to size and fixed to the frame using countersunk screws. The spring mechanism for the plate compartment was installed beneath the base plate to allow height adjustment as plates are stacked or removed. The 77 L HDPE food waste bin was mounted centrally, and the utensil compartment was fixed alongside the plate slot.

Four 4-inch swivel caster wheels with dual locking brakes were installed to provide mobility and stability during operation. The completed prototype as shown in Figure 11.

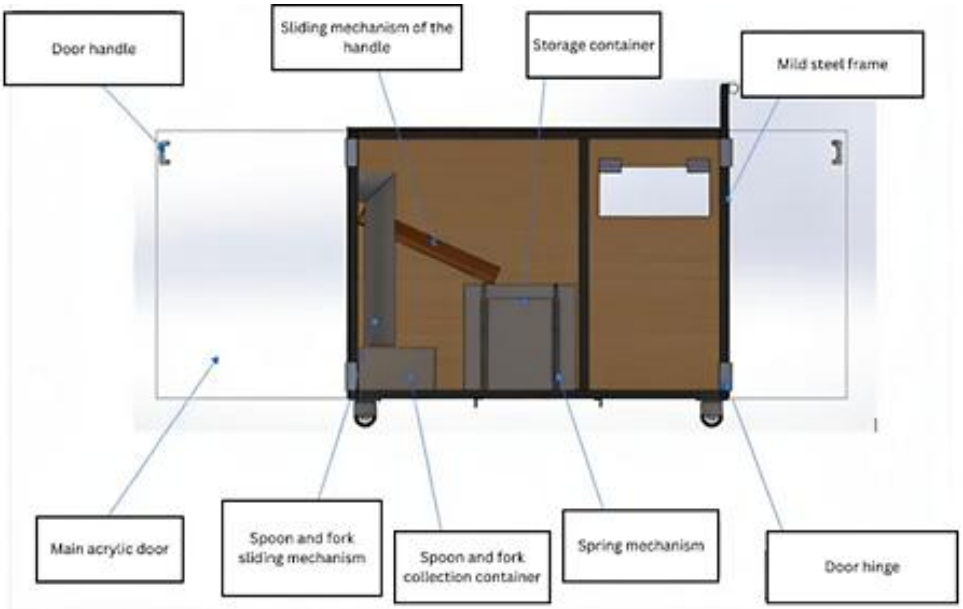


**Figure 11: Side view of trolley**

The fabricated prototype of the 3-in-1 Collection Trolley was subjected to a series of tests to verify its functionality, durability, and user acceptance, as shown in Table 1. The testing phase focused on the following key aspects:

(a) Load Capacity Test
The trolley was tested to ensure it could support the intended load of plates, utensils, and food waste simultaneously. The spring-loaded plate compartment was loaded with up to 80 plates (approximately 20 kg), confirming that the spring compression maintained a stable and accessible stack height.

(b) Mobility and Stability Test
The trolley was manoeuvred across flat and uneven cafe surfaces to evaluate the performance of the 4-inch swivel caster wheels. The results showed smooth mobility, and the dual-locking brakes provided stability when stationary.

(c) Food Waste Containment Test
The 77 L HDPE waste bin with a hinged lid was tested for odor containment. Observations confirmed that odour leakage was significantly reduced compared to open-bin systems, minimizing hygiene concerns in cafe environments.

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(d) User Feedback

A survey was conducted among UTHM cafe staff and student users. Respondents highlighted the following advantages:

- Easier collection of plates and utensils.
- Reduced odor and pest issues.
- More efficient cafe cleaning process.

Some feedback also suggested future improvements, such as integrating sensors for bin level detection and lightweight composite panels to reduce overall weight.

The evaluation confirmed that the 3-in-1 Collection Trolley met the primary design objectives of efficiency, hygiene improvement, and user-friendliness.

**Table 1: Prototype Development Test Category**

| Test Category | Methodology | Result / Observation |
|---|---|---|
| **Load Capacity** | Loaded 80 plates (~20 kg) into the spring tray | Spring compressed smoothly, plates remained accessible |
| **Mobility & Stability** | Moved across flat & uneven cafe surfaces | Smooth movement: brakes secured the trolley firmly |
| **Food Waste Containment** | Odor test with 77 L bin | Odor leakage has been significantly reduced |
| **User Feedback (Survey)** | 20 cafe staff & student responses | Positive usability; suggested future improvements |

The findings of this study demonstrate that the proposed 3-in-1 Collection Trolley significantly improves operational efficiency and hygiene in comparison to conventional waste handling systems. The integration of multiple functions into a single unit reduces handling time and minimizes unnecessary movement, which aligns with lean operation principles in food service systems (Dora et al., 2021).

From an ergonomic perspective, the spring-loaded plate mechanism reduces repetitive bending and lifting, thereby lowering the risk of musculoskeletal disorders among workers (Marras, 2008). This supports previous findings that ergonomic interventions in material handling can improve worker safety and productivity (Karwowski, 2012).

In terms of hygiene performance, the enclosed waste bin effectively reduces odour emission and pest attraction, which are common issues associated with open waste systems. This improvement is consistent with established food safety practices that emphasize proper waste containment to prevent contamination (Todd et al., 2010).

Compared to automated systems such as conveyor belts and sensor-based return systems, the proposed design offers a more flexible and cost-effective solution suitable for small-scale operations. While automated systems provide higher throughput, their implementation is often constrained by high capital costs and infrastructure requirements (Gu et al., 2007).

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Overall, the results indicate that the proposed trolley provides a practical balance between performance, cost, and usability, making it a viable solution for institutional food service environments.

## Conclusion and Recommendations

This study successfully developed and validated a portable 3-in-1 collection trolley designed to improve efficiency, ergonomics, and hygiene in institutional cafe operations. The integration of a spring-loaded plate system, utensil compartment, and enclosed waste bin into a single mobile unit provides a practical and cost-effective solution to existing operational challenges. Experimental results confirmed that the system can handle operational loads while maintaining stability and usability. Furthermore, the design significantly reduces odour leakage and improves workplace cleanliness. Future research should focus on integrating smart monitoring systems, such as IoT-based sensors for waste level detection, and exploring lightweight composite materials to enhance mobility. The scalability of the design for larger commercial applications also presents a promising direction for further investigation. The study contributes to the field of sustainable product design and food service engineering by providing a practical solution that aligns with modern requirements for efficiency, hygiene, and sustainability.

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**Ethics Statement:** This study did not involve any human participants, animals, or sensitive data requiring ethical approval. The authors confirm that the research was conducted in accordance with accepted academic integrity and ethical publishing standards.

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