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DESIGNING A USER-CENTRIC MOBILE INTERVENTION FOR FOOD WASTE REDUCTION IN MALAYSIAN URBAN HOUSEHOLD: A DESIGN THINKING APPROACH

Wong Hui Lin[1], Haliyana Khalid[2*]

[1]Azman Hashim International Business School, Universiti Teknologi Malaysia, Malaysia
wonghui.lin@graduate.utm.my https://orcid.org/0009-0003-4241-632X
[2]Azman Hashim International Business School, Universiti Teknologi Malaysia, Malaysia
haliyana@utm.my https://orcid.org/0000-0002-5608-2688
*Corresponding Author

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Abstract:

In Malaysia, generation of household food waste is more serious than the food waste generated from other industries or sectors. Urban households generally generate more food wastes although high level of awareness on the impact of environmental sustainability. They aware the issue and understand the consequences, but less effective action has been taken to manage or reduce the food waste, and therefore, create a say-do-gap. This study aimed to explore the perspectives, needs, challenges, and motivations of food waste reduction in urban household Malaysia using design thinking approach. Semi-structured interview and site-observation were conducted in empathy stage. A total of 11 participants were targeted in the interview session. The 11 participants were categorized into five distinct user personas, including Health-Conscious Individual Cook, The Cultural Compliance Professional, The Green-Minded Urban Renter, The Guilty Minimalist Professional, and The Practical Disposer. Study revealed the reasons of forgetfulness, over-purchasing, and improper food storage contributed to the generation of food waste. To address the challenges, the "GLANCE" digital app for food planning and inventory tracking was designed, introduced, and tested by four users in prototype and test stages. Online survey form was distributed to the participants, and the testing results showed the participants were strongly agreed the user-friendliness and practicability of the app. Overall, the study was designed as an exploratory pilot to establish proof of concept, the app can further improve for long-term user engagement.

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Introduction

Background

Food waste is defined as the food that is removed from the food supply chain, usually happens at retail and end-consumers levels (Phooi et al., 2022). Under certain conditions, food waste happens unavoidably. However, as consumers moving towards healthy lifestyle and look for premium food products, more food wastes are generated as high quality and safe food are usually consumed fresh (Ministry of Agriculture and Food Industries, 2021).

At global level, food waste threatens the food security, a condition where the food should be available in enough quantity and quality, in order to meet people dietary needs and food preferences in all the year (Ariffin et al., 2023; Ministry of Agriculture and Food Industries, 2021). In 2022, about 29.6% of the global population was significantly impacted by food insecure (United Nations Environment Programme, 2024). Food waste is against the Sustainable Development Goal 12.3 (SDG 12.3), which is global food loss and waste. Besides that, it is considered as an obstacle that hindering the progresses such as greenhouse gas emission reduction, water and land resources pressure reduction, food security and nutrition improvement, and increasing in economic growth (Phooi et al., 2022).

To achieve the goal of SDG 12.3, Malaysian government emphasizes the regional commitment, highlighted the food waste reduction along the food supply chain in the National Agrofood Policy 2021-2030, known as NAP 2.0 (Nik Masdek et al., 2023). This is supported by the implementation of strategy such as conduct structured programmes to increase awareness on extent of food waste along the value chain and strengthen joint efforts between downstream players with Non-government Organization such as Food Banks and Charity Bodies to minimize Food Waste and encourage Zero Waste (Ministry of Agriculture and Food Industries, 2021). According to the Ministry of Agriculture and Food Industries, in 2018, household food waste was the main contributor to the food waste generation, recorded 50% higher than other industries and sectors (Nik Masdek et al., 2023).

The higher living standard influences the attitude and behaviour of Malaysians towards food waste, resulting in increasing the waste generation. The issue is intensified during festival celebration (Nik Masdek et al., 2023). High perishable food such as fruits and vegetables, dairy products, and meat are most likely to be wasted. End users may dispose of the food with different reasons such as over-buying, not finished food and extended storage, and

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misinterpretation of food date labels (Kavanaugh & Quinlan, 2020). People think they are affording to dispose of the food and hence, they perceived food waste as acceptable. Insufficient of food planning and management skills also contribute to the food waste generation (Lau et al., 2024).

According to the Solid Waste and Public Cleansing Management Corporation (SWCorp), about 17000 tonnes of food was disposed of daily, which 4005 tonnes is still edible (Lau et al., 2024). Malaysia heavily relies on the landfill method as the traditional waste management system (Nik Masdek et al., 2023). Food waste decomposition leading to the leachate, contaminate the underground water and seriously impacts on the aquatic living organisms and ecosystems. Moreover, the Malaysian governments and authorities are need to address the significant issues such air pollution, water pollution, and climate change contributed by the food waste (Nik Masdek et al., 2023). Effective and sustainable methods for food waste management to reduce the household food waste should be taken to lessen the dependency on landfills disposition (Nik Masdek et al., 2023).

Problem Statement

In Malaysia, household food waste is contributing to more waste generation compared to other sources. Although the national policies such as NAP 2.0 highlight the reduction of food waste, but the urbanization, and rising living standards resulting a perception of wasting food is generally acceptable and cannot be avoided. At present, landfilling is the primary method for waste management or disposition. This method negatively impacts the environment and sustainability such as greenhouse gases emission. A say-do-gap is observed in the consumers where they aware the issue and understand the consequences but often fail to take effective actions to manage or reduce the food waste.

Research Gap

Existing literatures on Malaysian household food waste mainly utilize quantitative method such as online survey to identify the causes food waste generation. Technology-based solutions had been primarily suggested in previous studies. However, there is lack of qualitative, user-centred research on this topic. The application of design thinking approach in this study filled the gap by exploring the insights of urban dwellers and co-creating solution that emphasize the user needs within the Malaysian urban households.

Research Objectives

- To explore the perspectives, challenges, and motivations of food waste reduction in urban households in Malaysia using design thinking approach.
- To categorize the user persona and define the core “Point of View” (POV) for each persona to understand the insights of food waste in urban households.
- To develop a prototype solution based on the “How Might We” (HMW) statement and test the prototype to evaluate the effectiveness to address the needs of household food waste.

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Research Questions

- What are the unexplored perspectives, challenges, needs, and motivations that influence food waste reduction behaviour among urban households in Malaysia?
- What criteria to categorize the user persona into distinct user personas, and what are the core problems and underlying insights for each persona?
- In what way does a developed prototype effectively address the identified needs and challenges of household food waste management?

Research Approach

Mixed-mode research approach was used in this study. Data was collected through semi-structured interview and site-observation in empathy stage, while online survey form was used to collect the feedback of participants after prototype testing. The iterative process allowed for enhancement based on direct user feedback.

Literature Review

Design Thinking & User-Centred Design

Design thinking is a set of activities incorporating various methods and involves structured process, which is critical in design-driven innovation. It has potential to reduce the cognitive biases and facilitate creativity and innovation (Auernhammer & Roth, 2021). In current era, Design thinking provides a new way of thinking particularly in solving highly uncertain and complex problems (Cai et al., 2023). In recent years, design thinking has captured the interest among the academicians and practitioners as a human-centred problem-solving approach, increasingly incorporating in research and innovation such as new product development, innovation strategy, innovation capability, and organizational innovation (Cai et al., 2023).

User-centredness is the foundation of design thinking approach. It primarily focuses on the perspectives and needs of users. User-centred refers to in-depth user understanding and exploring the user needs, encourage users to join actively in generating the ideas, providing feedback, innovative design and solution, and other activities. Learning, trial and error between the problem and solution is referred as iteration. Degree of match among user needs, environment, cost and product functionality can be achieved through iteration (Cai et al., 2023).

Design thinking emphasises iterative, allowing continuous refinement based on user feedback and testing results to solve problem (Deng et al., 2026). Unlike strict linear processes, many steps in design thinking can be run simultaneously and repeated when necessary (Durski et al., 2020). The approach comprises 5 stages which are Empathy, Define, Ideate, Prototype, and Test.

Empathy

Empathy is the first stage of design thinking (Pande & Bharathi, 2020). It involves the activities to understand user's opinions and challenges, identify the potential needs of users in both physically and emotionally, and motivation of an action within the context of the design challenge (Hou et al., 2020).

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Define

In design thinking, Define is refers to thinking about and processing the information collected from the empathy stage, and highlighting the users' insights and needs (Pande & Bharathi, 2020). The problems are clearly defined and transformed into Point of View (POV**)** (Pande & Bharathi, 2020).

Ideate

Based on the POV statements and insights, in this stage, various potential new ideas and creative solutions are brainstormed (Hou et al., 2020; Pande & Bharathi, 2020). "How Might We" (HMW) statements are created by considering the following:

(i) The idea generated should be on the outcome or impact;
(ii) HMW statements should not be too narrow or too broad;
(iii) The constraints and context should be highlighted.

To understand whether the artifacts have captured core of the requirements in previous stages, the HMW statements will be shared with the users for voting (Pande & Bharathi, 2020).

Prototype

The prototype step involves the iterative synthesis of artifacts intended to answer questions that get closer to a final solution. The designer communicates with target users to reduce the difference in understanding and test the ideas without spending too much time and money in programming (Hou et al., 2020).

Test

In this stage, the designer collects feedback through demonstrating the prototype to target users. This activity support in identifying the opportunities for improvement and optimizing the prototype and final solution (Hou et al., 2020).

Design Thinking in Prior Studies

Design thinking approach had been used in different fields such as healthcare, education, business and innovation.

In healthcare sector, mHealth apps had been proved significantly improve the healthy lifestyle, and its design and development interest is increasing over years. There are 9 principles to guide the digital development, one of principles is design with user (Deniz-Garcia et al., 2023). Design thinking approach had been used to develop a self-management support mHealth app through investigate the information needed by the Taiwanese women with breast cancer. This study was conducted by interviewing individual and focus group to gather information on the requirements and expectations with respect to the app. A total of 8 major themes and 2 minor themes were identified at the end of the study (Hou et al., 2020). Another literature presented the mHealth can be an educational app by providing treatment-related information and there was a positive correlation established between patient-reported quality of life and the use of

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mHealth app, which serve as reliable tool for relevant clinical knowledge sharing (Rowland et al., 2020).

In another study, a longitudinal study for a hospital's innovation department applied design thinking to support the development digital transformation and innovation for six years. The results showed the approach was positively contributed to the capability development over time (Oliveira et al., 2024).

In the education sector, design thinking has been employed in Information Technology course to investigate the influence of design-oriented thinking on students' learning of programming, creativity, and design thinking. The results showed that when design thinking approach was incorporated in problem-solving context, it fostered student thinking and creativity, which made it a pedagogy in maker education (Liu & Li, 2023).

In the business setting, design thinking approach has been gaining popularity as a tool to promote the creation of novel user experiences, new business, strategic transformation, organizational and cultural changes. A previous study explored the role of design thinking in addressing various innovation projects. Findings revealed that market value generation was certainly influenced by the projects focused on innovative solutions that captured the current users needs and also visualizing future society (Magistretti et al., 2022).

The CEASE (Communities, Engagement, Actions, Shareability, Ecosystems) design thinking approach had been integrated in the study of sustainable food waste habits during Covid-19 lockdown and maintain a high-level consumer awareness. By using this approach, it fostered the consumer engagement and influenced the consumer behaviour by maintaining the growing practices during lockdown, including the reduction of food waste, encouraging a responsible food consumption and waste management (Massari et al., 2022).

Literature Relevant to Study

In previous research, the urban households' intention towards sustainable food waste management in Malaysia had been conducted by collecting data through online survey. High intention for implementing sustainable food waste management was reflected by the respondents as they claimed this could reduce the expenses on food and minimize the environmental harms. Educational background, income level, and occupation were the highly related to the intention. In addition, factor analysis findings revealed the attitude, perception of social pressure, perceived behavioural control, and desire to reduce wasted food drive the intention of practice sustainable food waste management (Nik Masdek et al., 2023). Another research also showed a positive relationship between motivating factor including social pressure, attitude, and negative emotions and the reduction of food waste intention (Lau et al., 2024).

In another research, Malaysians' awareness on behaviour of food waste generation and food waste component for decomposition had been studied by conducting an online survey based on 400 respondents. The results highlighted that majority of respondents highly aware on the causes and effects of food waste, but less action was taken to reduce food waste. Instead of sustainable practice of food waste management, the food waste was disposed of into normal waste. At the end of the study, the authors suggested simple and manageable composting method such as Bokashi can be presented to Malaysians (Phooi et al., 2022).

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Another study focused on the factors that influence the behaviour of household food waste generation in the Klang Valley by collecting data through online survey. The findings revealed the food waste behaviour related to the food expenditure and reusable of the waste. Poor planning and discipline in purchasing household necessities led to food waste. The respondents who concerned more about the food expenses produce less food waste (Ariffin et al., 2023).

Synthesis and Research Gap

Most of the literatures highlighted that Malaysian consumer highly aware on the environmental impacts of food waste but failed to act. Previous studies primarily focused on factors analysis such as attitude, social norms, perceived behavioural control relates to the intention of food waste management. These studies failed to understand the real challenges and needs of the users in this modern era and urban landscape.

The CEASE design thinking model had been successfully used in the international study of the sustainable food waste habits during Covid-19 lockdown. However, existing Malaysian research suggested some solutions that focusing on the food waste handling rather than preventive solutions. The corrective action such as Bokashi composting as an effective solution for the household with limited space and those who lack of time to manage the composting. The suggestion highlighted a disconnect between the proposed technical and the actual living conditions of the urban households. The application of design thinking in this study bridged the gap by focusing the challenges and needs of the target users and looking the desirable solutions to fit into their daily constraints.

Methodology

Research Design

This study used qualitative method including semi-structured interview and site-observation in empathy stage. Interview guide included open-ended questions was prepared according to the research context. The interview session was then conducted with the selected participants individually from different households in urban area of Malaysia. Due to the travel distance, the on-site observation was concurrently conducted in certain participants' houses that near to the author residential area. The on-site visits captured the contextual behaviours such as fridge arrangement and food waste handling methods through photos with informed consent. In the prototype and testing stages, user feedback was collected using online survey method. A Google Form consisted of Likert scale and open-ended questions was distributed to the four participants. The feedback was then analysed to identify the limitations and improvement needed for the prototype.

Design Thinking Approach

Empathy

Depending on the participants involved in this study, one or two techniques were used in empathy study. The one-to-one interview session was conducted with all participants by asking a set of questions that specific to the participants' perception, challenges, needs, and motivation that author was trying to address. Some photos were taken from the participants' house to observe their kitchen habits, grocery shopping routine, and food waste disposal practice.

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After the interview session, an empathy map was created for every participant to capture the participant's view and feeling and emotion on the household food waste Every empathy map was divided into six quadrants included think and feel, see, say and do, hear, pain, and gain.

Define

After analysis of interview findings, based on the participants living arrangement, they were grouped into five distinct user personas and five "Point of View" (POV) in the format of user + needs + insights were identified and synthesized.

Ideate

A total of 16 HMW statements were brainstormed and created. Each participant was informed to vote for three HMW statements, based on their preferences. The prototype (step 4) for most voted HMW statement was then created.

Prototype

The low-fidelity prototype was conceptualized and developed through storytelling techniques. This idea was then shared with the four participants to collect the feedback for high-fidelity prototype improvement and creation. After received the feedback from the participants, the amendment was made to improve the design and features of the high-fidelity prototype and for user testing.

Test

High-fidelity prototype was tested by four participants. After testing, the feedback was collected from the participants through online survey form. This stage further validates the participants' needs and the evaluation results refines the prototype features.

Participants

In this study, a total of 11 participants who lives in urban household in Malaysia were selected to achieve the study objectives and provide in-depth insights about the food waste behaviour in their own household. The demographic form was distributed to the participants and collected demographic details included gender, age, current occupation, living state or territory, current residence, and household size. Through distributed the demographic questionnaire, this allowed to identify and understand their backgrounds and excluded those who are not from the urban area Malaysia.

Data Collection Methods

Semi-Structured Interview

Interview guide relevant to the study topic were established prior to interview session. The semi-structured interview was then conducted by asking the questions to explore the study topic deeply while the participants' unique insights were adapted to ensure the conversational freedom. The mix between pre-determined questions and unstructured interview provided a balance between both core information and unexpected particulars from the participants. For

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every participant, one-to-one interview sessions lasting 20 – 50 minutes through either physical or phone call interview. During the session, the audio was recorded for further analysis.

Site-Observation / Photo

On-site observation was concurrently conducted in certain participants' houses and the photos were taken with informed consent. Besides that, some participants were requested to submit the photos of their refrigerators, waste bins, and food leftovers. These photos may reveal the say-do gap, where the gap between what participants say and actual behave towards the food waste in their house.

Online Survey

Online survey questionnaire (Google Form) was distributed to four participants to collect the data for user experience and improvement needed for the prototype after they tested the high-fidelity prototype testing. The questionnaire consisted of four parts including:

(i) Section A: demographic information
(ii) Section B: user-friendliness (Likert scale rating)
(iii) Section C: practicality (Likert scale rating)
(iv) Open-ended questions including the visual perception towards the prototype and refinement needed in the prototype.

Data Analysis

The analysis of the primary data followed the steps as below:

All recorded audio obtained during interview sessions were transcribed into text. The transcriptions were individually read and key findings were extracted.

Ethical Consideration

Informed Consent

As this study collected the demographic information and private domestic setting of the participants such as the food waste management habits and the residential spaces, a plain-language consent form was distributed to every participant before collecting the data and interview session. Every participant was acknowledged and explained the nature and purpose of this study. They were informed the participation of this study was voluntary and they were deserved the right to withdraw at any time. By providing the consent, the participants agreed to join the study and process their responses.

Anonymity and Confidentiality

Participant identities were pseudonymized by using Participant 1 to Participant 11 (P1 – P11). The audio-recorded and their responses were transcribed, extracted, and anonymized quoted in

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journal articles. The collection of demographic details was compiled and reported in publications or presentations, but no identifiable details were disclosed. The photos of the residential space were used only for study purposes.

Results

Empathy Stage Findings

Semi-Structured Interview & Site-Observation

In think and feel quadrant, the participants generally fall into two categories: (i) those who feel guilty in wasting food, and (ii) those who viewed food waste as normal or no feeling about the food waste. Many participants expressed heartache or guilt when wasting food:

> *"Sometimes I do feel it is a little bit heartache, because it was the food previously, maybe before the expiry date. But then due to some reasons, this food is not consumed, and it has been wasted or the quality is not safe to consume anymore." [P4, 5 household size].*

While less felt indifferent or believed food waste cannot completely be avoided:

> *"I feel like food waste to some degrees are unavoidable, that is why I feel indifferent about it." [P5, 4 household size].*

Majority of participants expressed lack of awareness regarding the food waste on environmental impacts, only a few participants highlighted the environmental consequence of food waste such as methane gas emission.

All the participants believed that preventive action was more important than corrective action. Many participants believed that culture such as the family culture plays a key part than religion in shaping their behaviours. Religion wise, some participants mentioned religion emphasizes the appreciation of food or those wasting food will receive punishment afterlife, while others mentioned religion was no longer a driving force nowadays or did not directly affect the behaviour of wasting food.

In see quadrant, a few participants compared the situation between Malaysia and other countries. One participant mentioned the "Empty Plate" campaign banners in China, but noticed the campaign often led to little actual behavioural change. Another participant highlighted that, in general, Taiwan has strong awareness and culture of food waste management, but both culture and awareness generally weaker in Malaysia. In UK, the initiative such as small food waste box was given to every household and the food waste was directly collected from the households.

In say and do quadrant, fresh fruits and vegetables, cooked meals and leftovers, bakery and cereal products, meat and seafood, and inedible parts were the common food items discarded by the participants. Forgetfulness led to extension storage of the food items in fridge or kitchen, over-purchased the food, and improper storage of food led to earlier spoilage were the common reasons of food waste generation.

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> *"Previously, we noticed that the vegetables or fruits we bought from the outside and we did not put any proper plastic bag and store, then leave it in the fridge. They cannot long last, around one week or maybe some less than one week, we cannot consume anymore, we just throw it." [P2, 5 household size].*

In general, most of the participants able to differentiate and explained between food date label, "Best Before" and "Use by". The food was consumed even though after "Best Before" date if the food was safe to consume and still in good quality, but the food after "Use By" date was disposed of immediately even the food is still look good. A few of participants highlighted that they discarded the food immediately after it passed the best before or used by date, regardless of the quality and safety of the food. Besides that, some participants found cooking portion estimation was harder when cooked for other household members or hosting party led to food waste.

Inconsistent schedule such as busy working life led to late lunch, dining out, causing pre-planned or cooked meals discarded into the waste bin. In small household, big portion of pre-packed food bought from retailers or sellers were difficult to finish in time. Extra components in standardized food set such as side dishes and sauces were often discarded into the dustbin. For waste segregation, some participants tried to separate the dry and wet wastes, but these wastes ultimately combined into one garbage bag for disposal.

In hear quadrant; family members frequently act as the primary source in influencing the food waste reduction.

> *"We will eat the food brought from prayer hall; this is for everyone."* when putting the leftovers in the fridge. [P3, 3 household size]

For the pain points, lack of accessible composting facilities at or near the residential areas was the most highlighted challenge by participants. For the participants interested in composting at home, they were deterred by pests, bad smell, and expensive electronic composters:

> *"I don't know where the composting or recycling facilities are. Because they might be in one place, but it is very troublesome for us to go there, and we may have to drive there."* [P9, 3 household size].

Most of the participants highlighted that saving money was the primary motivator to reduce the food waste. Healthier lifestyle through controlling the prepared food portion and environmental protection were also highlighted as motivators to reduce generation of food waste. Figure 1 showed the individual empathy map of Participant 1 (P1).

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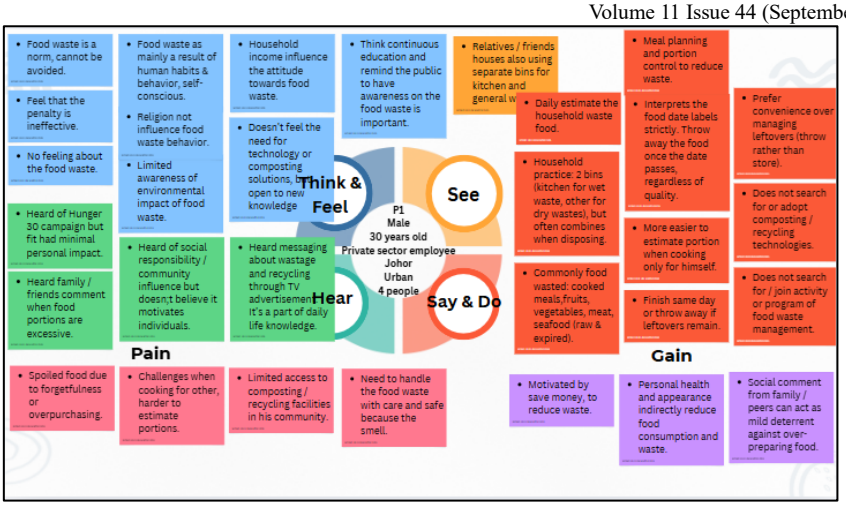

Figure 1: Empathy Map of Participant 1 (P1) of This Study

The photos taken from the participant's house.

Figure 2: (1) & (2) The Storage Condition of Food and Fridge in The House of Participant 6; (3) The Expired Orange Juice Found in The Fridge

Define Stage Outcomes

Among the 11 participants, they were grouped into 5 distinct user personas. The grouping made was based on the living arrangement of the participants.

Table 1: The Summary of The User Persona and POV Statement in This Study

User Persona	POV Statement		
	User	Needs	Insights
The health-Conscious Individual Cook	He was living with other 3 company staffs but often practices individual cooking. He was much taking care of his external appearance.	- He needed estimate the food portion accurately. - He opened to new knowledge of food waste management solutions. - He needed convenient disposal method.	- It was easier to control the portion when cooking individually. - He was motivated by saving money as well as the personal health and appearance rather than environmental impact and technology.

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User Persona	POV Statement		
	User	Needs	Insights
			- He preferred convenience by just throwing the leftovers into the dustbins instead of managing them.
The Cultural Compliance Professional	She lived in a multi-generational family including her grandmother, parents, and younger brother. She worked as a salesperson.	- She needed easy to use and user-friendly methods or technologies. - She needed accessible and effective composting facilities and system. - She needed better tools or communication strategies to help her family adjust cooking volume.	- She viewed adopt corrective actions on food wastes were too tedious and consuming. - Lack of proper infrastructure disincentives personal effort in separating food wastes and makes recyclable materials unusable. - She felt frustrated due to her working nature as a salesperson often leads to late lunch, which clashes with her family's fixed dinner time. The elder cooking too much of food for fear of starving children which contributes to wastes.
The Green-Minded Urban Renter	She lived with one housemate in a rented apartment in Kuala Lumpur. She had no own transport and is rely on public transport for travelling.	- She needed knowledge on proper storage and nature of foods. - She needed knowledge on repurposing leftover. - She needed convenient waste disposal infrastructure.	- She felt uncertain whether certain foods can be stored together due to limited knowledge on nature of food. - The limited storage place, small fridge, and no proper dry place in the rented apartment caused food spoilage. - She was proactive in waste management, but lack of on transport causes inconvenient travel to the disposing centre.
The Guilty Minimalist Professional	She was an urban working professional	- She needed solutions to avoid leftovers when food is in a	- The fast pace of urban, working life, caused her meal planning

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User Persona	POV Statement		
	User	Needs	Insights
	living in a multi-adult household.	standard packing size. - She needed convenient, affordable, and user-friendly methods or technologies for food waste management at home. - She needed shared responsibility within household.	inconsistent, could not finish the standard portion of prepared foods, and ultimately all foods being discarded. - Different family members attitude caused it less possible for her to consistently manage the waste.
The Practical Disposer	He aware of the financial cost of food waste. He or his family members act as primary source of waste generation.	- He needed practical knowledge and tools for repurposing leftovers. - He needed reliable and convenient disposal method for unavoidable food waste that free from pest, safety, and smell issues. - He needed affordable and verified technology.	- The food waste generation was unavoidable due to forgetfulness, over-buying which led to extended storage and freshness deteriorate, over-preparing, and skip meals. - The simple way to manage food waste was composting, but it may attract pests, having bad smell at home. - Unverified repurposing methods may develop toxin which lead to safety issue.

Ideation Results

A total of 16 HMW statements were brainstormed and created. The category of ideation explored were (i) portion & financial management, (ii) planning and storage efficiency, (iii) waste disposition and separation habits, (iv) behavioural and lifestyle integration, and (v) specialized waste processing that focusing on technical and safety issues of turning waste into a valuable resource. Among these HMW statements, the highest voted HMW question was "How might we help to improve food planning and storage management", under category of planning and storage efficiency. The overall voting results were shown in Figure 3.

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Figure 3: The Overall Voting Results of The HMW Statements

Prototype Description

Low-Fidelity Prototype

Based on the most voted HMW statement, the idea of low-fidelity prototype was brainstormed and created. The chosen idea named "GLANCE" and it combined a magnetic board with mobile app. The magnetic board was served as a physical awareness dashboard, and the app was the "brain" of this system. This combination was a system-flow prototype, served as a communication tool for household members, ensure that the food storage status was always on in the kitchen, while providing personal accountability through mobile notification.

To collect feedback for prototype's improvement, a total of four participants were randomly selected from 11 participants in empathy stage to present the selected idea through interview method. The key findings justified the transition from low-fidelity concept to the high-fidelity prototype where the participants highlighted the user-friendliness, practicality, affordability of the concept for all household users including the elders and low-educated person.

High-Fidelity Prototype

The Proto.io application was used to create the high-fidelity prototype. The amendment made according to the participant's feedback and the explanation for each interface as below:

Interface 1: login interface incorporated language selection and password system. The password served as a "sync" function, allowed the household members to access a shared, real-time inventory across multiple devices.

Interface 2: food item registration interface with automated date and time updates. The voice typing feature had been integrated to help the elder users for efficient data entry.

Interface 3: the dashboard for registered food item with "traffic light" colour-coding. The red light represented the immediate attention needed for food expires within 24 hours or expired. The yellow light represented the food to be expired within three days. The green light represented the fresh inventory.

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Interface 4: proactive alert system. The mobile push notification to alert the user about the status of food items specifically in red and yellow pulses. This providing a prompt reminder to ensure the food is consumed before expiring, hence reducing household food waste.

The final prototype (the app interfaces) was shown as below:

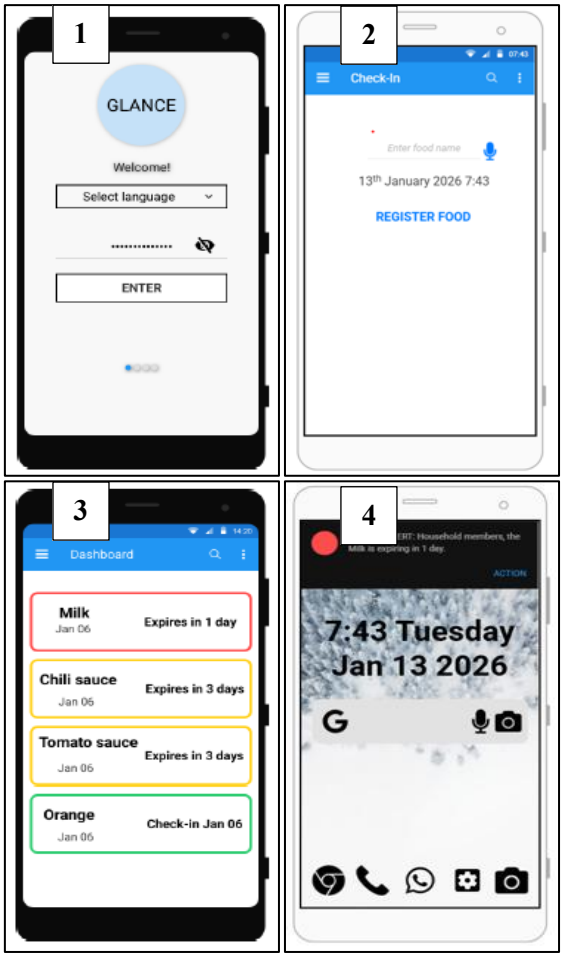

Figure 4: Interfaces of The GLANCE App. (1) The Login Interface of The App; (2) The Food Item Check-In Interface; (3) The Dashboard to Show the Registered Food Items; (4) The Phone Screen Receiving Push Notification About the Status of Food

Testing Results

The survey results showed the participants strongly agreed the interfaces were easy to navigate, the gesture controls were natural and intuitive, and the "red pulse" gave a clear indication on the food needed immediate attention. The figure 5 showed the rating results of user-friendliness of the app.

From the practical viewpoint, the participants expressed strong confidence that the app would help them reduce food waste at home and the push notification was helpful rather than annoying. The high intention of using the app for daily check-in would suggest the app resolve the needs of managing inventory. The figure 6 showed the rating results of practicability of the app.

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In term of visual design, participants highlighted the clear and easy-to-read fonts, and sufficient contrast between the text and background colour suitable for elderly users. Another participant recommended to enhance visual appeal and the design by including unique and charming buttons, and vibrant colour palette on the current app interfaces. To further enhance the user experience, the participants suggested that voice recognition, reward program, and search functionality such as predictive text or auto complete could be integrated to the app as advanced features.

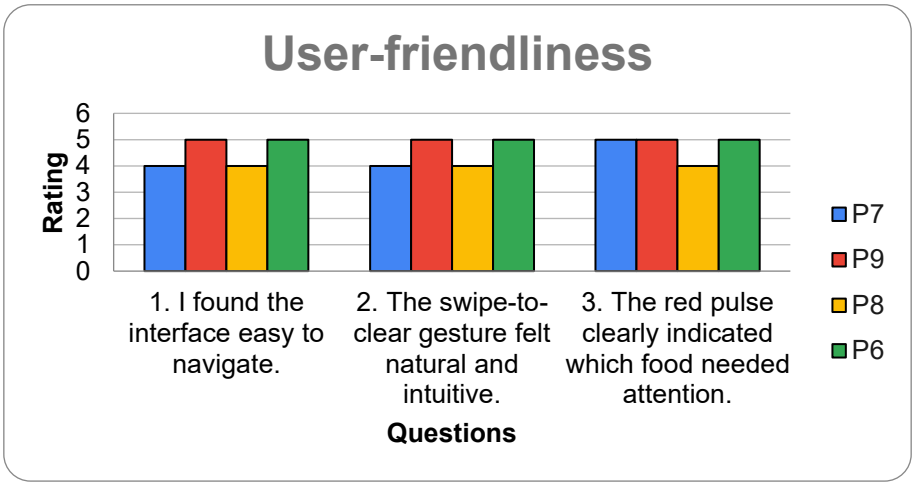

Figure 5: The Rating Results of User-Friendliness of The App

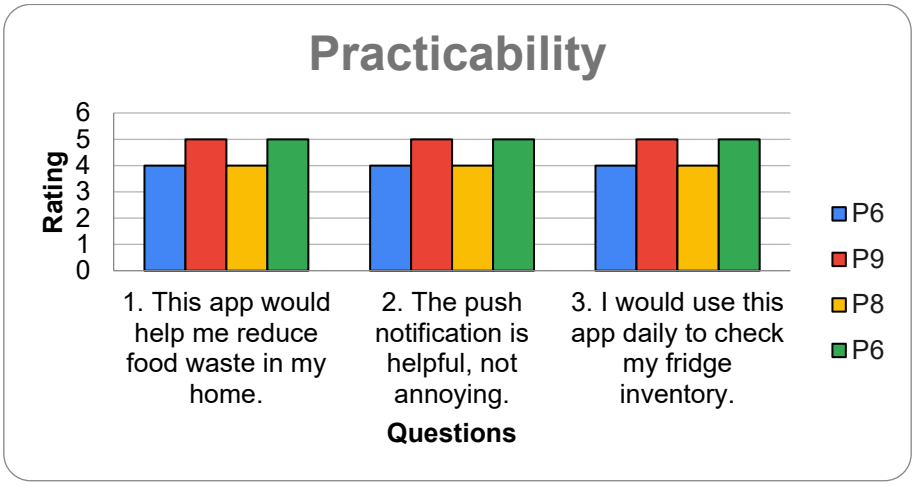

Figure 6: The Rating Results of Practicability of The App

Discussion

Interpretation of Findings

The findings of this study revealed an intention-action gap. While many participants expressed that they were guilty of wasting the food and realized wasting food was "wasting of money", despite the emotional and cognitive attitudes, this rarely changed into better food waste reduction behaviours. Saving money was highlighted as a strong motivator in reducing the food, while the environmental sustainability remained ambiguous for many. This was

inconsistent with previous research where negative emotions were identified as key motivator in reducing household food waste (Lau et al., 2024). In general, the food waste was perceived as a norm in Malaysia, and it was unavoidable in modern lifestyle. Therefore, individuals felt less personal responsibility to improve it.

The reasons that led to food waste included forgetfulness, extended storage of the food items in fridge or kitchen, over-purchased the food, and improper storage of food led to earlier spoilage. The lack of regular plan and memory deficits were always associated with over-purchasing of food items. The underestimation of time required to cook and consume food before expiration date may lead them to purchase more food. Besides that, unpredictable events or unplanned commitments increase the chance of overestimation the meals will be prepared at home (Castro et al., 2023). The most common food items discarded by the participants included fresh fruits and vegetables, cooked meals and leftovers, bakery and cereal products, meat and seafood. Extension of shelf-life of perishable items and avoid the foods to be discarded prematurely can be achieved through proper food storage practices such as correct temperature control and separating raw and cooked foods (Dr. Abid Jan et al., 2025).

For urban living community, barriers such as limited space in housing area, lack of accessible community collection centres and composting facilities, and insufficient implementation of waste segregation practice make the participants felt their individual action impractical. Lack of these infrastructures lower the motivation and lead to poor efficiency and difficulty in engaging food waste management (Ruoh Jau & Ali, 2024).

Household food waste was not only an individual problem but also the outcome of other household members behaviours. In a multi-generational home, the elder family member may prepare the food more than necessary due to care of the children by not starving them. The household with young children or large household size tends to waste more food due to difficulty in estimating portion and tendency to prepare more food (Zaharuddin et al., 2025). This situation frequently happened during festival seasons. In addition, the household members with limited awareness in reducing food waste generation and less motivated to undertake the responsibility further hinder the efforts at home.

The most selected HMW statement represented the participants agreed prevention of food waste generation was more important than managing the waste already established. The GLANCE prototype was ideated as a way to address the most selected HMW statement for improving food planning and manage storage. Household inventory application could provide a summary of previous shopping and consumption experiences by displaying previously bought items and keep track the needed and unneeded items (Castro et al., 2023). Using smartphone to support the food waste reduction as the device is associate with daily life, enables individual and community to contribute to sustainable environment (Tuah et al., 2022). In the context of Technology Acceptance Model (TAM) model, perceived ease of use, perceived usefulness, and perceived trust are critically driving the adoption of a new technology by users (Shishakly et al., 2023). Although the participants strongly agreed to the user-friendliness and practicality of the digital app, there were some improvements such as reward program for future iteration suggested by the participants to maintain the user engagement in long run. Since the app was designed to support the food waste reduction, the rewards system can motivate and get more users involved (Tuah et al., 2022). Previous research findings showed both perceived ease of use and perceived usefulness serve as positive

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determinants influencing the consumers' willingness to engage mobile apps to mitigate food waste issue (Fraccascia & Nastasi, 2023).

Linking Findings to Literature

The findings in this study align with and expand upon previous research studies on food waste management in Malaysia. In this study, moral guilt as well as positive influence by the cultural and religion beliefs expressed by the participants, but these thoughts and feeling did not convert into sustainable action. This aligns with the previous research study on the awareness on food waste reduction behaviour and food waste component for the decomposition among users in Malaysia, where the participants aware the negative impacts of food waste, but less action taken to resolve the issue.

Previous study identifies the financial saving motivates the user's intention to reduce food waste. This aligns with this study where most of the participants highlighted save money was the primary motivator to reduce food waste generation. This study suggested that there was a link between the healthy lifestyle and food waste reduction. However, previous research showed no significant connection between health risk concern and the intention of reducing food waste. Previous literature suggested a positive relationship between minimizing the environment harm and high intention of implementing sustainable food waste management. This study also found that environment protection motivates some participants to reduce the generation of food waste. However, majority of the participants still less aware on the environmental impact of food waste.

While previous study mainly focused on the individual intention of food waste management, this study revealed that attitude and awareness of other household members also play an important part in reducing food waste generation. The GLANCE prototype specifically targeted this by including a shared password to foster shared responsibility among the household members.

The literature recommended the post-actions like Bokashi composting targeted the users with limited living space and busy lifestyle. This study shifted the focus from managing the generated food waste to prevent it from happening. Most believe the bio-composting is a best method to manage the food waste. This study revealed doing composting at home may attract the pests and having bad smells, hence, reduced the intention to do composting at home.

Previous study related the wasting food behaviour to the food expenditure, food preferences, and planning of grocery purchase, and findings showed the food expenditure and planning play some parts in causing the food waste. In this study, the participants highlighted forgetfulness, over-purchasing of food, improper storage, and busy daily schedules were the main causes.

Contribution of Design Thinking

Design thinking approach added value to the study by shifting the focus from a common issue to a user-centred issue and moved beyond the quantitative method to iterative method to understand the reasons behind every action and thought. Interview session allowed author to gain insights and understand the perspectives, emotional motivator of food waste, as well as the critical challenges that demotivate the participants to proceed to the food waste reduction.

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From the analysis, high-fidelity prototype was ideated that focused on the prevention rather than corrective actions after the food or leftovers were disposed of.

By using the design thinking approach, it addressed a few gaps identified in current literature. Most of the literatures highlighted Malaysian household consumers aware of the impacts of food waste to the environment and society, but they often fail to act. Design thinking uncovers the causes of this say-do gap, such as lack of community composting facilities, busy lifestyle, and attitude and awareness of other household members.

Implications

Practical Implications

The findings of this study translate into a practical implementation. As highlighted by some participants, forgetfulness led to extension storage of the food items in fridge or kitchen, over-purchased the food, and improper storage of food led to earlier spoilage were the reasons that led to household food waste, GLANCE app worked as an inventory tracking with notification to alert the users on the expiry status of food items. The digital app reduced the mental burden or forgetfulness of the household members and foster the shared responsibility among the household members without heavily rely on the members who bought and prepared the food.

The findings may be useful for the local authorities to strategically locate the food waste collection. The study revealed participants want to separate food waste and leftovers, but the composting facilities were not available near the residential area, and the home-based composting often led to pest issues and smell may stop the household to continue the composting. Placing and implementing community composters in the suitable location would address the barriers pointed out by the participants.

Some participants highlighted the unfinished eating of standard size of package food led to leftovers and eventually being discarded in the waste bin. Food retailers or sellers can use these findings to justify the flexible package sizes and the consumers having more choices on the packed food sizes.

Theoretical Implications

This study contributed to the say-do gap academic literature. This was evidenced by the participants' moral guilty when discarding the food, but urbanization, high living standard, busy lifestyle, and limited in infrastructure make them perceived food waste is unavoidable and afford to pay for the food waste. By identifying the psychological and infrastructure barriers, future researchers can further study on these barriers in household food waste management context.

This study implied that external conditions were more predictive than internal intentions. This was suggested by the living arrangement of the household, and attitude and awareness of the household members affect the intention in reducing the generation of household food waste.

This study theoretically implied that financial saving, personal health or external appearance act as the base of the motivation, the environmental protection only became active when the financial and practical had been fulfilled.

However, this study using design thinking approach to understand the psychological and social mechanisms in Malaysia context. It showed the empathy map can be utilized as a tool to present the users' thinking, feeling, and behaviours that quantitative method might miss. The user personas created in define stage to segment and group the population not by demographic details, contributing to future study to categorize the consumers. Since Malaysia is committed to achieve the target of SDG 12.3 by 2030, this study provided an academic knowledge on how economic development can transform from handling the food waste to waste prevention through the digital intervention.

Limitations and Future Research

Limitations

Several limitations were identified in this study. First, only 11 participants were targeted for the interview session (empathy stage), and four participants were involved in the prototype testing. The results of small sample size may yield no statistical significance or evidence of long-term household food waste reduction and satisfaction of the GLANCE app.

Second, this study specifically focused the urban household in Malaysia, where individual is commonly characterized by busy lifestyle and high living standard. This may limit the relevance findings from the rural area in Malaysia. Besides that, the participants from Johor, Selangor, and Kuala Lumpur were recruited to this study. This restricted to specific states that fit the study goals, instead of a broad and representative population in Malaysia.

Third, the most wasted food highlighted by the participants was fresh fruits and vegetables, cooked meals and leftovers, and all these foods were eventually being discarded into waste or being composted at home. The findings provide a narrow data on the handling of inedible parts such as bone, eggshells.

While the digital app was proposed as a solution in this study, elder family members and low educated individual might find some practical barriers such as complicated digital interfaces and manual logging friction. Therefore, the suggested solution may be limited to younger and individual who is proficient in the use of modern technology.

Despite several limitations were identified in this study, this study could be positioned as an initial pilot proof-of concept.

Future Research Directions

Future study should include the data and analysis from rural household in Malaysia to compare the trends between urban waste and rural waste to have a broad and representative results, and to provide a more comprehensive context for Malaysian national strategy.

Longitudinal behavioural studies can be conducted in future research. Rather than one-time interview and testing sessions, future research should be performed over 6-12 months to track the households if the financial motivation or guiltiness leads to behavioural changes. In addition, the participant suggested to include reward program in the digital app, the future study can observe if this gamifying practice is more effective than driven by the moral guilt or pure financial saving.

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Another future research should focus on the high-fidelity prototype refinement and development. The integration of advanced features such as voice recognition, reward program, and search functionality like predictive text or auto-complete as highlighted by the participants should be considered. To further enhance the user experience, the integration of food-specific icons to the interface enhances the visual cue and enabling the users to identify the food status through push notifications.

Conclusion

This study aimed to explore the perspective, needs, challenges, and motivation of food waste reduction in urban household Malaysia by using Design Thinking approach including stages of empathy, define, ideate, prototype, and test. Semi-structure interview and site-observation were conducted in empathy stage.

A total 11 participants were selected from the urban household for the interview session. Through the interview session, the findings revealed a say-do-gap, where the participants mentioned the moral guilty when throwing the edible food, but the food waste was still generated, and less effective action was taken to reduce the generation of food waste. The reasons contributed to household food waste were the forgetfulness led to extended food storage and deteriorate in quality and freshness of food, over-purchasing of food, improper food storage. The attitude and level of awareness of other household members also influence the food waste reduction in household.

By categorizing the participants into five distinct user personas, it provided insights and understanding of urban food waste generation behaviours. The study concluded that to reduce the generation of household food waste, preventive actions such as improving in food planning and storage management was more important than the corrective measures. The GLANCE prototype as a user-centred intervention that primarily focused on prevention rather than post-handling actions.

The smaller sample size with 11 participants may provide a less significant statistical data and this study focused on a few urban households from a few states, which may not represent the overall population in Malaysia. While the digital intervention can be the potential solution to resolve the problems faced by the participants, especially the younger and tech-savvy individuals. However, the older and less-educated individuals may find it complicated. Overall, the study was designed as an exploratory pilot to establish proof of concept, where the future study should focus on the longitudinal study to track the long-term behavioural changes and refinement of the prototype with advanced features to enhance the long-term user engagement.

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Ethics Statement: This study was conducted in accordance with ethical research standards. Informed consent was obtained from all participants prior to data collection. Participation was voluntary, and respondents were assured of confidentiality and anonymity. The data collected were used solely for academic purposes.

Author Contribution Statement: All authors contributed significantly to the development of this manuscript. [Haliyana Binti Khalid] was responsible for the conceptualization, methodology, and overall supervision of the study. [Wong Hui Lin] handled data collection, analysis, interpretation of results, literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript prior to submission.

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