공학 석사학위 논문

# Proposing a mobile technology-based waste recycling framework: in the case of Cambodia

## 모바일 기술 기반 폐기물 재활용 프레임워크 제안: 캄보디아의 경우

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협동과정 기술경영경제정책전공

**Technology Management, Economics and Policy Program**

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이 논문을 공학 석사학위 논문으로 제출함
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## Abstract

# Proposing a mobile technology-based waste recycling framework: in the case of Cambodia

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Waste management is a major issue for developing countries. Environmental and public health hazards abound in Asia's emerging nations, especially in those where large volumes of municipal waste are dumped into open dumping sites, roads, sewers, and waterways without any regard for the consequences. United Nations Sustainable Development Goals (SDGs) provide explicit objectives and metrics for global waste reduction. These aims include increasing collection rates, promoting safe disposal methods, and increasing garbage reuse and recycling rates. Cambodia, which has a population of 16.72 million people (as of 2020), is confronting a variety of solid waste management difficulties. According to the Telecommunication Regulator of Cambodia (TRC), by 2020 there will be 20 million mobile phone subscribers and 15 million connected to the internet. Mobile phones have the potential to serve as a means of establishing contact between various parties. Based on the successful experience, that motivates people to get involved in waste recycling activities, and that really motivates us to think about the potential of

using mobile technology in waste recycling activities in Cambodia as well. The main goal of this study is to examine Cambodia's present solid waste management status and limitation, as well as the performance of the informal recycling activities, local government agencies, and contractual garbage collection services, in order to develop methods and strategies for an alternative approach to recycling. This article proposes a new mobile technology solution to enhance the efficiency of the recycling implementation process in Cambodia and also linking the waste dealer and waste merchant for recyclable waste items through a mobile application.

**Keywords: Waste Management, Recycling, Recycling App, Mobile Application, Cambodia**
**Student Number: 2020-28250**

# Contents

# List of Tables

# List of Figures

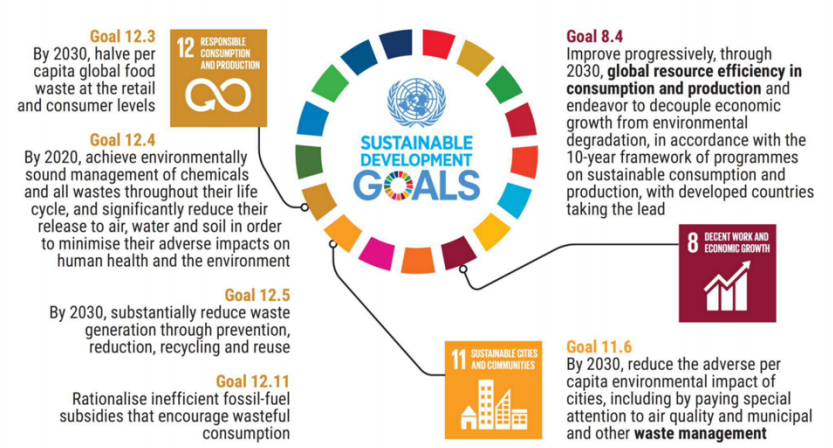
# Chapter 1. Introduction

## 1.1 Research Background

One of the most difficult environmental concerns in developing nations is solid waste. Regarding to the explanation of (Vassanadumrongdee and Kittipongvises, 2018), population growth, economic levels, industrial activity, and fast urbanisation all contribute to this phenomenon. Due to a lack of effective preparation for environmental measures to address these problems, substantial packaging is used, and large amounts of municipal solid waste (MSW) are generated.

It is obvious that MSW is a global problem, and waste management has been included in the Sustainable Development Goals, as seen in Figures 11 and 12, which strive to accomplish the following: Cities and human settlements that are sustainable, as well as consumption and production patterns that are sustainable, are all important considerations. Due to population increase, Cambodia and other developing regions have comparable waste management difficulties,

increasing income and consumption levels, increased urbanisation, and inadequate trash management (Programme and Strategies (IGES), 2018a).




Source: (United Nations,2017)

Figure 1. Sustainable Development Goals 11 & 12

Poor Solid Waste Management (SWM) includes smells from dumping grounds or open waste dumps, the possibility of leachate polluting ground and groundwater, and public health hazards. According to (Ali and Paaopanchon, 2019), a comprehensive approach known as integrated solid waste management (ISWM) is required to advance toward sustainable solid waste management. The ISWM strategy targets the root causes of the problems by prioritising waste minimisation by recycling, reusing, and decreasing waste rather than the usual downstream approaches of landfilling, incineration, and waste-to-energy.

By completing material loops and minimising pollution and human dangers, recyclable municipal solid waste contributes to long-term sustainability and well-being. People who live in cities are critical for successful waste recycling, and even little changes in recycling behaviours may significantly influence a city's ecological (and financial) sustainability (Gu et al., 2019). However, developing good habits is a very difficult task since people in metropolitan regions come from a wide range of cultural, social, and national origins. As a consequence, meaningful public engagement in this area may be challenging.

Waste collectors, such as truck collectors and waste pickers, collect recyclable materials from residential, commercial, market, and public areas, as well as dumpsites, in Cambodia. Most households separate recyclable trash at the source, such as aluminium cans, plastic bottles, and carton papers, for sale to waste merchants or junkshops, according to (Sethy, Sothun, and Wildblood, 2014). Waste recycling has long been done informally in Cambodia, with all work done by hand. Materials of huge value were retrieved at different intervals from the waste stream. For instance, scavengers collected any recyclable things

at the moment of rubbish formation throughout the gathering process at disposal locations and at the waste dump. Many nations, including India, China, and Thailand, practice these recycling practices (Seng et al., 2011). The quantity of recyclable garbage collected in Phnom Penh is approximately 4.3 percent of the total, or 39.7 tons per day. Garbage created by the Phnom Penh municipal government is believed to exist according to (Sethy, Sothun, and Wildblood, 2014).

Mobile phones are becoming more popular in both developing and developed nations, and leading worldwide corporations are making significant efforts to seize and develop this potential. This innovation in technology provides a new route to possibly enhancing SWM systems by providing a low-cost two-way communication system that leads to further benefits (Ali and Paaopanchon, 2019). Several studies mentioned that mobile apps have previously been used to encourage people to recycle garbage more effectively in the waste domain.

The main goal of this study is to examine Cambodia’s present solid waste management status and limits, as well as the performance of the informal recycling activities, local government agencies and

contractual garbage collection services, in order to develop methods and strategies for an alternative approach to recycling which propose a new solution to enhancing the efficiency of the recycling implementation process in Cambodia by using mobile technology and aims to investigate the feasibility of a mobile online waste market in Cambodia by linking all the waste merchants, waste sellers (waste pickers, and households, etc.), for recyclable waste products through a mobile application.

## 1.2 Research Problem

Due to the population growing up, rising income and consumption levels, developing urbanisation, and insufficient garbage treatment, Cambodia has comparable waste management concerns. According to (Singh et al., 2014), the lack of funding and human resources, waste collection, transportation, and disposal site management are still restricted. As a result, Cambodia must establish an effective garbage disposal system. Regarding (Programme and Strategies (IGES), 2018b), the following describes the difficulty with waste management:

- There are insufficient garbage collection and treatment facilities, as well as technical personnel and unclear responsibilities among employees.

- The infrastructures for the waste collecting system are still inadequate, and the technologies used are improper.
- One of the most significant challenges continues to be the lack of evaluation and monitoring capabilities.
- Users' lack of participation, as well as the interaction between impacting factors and their socio-economic aspects.
- Informal waste collectors (households, scavengers, garbage pickers, etc.) play a vital role in collecting and sorting waste, but they find it difficult to connect with waste collection companies or waste merchants to sell waste recyclables.

## 1.3 Purpose of the research

The following are some examples of studies that have been conducted that have shown the potential of utilising mobile technology in waste recycling activities: According to (Jankee, 2021), their research aims to improve solid waste management procedures, especially in the case of PET beverage bottles, by developing a compelling mobile application technology tool that encourages inhabitants of Mauritius to recycle. Another study (Zheyan et al., 2017), found that their study is supposed to benefit Malaysians who promote the notion of utilising a mobile application to improve their country's recycling rate by

allowing users to arrange the pickup of recyclable material in the same manner they book an Uber cab. Likewise (Pagan, 2019), this research aims to show that the mobile application could be utilised throughout the nation to educate, inspire, and engage children and adults to recycle actively.

Based on the successful experience, that motivates people to get involved in waste recycling activities and really motivates us to think about the potential of using mobile technology in waste recycling activities in Cambodia. The main goal of this study is to examine Cambodia's present solid waste management status and limits, as well as the performance of the informal recycling activities, local government agencies, and contractual garbage collection services, in order to develop methods and strategies for an alternative approach to recycling. This study proposes a new solution to enhance the efficiency of the recycling implementation process in Cambodia by using mobile technology and aims to investigate the feasibility of a mobile online waste market in Cambodia by linking the waste dealer and waste merchant for recyclable waste items through a mobile application.

## 1.4 Research questions

- How useful will the mobile application solution be with respect to existing solutions in the context of Cambodia?
- How will the mobile application solution facilitate communication between waste dealers and waste merchants for waste recycle activities?

## 1.5 Originality

I am certifying the following to verify that the research paper I submitted is the product of my independent and original work: All of the sources from which the ideas and extracts were obtained will be appropriately credited. The project contains no plagiarism, and it has not been submitted for publication anywhere.

# Chapter 2. Literature Review

## 2.1 Research Location: Cambodia

Cambodia, as illustrated in Figure. 2.1, is located in the southeast of Peninsula of Indochina, Cambodia is situated. Cambodia's gross land area is 181,035 km2 bordered west by Thailand, north by Laos and east by Vietnam. Waste management has become a major problem in many developing nations, particularly in disadvantaged metropolitan areas. Regarding to (Sethy et al., 2018) Cambodia is classified as a "least-developed country"3 and is rapidly urbanizing as a result of rapid population growth and internal movement from rural to urban regions in search of employment and business opportunities. The solid waste management system is becoming increasingly complicated as a result of these causes. In Cambodia's biggest cities and towns, supervise garbage collection, transportation, disposal, and Local governments and government technical line agencies supervise the project. However, solid trash collection services are still unavailable in numerous Cambodian provincial towns and cities. As a result, each family handles its own garbage, whether by burning, burrowing, or

unlawful dumping on unoccupied land, rice fields, or into bodies of water.


Figure 2. Map of Cambodia

## 2.2 Waste generation and composition

Regarding to (Fujiwara, Mongtoeun and Sethy, 2012), which mentioned that solid waste management information is limited in Cambodia, SWM data is insufficient, inaccurate, and inconsistent across the agencies involved. The dependability of the data is still poor since various sources provide different data. That studied also mentioned that in Phnom Penh the number of solid wastes was

increased dramatically over the last two decades. It is predicted to reach 2784 tons per day in 2020. It is difficult to calculate the amount of garbage produced. A number of variables, particularly GDP, have an impact on it. In most cases, a rise in waste volume corresponds to an increase in revenue (GDP per capita).

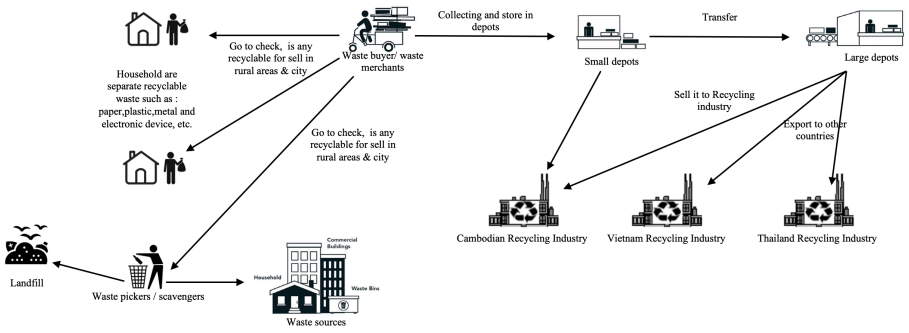
Normally, the total quantity of garbage created is calculated using the amount of rubbish discarded at disposal sites/landfills and an annual waste growth rate of 10–20%. Households, businesses, construction, marketplaces, roadways, and other sources of income are among them. On the other hand, residential solid waste accounts for up to 63 percent of overall rubbish, followed by business waste. Home rubbish accounts for 75% of total waste in Vientiane, Lao PDR. Food waste made up 63.3 percent of household solid waste in Phnom Penh. The informal sector contributes significantly to recycling, accounting for 9.3% of total recycling.

## 2.3 Recycling of municipal solid waste

Recycling takes place in all sectors of the industry because various waste streams include components with value that may be transformed into new recycled products, such as plastic bottles, which can be

turned into sportswear. As a result, it saves energy and money by avoiding the costly process of mining fresh resources for the creation of new products.

Since the beginning of the city's history, waste recycling has been carried out in an informal manner, with the bulk of the job being performed by manual labor. At different stages along the process, valuable elements are extracted from the waste stream. As an example, recyclable items were gathered by scavengers at the point of garbage creation, throughout the collecting process, at disposal sites, and at the landfill. According to (Seng et al., 2011), there are many nations, including India, China, and Thailand, have adopted similar recycling practices. Under the Ministry of Environment's (MoE) licensing program, the quantity of recyclable rubbish acquired for recycling by junkshops around Cambodia is decreasing, paper, plastic (bags and bottles), aluminum (broken items and cans), iron, glass bottles, and shattered bottle glass are all types of recyclable materials. The recovered materials were shipped to other countries such as Thailand, South Korea, Vietnam, China, Singapore, Malaysia, and Taiwan.




Source: (Seng *et al.*, 2011),

Figure 3. The existing system of informal recycling

Waste collectors, including truck collectors and waste pickers, gather recyclable items from residential, business, market, and public places, as well as dumpsites, in Cambodia.

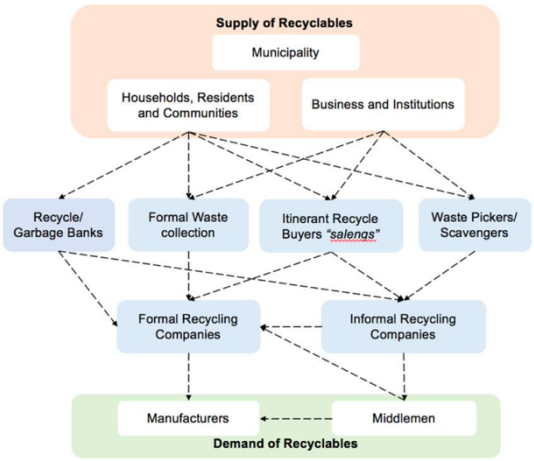
According to (Sethy et al., 2018), The majority of Cambodia's recyclables collectors are impoverished citizens who gather recyclables from waste bins or illegal dumps, and they are waiting for the waste merchant to come and buy any recyclables from their address in exchange for money.

Furthermore, most families separate their recyclable garbage at the source, such as aluminum cans, plastic bottles, and cartons of paper, for sale to waste pickers or junkshops. The informal recycling efforts, as illustrated in Figure 3, are highly active in gathering and sorting

recyclable goods. The municipality of Phnom Penh is expected to collect 39.7 tons of recyclables every day, accounting for 4.3 percent of total rubbish generated. The vast bulk of recyclable materials are sent to Thailand and Vietnam with little or no processing taking place in Cambodia.

Another well-known case is in Bangkok, which has had a population of 9.5 million people since 2018. According to (Ali and Paaopanchon, 2019), the city is dealing with a number of SWM issues. They are investigating the potential of a virtual garbage market in Bangkok by using mobile application technology to link the supply and demand of recyclable waste products. Its feasibility is being investigated in particular in the confluence of government institutions, informal garbage recycling networks, and Bangkok's population groups. The use of virtual markets to boost recycling rates has been investigated, and key stakeholders in the recycling chain (especially those who deal directly with waste sources) have been interviewed. A virtual market provides real-time data on material quality, quantity, pricing, and locations. It also facilitates money transmission. Both buyers and sellers may rate one other's services.

At the same time, as the case studied of (Paaopanchon, S, 2018), also mentioned that the both the formal and informal sectors participate in recycling initiatives. Figure 4 depicts the interactions between the various stakeholders. The household and commercial waste is collected by either sector and sold to recycling companies before being delivered to the demand side. The stakeholders shown in blue in Figure 4 are responsible for collection services. The most common method of recycling materials is by itinerant recycle buyers, or as locals refer to them, who go from door-to-door collecting and purchasing recyclables. This approach makes for 41.5 percent of the total, with the rest coming through tactics such as giving garbage pickers or personally traveling to local junk shops to sell their items.



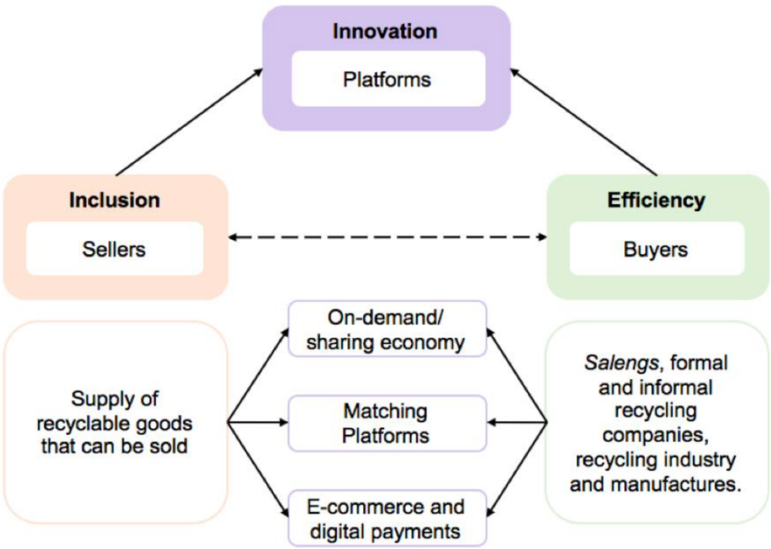

Source: (Paaopanchon, S, 2018)

Figure 4. Interaction between stakeholders in the waste sector

According to (Paaopanchon, S, 2018), due to the lack of an economic problem, institutional structures, technical knowledge, norms and regulations, and socioeconomic issues are all factors to consider. In developing countries, informal waste collection plays a very important role. Waste banks were pushed in large towns or schools to enhance recycling rates. These trash banks gather recyclables and sell them to recycling companies. The amount of money earned is determined by the weight and kind of recyclable material sold in the transaction. Plastics, paper, glass, and aluminum are the most frequently purchased and collected materials by IRBs (Itinerant Recycle Buyers), accounting for 87 percent, 77 percent, 68 percent, and 63 percent, respectively.

## 2.4 Platform & Digital Transformation

Technology advancements aid in the strengthening of bonds between individuals, corporations, and governments, as well as the creation of an inventive platform. According to a case studied of (Ali and Paaopanchon, 2019), 8 out of 10 people in developing countries own a mobile phone.




Source: (Ali and Paaopanchon, 2019)

Figure 5. Proposed innovation mechanism

Figure 5 shows how technology, internet connections, and new ideas may be used to create a platform that connects the many stakeholders. Digital technologies have drastically improved access to information while also lowering the cost of spreading it, resulting in the creation of a virtual market. As a result, numerous vulnerable groups, such as people with impairments, the elderly, and those who live in rural locations, may be included. Providing access to possible purchasers for households that have gone out of service. In addition, technology has improved both sides of the market's capacity to search,

connect, and share information. Payments made over the internet have grown much quicker, cheaper, and more convenient, resulting in more efficient transactions and responsibilities for all parties.

## 2.5 Mobile Technologies in Recycling

In East Africa, Plastic pollution and a rise in the use of plastic bottles have also had an impact. Despite the fact that plastic recycling is promoted on the island, there is a poor recycling rate (40 percent). In this context, the goal of this study is to improve Mauritius' solid waste management systems, by building a persuasive technological tool that motivates people to recycle PET beverage bottles, in particular. Regarding to (Jankee, 2021) intends to enhance solid waste management practices, especially in the case of polyethylene terephthalate (PET) beverage bottles, by creating a compelling technology tool that encourages inhabitants of Mauritius to recycle. The study's purpose is to develop a smartphone application that enables users to locate recycling bins near them while simultaneously offering information on the consequences and importance of plastic pollution and recycling. According to the results, the application aided 80 percent of users in starting their recycling efforts, with the remaining 20% saying that the tool aided them in growing their

recycling efforts.

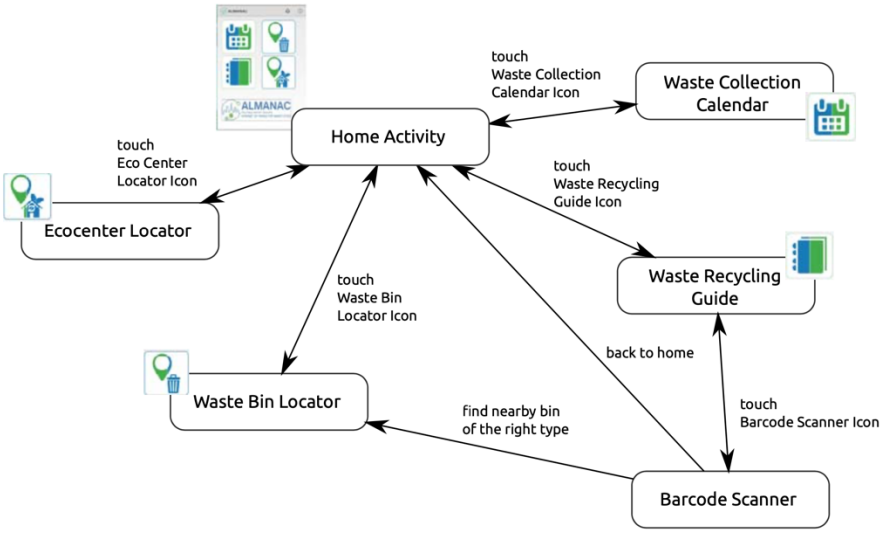
In Malaysia, waste that is now dumped in landfills might be recycled and used in a more beneficial way than being buried in the ground. Although Malaysians are becoming more environmentally conscious, their grasp of garbage reduction via recycling is still limited. According to the studied of (Zheyan et al., 2017), the purpose is to develop a mobile application that would enable users to arrange the pickup of recyclable garbage in a similar way to how they would book an Uber taxi ride. Users of the smartphone application who are interested in recycling may offer to carry recyclable trash to the local waste management facility, if one is available. It is the waste management center's responsibility to compute the market price of recyclable garbage and then pay for it using the application. The payment will be sent to the disposer and the transporter by the application at that point.

Another well-known example is that of the Dominican Republic, which generates waste each day approximately 14,000 tons per day, of which 49 percent is recyclable and just 5 percent is not according to

(Pagan, 2019). This rubbish is causing health problems, as well as damaging the tourist sector and the overall quality of life of the residents are both under decline. The decision-making process for recycling is influenced by confusion, a lack of passion, and a lack of activity priority. The goal of this project (Pagan, 2019), is to create a smartphone app that uses engaging pictures and interactions to help educate, promote, and show the impact of recycling activities in a memorable way. As a result of this study, a demo of the mobile app's main interactions was built. The final system provides real-time data to help users make informed recycling decisions and keeps them engaged by rewarding them with real-world incentives after each recycling action. It engages the target audience with creative tools, leverages Augmented Reality as a social trigger, and uses a virtual community to create awareness of individual and collective actions.

Persuasive tactics are approaches that are used in conjunction with persuasive technology to assist users in developing long-term habits. Interactive programs (mobile and desktop systems) that are meant to inspire users to alter their behavior without the use of force or fraud are known as persuasive technologies. In Italy, the studied of (Bonino

et al., 2016), presented in Turin for trash recycling applications that are built on the basis of a review of the literature on behavioral theories connected to the waste sector, an initial assessment of already accessible mobile applications, as well as customer co-design workshops with a small group. They developed the "WasteApp" by integrating behavioral research and existing mobile app features with a co-design approach to produce a new material recycling mobile app.




Source: (Bonino et al., 2016)

Figure 6. The major actions of WasteApp

The Waste App concept consists of six functional areas: one "Home Activity" that provides access to four function-specific activities such as waste collection calendar, waste recycling guide, waste bin locator,

ecocenter locator, and barcode scanning (as shown in Figure 6), and the last function activity provides barcode scanning. They include: (1) The municipality can update a static trash collection; (2) The user will receive a notification to remind them to drop off required waste on specific days (for example, paper on Thursday morning); and (3) A user can search for the recycle guidelines with a bar code scanner to see the kind of recyclable waste, type, and other information; (4) an online map that shows bins in the user's immediate vicinity, along with their current fill level; and (5) Users can use the map to see where they can drop off their waste, as well as the operating hours and types of waste that they can dispose out.

In Indonesia, according to (Yunanto, 2018), at the local regional and global levels, household waste is becoming more of an issue. Household waste management is a discipline concerned with the control, storage, collection, transportation, and disposal of garbage to landfills. Effective waste management in the home requires accurate geographical data. This data relates to the geographical context of the region under inquiry, as well as particular data about the garbage collecting technique. The goals of this research are to develop the user

interface for an Android-based social media system for household trash recycling (“Pilah Matur App”) and to utilize the survey technique to gauge user satisfaction in user acceptance test writers. Pilah Matur App may be used as a medium for exchanging information about recycled garbage so that it can be exchanged by urban people who may need it to be reused. The Pilah Matur App is expected to reduce the amount of waste disposed to the landfill by sharing recyclable material information.

In Spain, the use of plastics in the economy has steadily increased over the previous 50 years, posing an environmental concern for society and the earth. Plastics output has expanded twentyfold since the 1960s, reaching 360 million tonnes in 2018, according to the PlasticsEurope report 2020. There are also a studied of (Gibovic and Bikfalvi, 2021), which mentioned that by 2025, Europe's plastic recycling goal is predicted to rise from 22.5 percent to 55 percent, highlighting the importance of incentive programs and the necessity to come to decisions on how to motivate households to recycle more. The study's goal was realized, and RECICLOS, a virtual reward token, was established to promote recycling among families by employing

incentives and prizes to enhance recycling behavior, as well as a webapp prototype to track recycled plastic. Because of the multifaceted nature of recycling operations, their close linkages to human behavior patterns, and the high need for communication and engagement, mobile technologies have a big role to play in this sector. The findings suggest that via a variety of successful and novel incentive systems, individuals may be persuaded and their recycling habits modified.

Another, regarding to (Gaggi et al., 2020), the cost of garbage collection and transportation accounts for 13.2% of the entire cost of unsorted MSW management and 23.4 percent of the total cost of sorted Municipal Solid Waste (MSW) management, according to an Italian study on recycling and waste management published in 2019. Garbage sorting is a major problem in many nations, both economically and ethically, since it helps to safeguard the environment. Empirical research reveals that not everyone separates trash properly, maybe because they are unsure how to do so or simply because they are not driven enough. They introduce PadovaGoGreen in this paper, a serious game that teaches individuals how to match

different garbage cans with different types of waste. Inefficient recycling is hampered by incorrect trash sorting. One of the primary causes of this disadvantage is the users' lack of awareness, which is exacerbated by the fact that rules vary by municipality.

Individuals' recycling actions have provided important experience and perceived value. According to (Noorasikin et al., 2018), is a crucial instrument for motivating sustainable recycling behavior. Residents would be more likely to see the advantages of recycling activities if they were rewarded for their action. (Shaw and Maynard, 2008), looked at the possibility of employing incentives to encourage people to recycle their trash at home. The majority of respondents viewed society benefits and local taxation rebates. Financial incentive-based recycling, on the other hand, necessitates changes to the recycling process and system for recyclable household garbage, as well as monitoring procedures.

Another studied of (Shevchenko, Laitala and Danko, 2019) presented a recycling incentive scheme based on an electronic bonus card system, which would increase the rate of electrical and electronic

equipment recycling. The expense of incentives is split among a number of parties. Consumers may use their bonus money to buy remanufactured goods. The incentive amount must be appropriate in terms of cost and environmental impact. In the meantime, it may offer adequate encouragement for users to recycle.

# Chapter 3. Methodology

This chapter discusses the study's methodological framework. The proposed study goals and background were established in Chapter 1, the nature of the topic to be examined. Next, in chapter 2, we have collected the literature review to obtain more material connected to our research subject and to provide form to our research activity. In Chapter 3, we explain the strategy that we will use for our research work. This strategy includes the study design given in a step-by-step format and the methodology used to gather and evaluate the data, system analysis, prototyping, mobile technology, and proof of concept.

## 3.1 Research Design

This study aims to find the most effective persuasion tactics for promoting sustainable waste recycling practices. In addition, we wish to leverage these tactics to develop and test a mobile app prototype for this goal. To attain the thesis's final goal, we followed a set of stages in our study design. The first and most important stage is to research relevant studies in the waste recycling field and the advantages of mobile application technology in waste recycling. This stage aids in comprehending the present state of recycling techniques, the potential

of mobile technologies, and tactics that may be utilised in combination with persuasive technology to help users create long-term habits.

Our research revealed the necessity for a development framework and mobile application prototype to offer mobile technology solutions for Cambodia's informal garbage recycling. As shown in Figure 3 (Chapter 2), the most popular way of recycling materials in Cambodia is by itinerant recycle buyers, or as locals refer to them, who travel from door to door collecting and buying recyclables. So, it becomes essential to have some kind of development framework solution that is required to make waste recyclers more connected and interested in the collection and recycling process. Following the identification of a need for a framework, we conducted research, developed, and built the suggested framework.

### 3.1.1 System Analysis and System Requirements

Requirement analysis is both an important and difficult part of any software development effort. Requirement analysis is an important aspect of every software project and should serve as the basis for all future efforts. These are some of the strategies utilised to collect requirements. The requirement gathering procedure was accomplished

via the use of interview questionnaires and the creation of prototypes.

### 3.1.2 Observe similar systems

For this research, we observed and examined the current waste recycling management solutions throughout the globe, as well as cross-reviewed the functionalities of existing apps and read several research publications.

### 3.1.3 Literature review

Literature review was used to gather the general understanding of solid waste management, recycling, and technology development. The purpose of this review is to get an understanding of how different research have commented on mobile technology in recycling activities, customer recycling behaviour, waste picker solution, and technology in practice, etc.

### 3.1.4 Prototyping

Prototyping is a newer method of acquiring requirements. The research employed this technique to collect preliminary requirements, which were then used to create a prototype of the solution. This was then displayed to the customer, who provided further specifications. Afterwards, the application would go through the application updates

and cycle back around with the client. This cycle was repeated until the product fulfilled a critical mass of business requirements.

### 3.1.5 Survey

The survey questionnaire was designed as a major information source in order to offer evidence as to whether or not employing a mobile application for recycling activities is feasible to deploy in the context of Cambodian society. Understanding the people's point of view was particularly crucial since they were the prospective users of the suggested mobile technology recycling solution. To gather information regarding people's perspectives, we produced two types of questionnaires: one with questions targeted at the common citizen's viewpoint and the other with questions customised to the expert's perspective.

Additionally, we began by creating a presentation that detailed the whole process of Cambodia's existing recycling efforts, as well as our recommended solutions and application features. Finally, all attendees were requested to complete our survey form after the completion of our presentation.

However, in the process of performing the questionnaire, we adapted several questions from previous studies; (Oliveira et al., 2019) and (Juaneda-Ayensa et al., 2021).

### 3.1.6 Focus Group

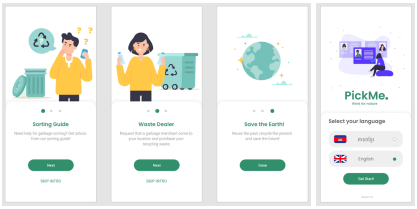
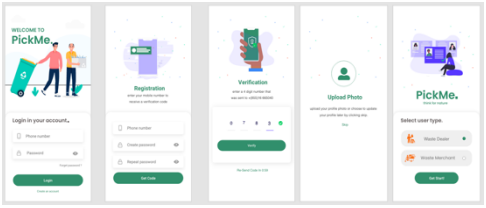
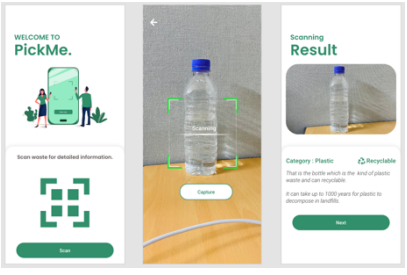
Focus groups are used in this research to better understand people's reactions to any issues or participants' perceptions of shared experiences. In order to get more ideas, in this study, we interviewed with experts who are skilled enough to evaluate the application and business model (Tremblay, Hevner and Berndt, 2010). In this research, we invited nine experts to interview in order to evaluate our application which refers to performance expectancy and effort expectancy. However, due to a scheduling difficulty, two participants could not participate in this interview. In the end, interviews were conducted with seven of the participants.

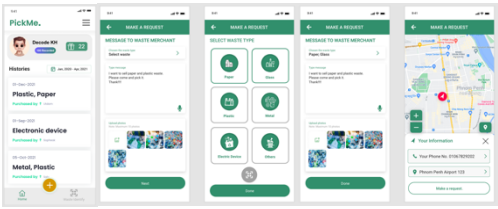
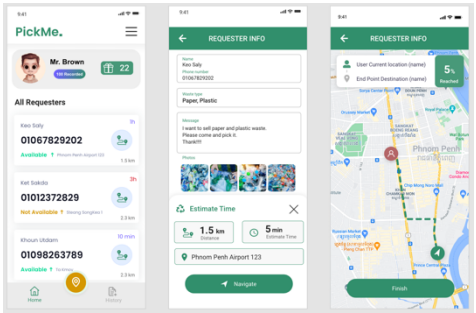
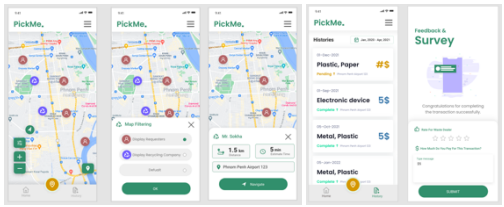
## 3.2 Propose Mobile Technology and Proof of Concept

In Cambodia, in particular, informal waste collection is benefited by mobile technology in waste recycling activity. Recycling is a priority for all Cambodians to work together on in order to enhance our living circumstances. Income level, availability of recycling infrastructure,

and the depth of environmental knowledge and recycling participation are some elements that drive variations in recycling rates. This phase comprises the development of user interfaces to allow users to interact with the system. The following figures illustrate the overall layout of the UI Design.

Table 1. Mobile App Prototype

| User Interface | Descriptions |
|---|---|
|  | ***Information Pages***<br>Users can select their prefer language, and to introduce users with the general info about this app. |
|  | ***Register & Login Pages***<br>Users are required to have an account to login to the system. Users are required to choose the user type, what they want to be. Ex: Waste dealer or Waste merchant |
|  | ***Waste Identification***<br>By utilizing image recognition to detect the waste information, this page was created for waste dealers in order to give information on waste categorization. As well as providing them with important information. |

| | |
|---|---|
|  | ***User make a request***<br>This is the home page of Waste dealer, they can see the recycling history, and reward points, etc. Users can make the request anytime, and they need to fill the requesting form and some information and make a request. |
|  | ***Requesters Information***<br>This page was created to serve as the home page and to check the requester's information. Waste merchants may see all of the requesters' information on the main page, including their name, status, phone number, estimated hours, estimated direction, and the number of points they earned. They may accept a requester directly from the home page, or they can examine the user's details in depth before making a connection. |
|  | ***Map Filtering & Survey***<br>This page was designed for waste merchant to looking for waste collecting company, depot, and all requester. The waste merchant can click on each element to see the information and also, they can click on filtering to sort for only waste |

| | |
|---|---|
| | recycling company or only the requesters list. Finally, both of waste merchants & waste dealer can fill the survey information and input the amount of money that they have been purchased for that transaction. And rating for the interaction services. |

## 3.3 Design of the system

When it comes to system development, the design and implementation phases will include creating a unified modeling language (UML) model of the proposed program and translating that model into the appropriate design specifications and source code. During this phase, all requirements acquired during the analysis phase are organized and then translated into an application architecture. A major goal of the implementation phase is to develop source code that is compliant with the requirements. In the chapter 4, the design phase defines application architectures, architectural layers, data structures, and many other elements will be used. Briefly, in this investigation, Adobe XD, flutter framework has been combined to create mobile application and user-friendly interface. System design is primarily concerned with the design of the system, which involves the usage of ER diagrams,

Sequence diagram, Use case diagram, and Class diagram, Interface design etc.

# Chapter 4. System design and Architecture

## 4.1 Software Architecture

Application architecture (also known as software architecture) is the process of developing a structured solution that fulfills all of the technical and operational requirements while improving common quality characteristics such as performance, security, and manageability (Vijayanthi, 2021). It entails a sequence of choices based on a variety of parameters, each of which may have a significant influence on the application's quality, performance, maintainability, and overall success.

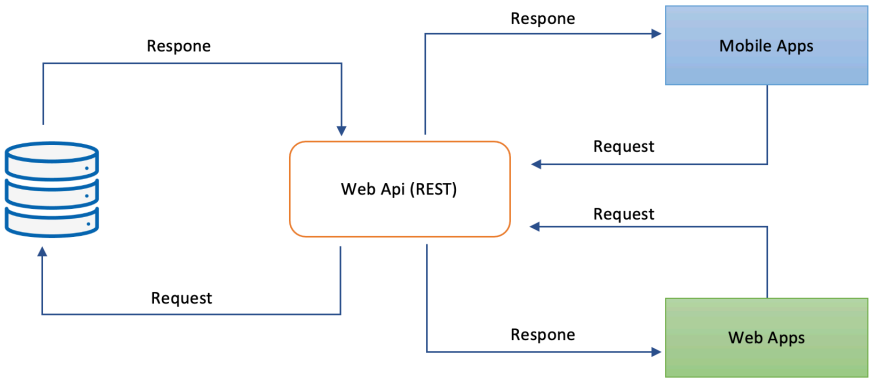



Figure 7. Software Architecture

## 4.2 System Overview

This section discusses the primary components of the system, as well as how they interact with each other. The System overview diagram, as illustrated in Figure 8, provides three different stakeholders corresponding to two different roles:

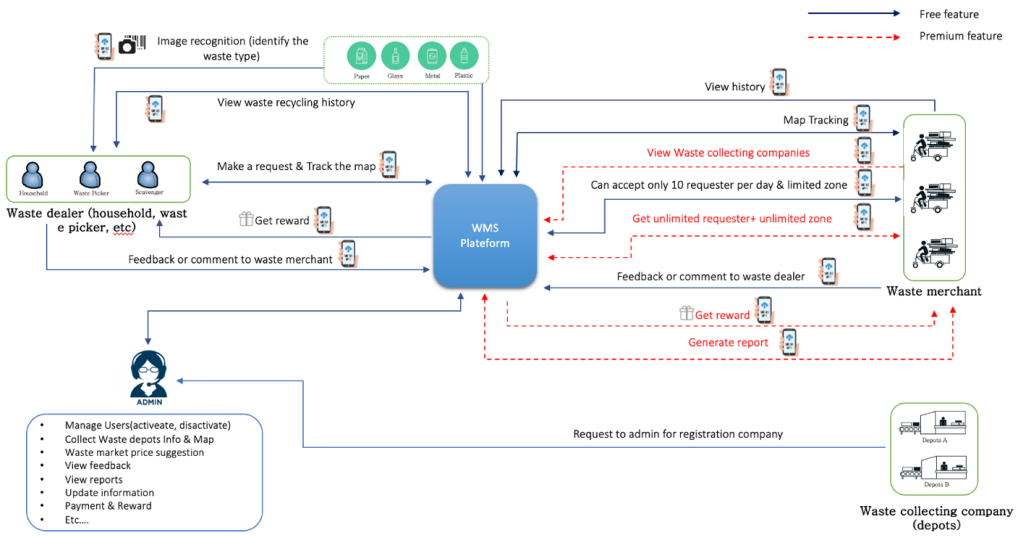



Figure 8. System overview diagram

### 4.2.1 Waste Dealer

Waste dealers were defined as those interested in collecting and managing waste in return for monetary compensation. In this system, the main functions of this actor are as follows: they can make a

request by sending the waste information to a waste merchant through the mobile application, and they can view a history of their recycling activities; they will also receive a confirmation notification when the waste merchant is connected, and they can track their location on a map. Additionally, the waste identification function, also known as the helpful function, allows users to categorise waste and get information about the kind of garbage they are dealing with. The user will be pleased if they utilise this program since they will obtain extra reward points for the amount of time they have spent using it.

After the transaction has been completed successfully, the waste dealer must submit a survey form and a rating to the waste merchant for that transaction to determine whether or not they were satisfied with the transaction.

### 4.2.2 Waste Merchant

Waste merchants were characterised as those who are on the lookout for others who are interested in selling recycling waste. Regarding the Figure 9, we can see that the web server will send out a message to waste merchants through the application for those who are in close proximity to the location where the information is being requested.

And those data are also shown in a list view to make it simpler for waste merchants to see them, and they may read the specifics of the requester, including user information, address, waste kind, and contact information, in the details of the requester.

Following the waste merchant's option of the approved or rejected choice, the message will be sent immediately back to the user to notify them of the decision. When the transactions are linked, the waste merchant can also follow the location of the transactions through the map. Additionally, they can see all the requesters shown on the map, which will be very valuable to the waste merchant to contact them as quickly as possible. Furthermore, a list of recycling companies will be made accessible to them so that they may connect with a garbage collection business close to their location, as shown on the map.

After the transaction has been completed successfully, the waste merchant must submit a survey form and a rating to the waste dealer to determine whether they were satisfied with the transaction. Aside from that, Waste merchants can access all of their transaction history and make a report by filtering it according to their preferences based

on day, month, or year.

## 4.3 UML Design

### 4.3.1 Use case Diagram

Another UML diagram used in system analysis is the use case. The user's interaction with the system is shown in a Use Case diagram. In one cooperative system, the system partners with four active actors. The actors listed below are accessible in the system. The actors in the mobile application are the waste dealer and the waste merchant. The web application's actor is the administrator.

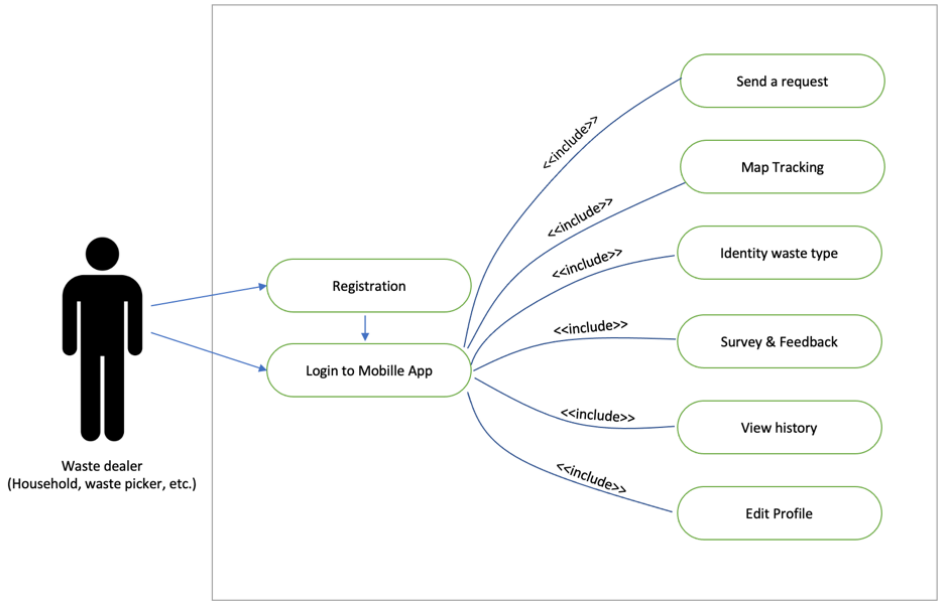



Figure 9. Use case Diagram (Waste Dealer)

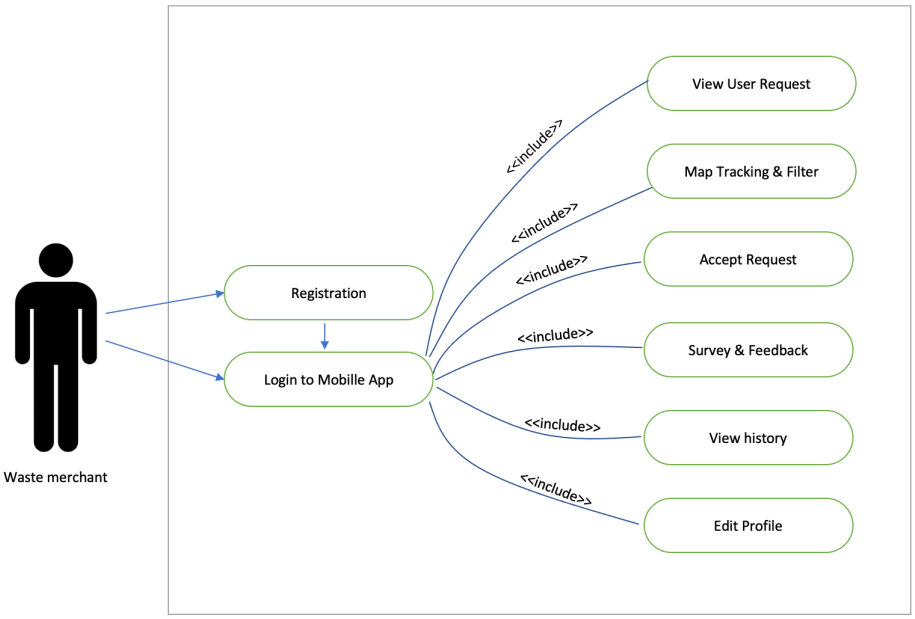



Figure 10. Use case Diagram (Waste Merchant)

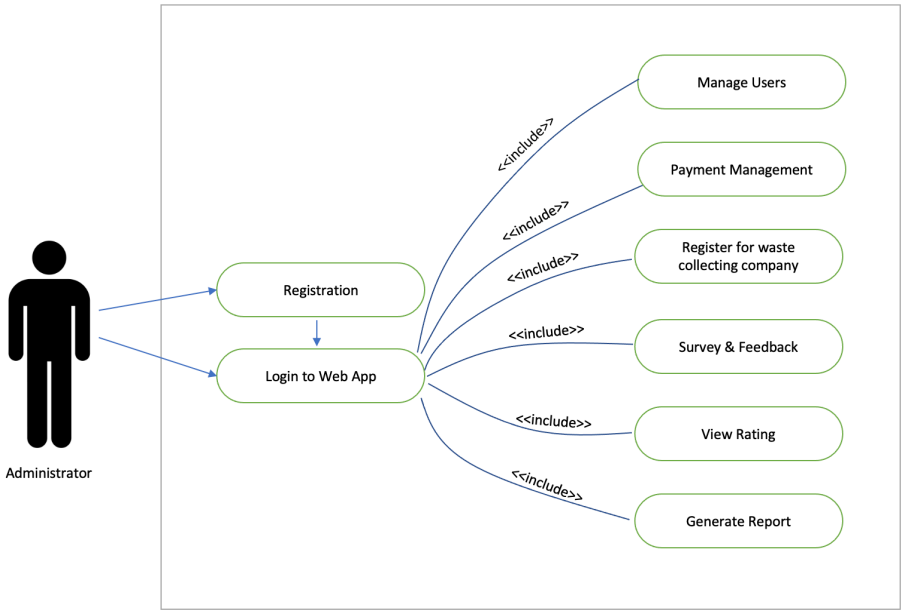



Figure 11. Use case Diagram (Administrator)

### 4.3.2 Descriptive Use Cases

Table 2. Waste Dealer Registration

| Use Case | Waste dealer Registration |
|---|---|
| Primary Actors | Waste dealer |
| Preconditions | |
| • Required to have a phone number.<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |
| Once a user registered user belongs to one category waste dealer, he can access it via mobile application. | |
| Main Scenario | |
| • Waste dealer must provide initial details to register with the system.<br>• Waste dealer must provide a password and confirm the password.<br>• Once the user is registered user will get the SMS notification to confirm his registration with the system. | |

Table 3. Waste Merchant Registration

| Use Case | Waste Merchant Registration |
|---|---|
| Primary Actors | Waste Merchant |
| Preconditions | |
| • Required to have a phone number.<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |
| Once a user registered user belongs to one category waste merchant, they can access it via mobile application. | |

| Main Scenario |
| --- |
| • Waste Merchant must provide initial details to register with the system.<br>• Waste Merchant must provide a password and confirm the password.<br>• Once the user is registered user will get the SMS notification to confirm his registration with the system. |

Table 4. Waste Dealer Send Request

| Use Case | Send a request |
| --- | --- |
| Primary Actors | Waste dealer |
| Preconditions | |
| • The waste dealer must register with the system<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |
| Waste dealer can request to waste merchant to come and buy their recycling wastes. | |
| Main Scenario | |
| Waste dealer can send the requests with the relevant information such as location, phone number, waste type, waste picture, and text message. | |

Table 5. Waste Identification

| Use Case | Waste Identify |
| --- | --- |
| Primary Actors | Waste dealer |
| Preconditions | |
| • The waste dealer must register with the system<br>• Internet Connection | |

| |
|---|
| • Smart Phone |
| Postconditions |
| Identify the waste category with OCR. |
| Main Scenario |
| Waste dealers can use their smart phone's camera to identify the type of waste they are dealing with. |

Table 6. Waste dealer (Feedback & Rating)

| Use Case | Feedback & Rating |
|---|---|
| Primary Actors | Waste dealer |
| Preconditions | |
| • The waste dealer must register with the system<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |
| To evaluate and improve service more efficient and save reward point. | |
| Main Scenario | |
| Waste dealers are required to provide feedback and ratings on how satisfied they are with the service, system, and value they received. | |

Table 7. Waste merchant (Feedback & Rating)

| Use Case | Feedback & Rating |
|---|---|
| Primary Actors | Waste merchant |
| Preconditions | |
| • The waste merchant must register with the system<br>• Internet Connection<br>• Smart Phone | |

| Postconditions |
| --- |
| To evaluate and improve service more efficient and save reward point. |
| Main Scenario |
| Waste merchant are required to provide feedback and ratings on how satisfied they are with the service, system, and value they buy for those transactions. |

Table 8. Waste dealer (View history)

| Use Case | View history |
| --- | --- |
| Primary Actors | Waste dealer |
| Preconditions | |
| • The waste dealer must register with the system<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |
| View history and they can see how reward point they received. | |
| Main Scenario | |
| Waste dealers may view and filter all of the history that they have processed, and they can also see how many points they have earned from those actions, as well as how much money they have earned. | |

Table 9. Waste merchant (View history & Generate Report)

| Use Case | View history & Generate Report |
| --- | --- |
| Primary Actors | Waste merchant |
| Preconditions | |
| • The waste merchant must register with the system<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |

| |
|---|
| View history and they can see how reward point they received and generate report. |
| Main Scenario |
| Waste dealers may view and filter all of the history that they have processed, and they can also see how many points they have earned from those actions. Additionally, they also possible calculate how much they have paid per day, month, year, and they also can generate reports. |

Table 10. Waste merchant (Accept Request)

| Use Case | Accept Request |
|---|---|
| Primary Actors | Waste merchant |
| Preconditions | |
| • The waste merchant must register with the system<br>• Internet Connection<br>• Smart Phone | |
| Postconditions | |
| Waste merchant can accept the request from waste dealer. | |
| Main Scenario | |
| Waste merchants may see relevant waste dealer information such as location, waste kind, name, and phone number, among other things. They can accept or reject requests, and the system will navigate them to the appropriate place on a map automatically. The waste dealer, on the other hand, will be notified when the transaction has been confirmed. | |

Table 11. Waste merchant (Map tracking & filtering)

| Use Case | Map tracking & filtering |
|---|---|
| Primary Actors | Waste merchant |
| Preconditions | |

| |
|---|
| • The waste merchant must register with the system<br>• Internet Connection<br>• Smart Phone |
| Postconditions |
| Waste merchant can see the list of requesters & waste recycling companies on map. |
| Main Scenario |
| Waste merchants may monitor their area on a map, as well as view all of the waste recycling companies and waste requesters that are close to their location, which will be shown on the map. They may also filter based on where they are on the map. |

### 4.3.3 Sequence Diagram

A sequence diagram is a graphic that shows how elements interact in a sequential manner, and it depicts item interactions in chronological order.

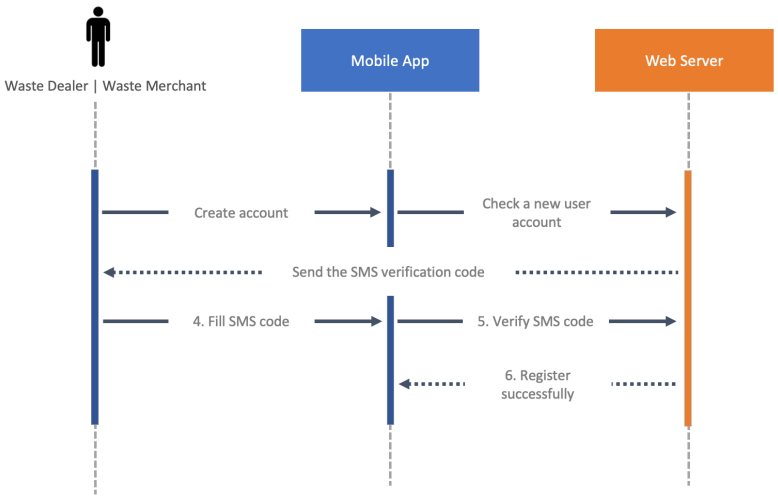



Figure 12. User Registration

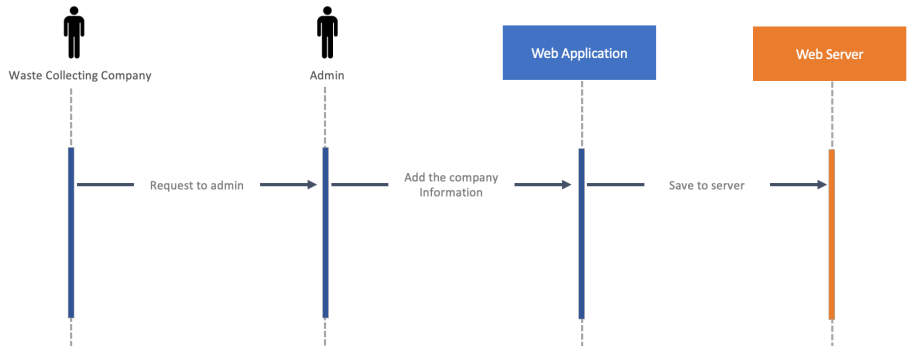



Figure 13. Waste recycling company Registration

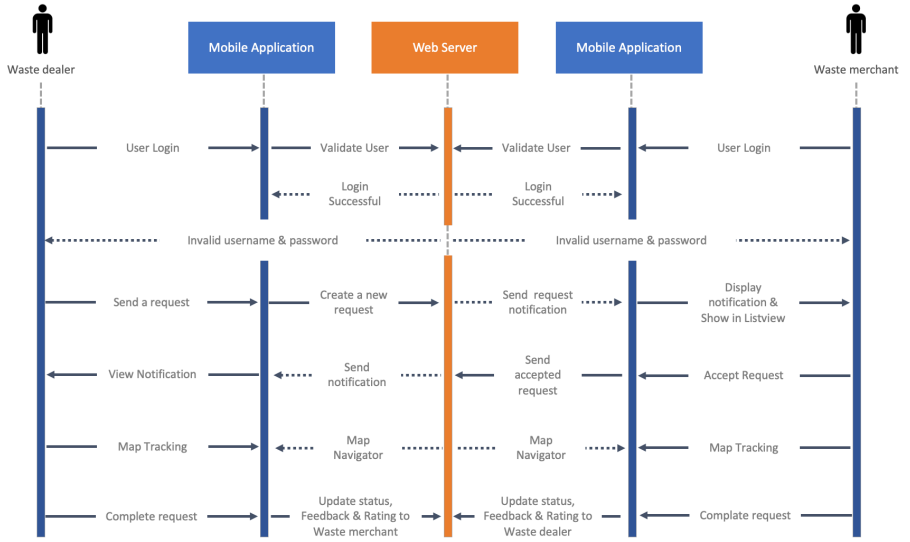



Figure 14. Make a request

## 4.4 Prototype Implementation Details

This software display will show an application that was prototyped using the Adobe XD program. The prototype of a mobile-based waste recycling application emerges from this stage.

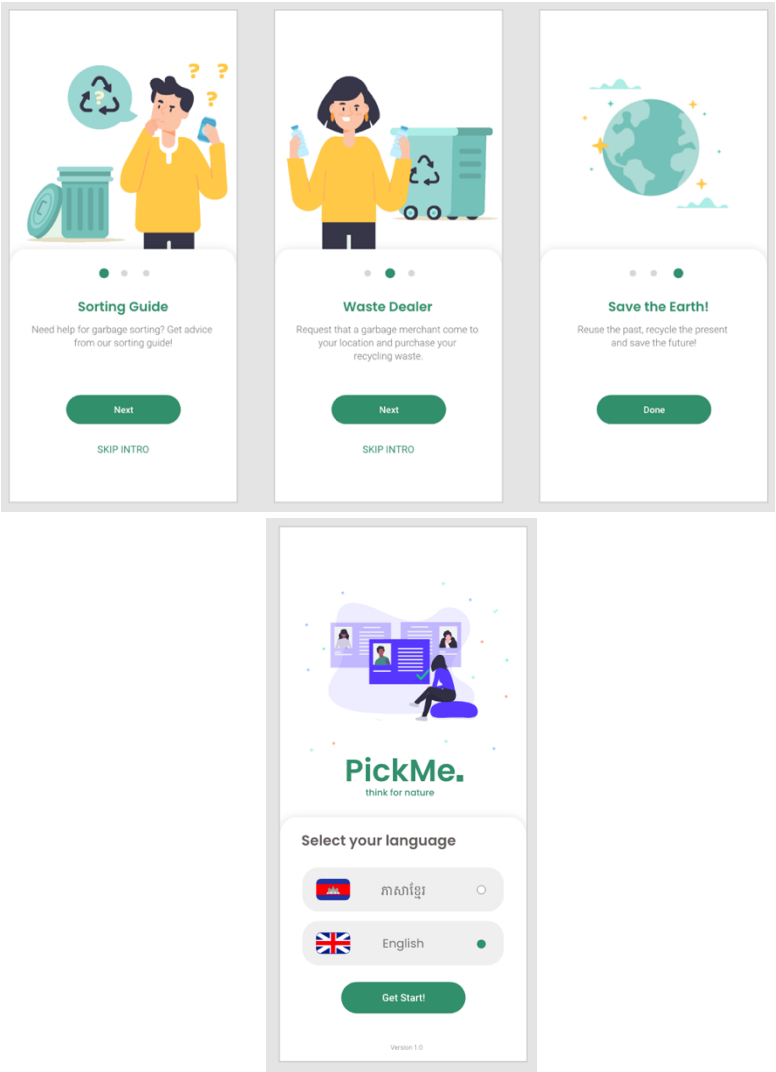



Figure 15. Information Page

As shown in Figure 15, this page was designed to introduce users and the general public to the need to constantly divide and store garbage as well as how they may earn money while using this service and they have the option of choosing their preferred language.

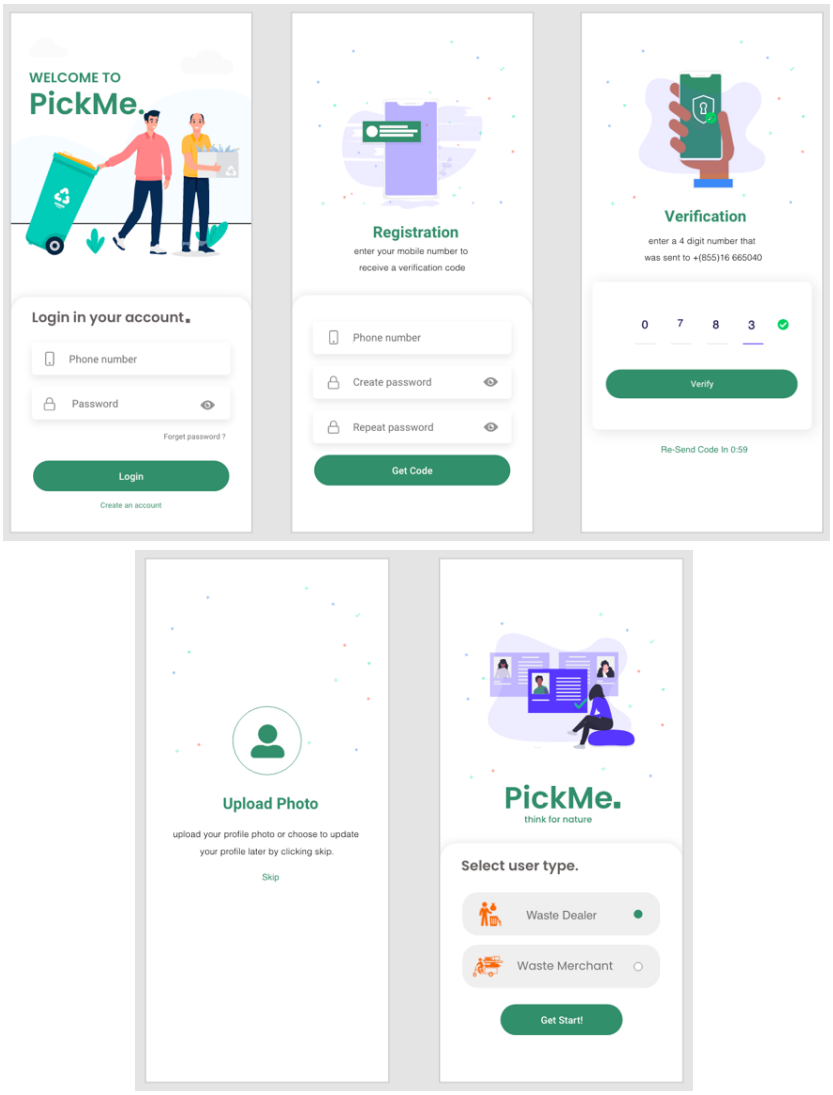



Figure 16. Register & Login Page

As shown in Figure 16, this page was designed for the user login process and the first user registration. This interface is utilised by all types of stakeholders, with the only difference being the “Select user type” option, which will be required to be verified in the next step with their phone number.

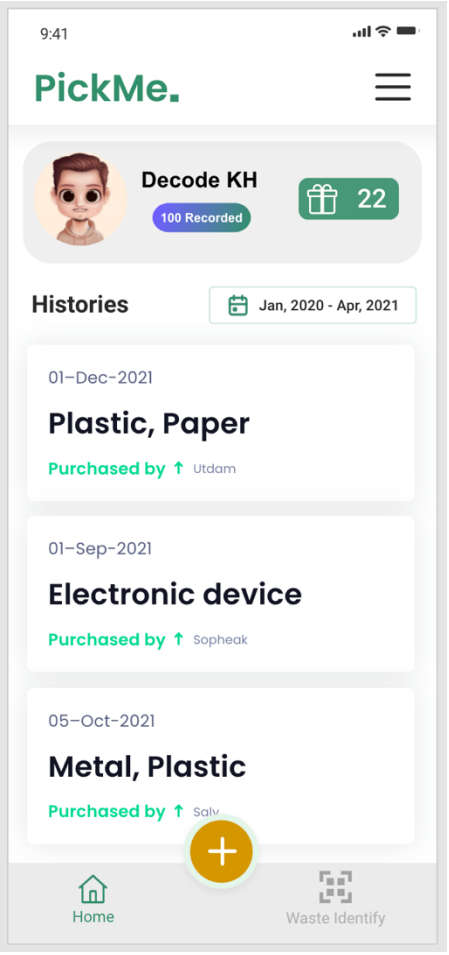



Figure 17. Home Page for Waste dealer

As shown in Figure 17, this page was created for the waste dealer's home page. After logging in successfully, users can see this page, which includes a list of their recycling histories, along with the types of waste and costs, reward points, and the ability to filter by date.

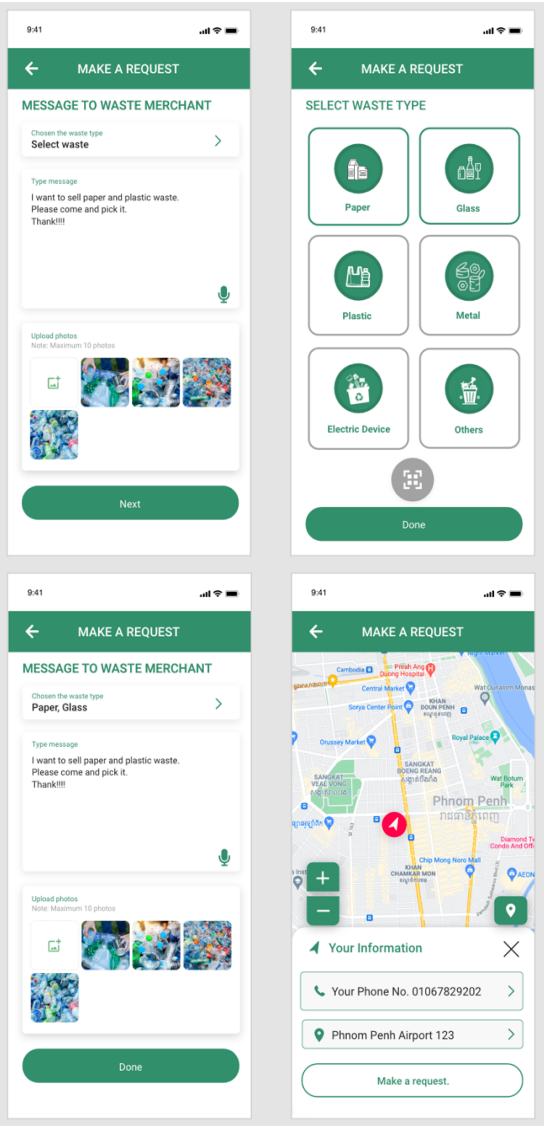





Figure 18. Make a Request for Waste dealer

As shown in Figure 18, this page was designed for a waste dealer to submit a request to a waste merchant for consideration. To trade recycling waste for money, users must first organise their waste into categories and then pick what kind of waste they wish to swap for money in the application. Following that, they may also send a message to the waste merchant which would include the current user's address and phone number, among other information.

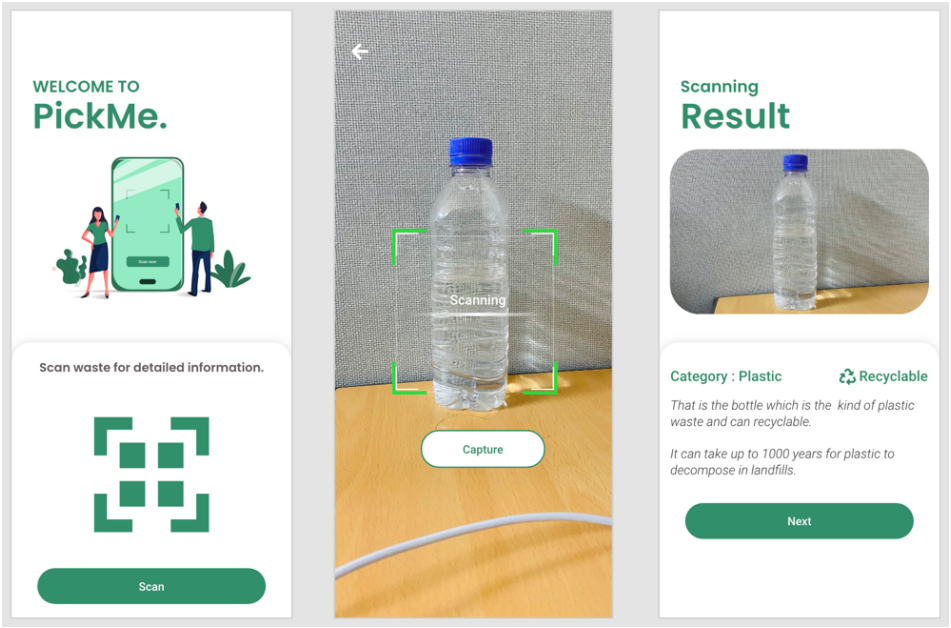



Figure 19. Waste Identification

As shown in Figure 19, by utilising image recognition to detect the waste information, this page was created for waste dealers to give information on waste categorisation. As well as providing them with important information.

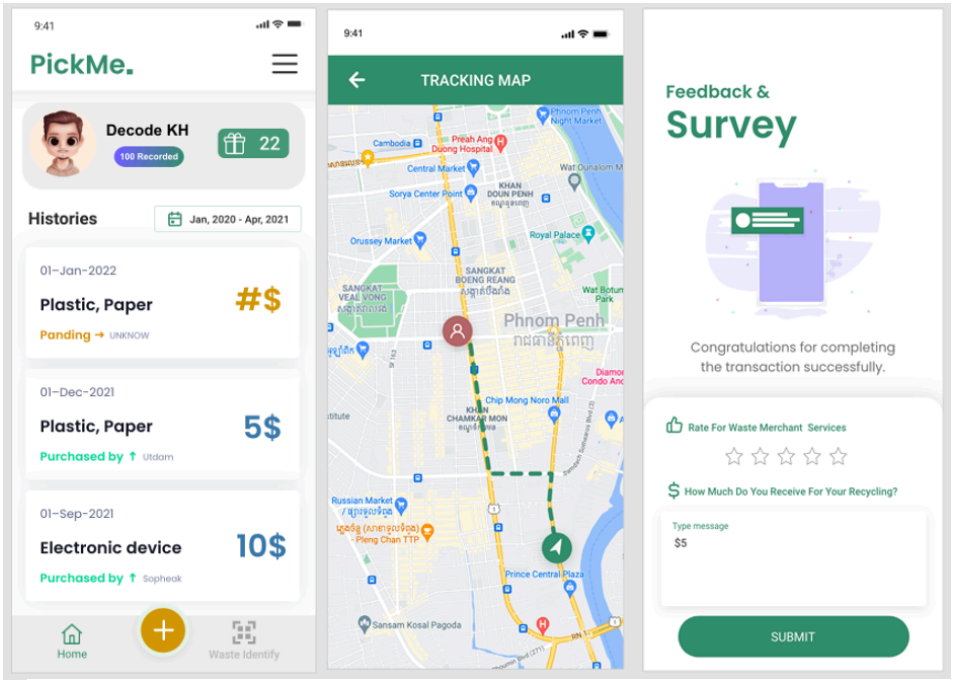



Figure 20. Tracking & Feedback for Waste dealer

As shown in Figure 20, this page was created for the waste dealer in order to keep track of the action related to the request. Following the submission of a request, the status will be shown as “Pending” with an unknown user name and price until they get an acceptance from the waste merchant. At the same time, after they have been approved, they

may monitor the location of the waste merchant to see how close they are to each other. Finally, after they have finished the purchase, they will be required to complete the Feedback Survey form, asking for the services information.

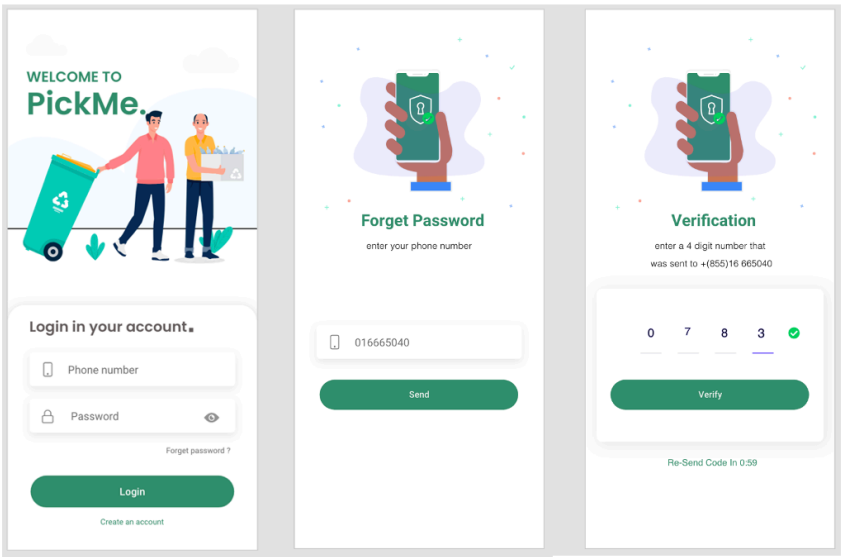



Figure 21. Login & Forget password

As shown in Figure 21, this page was created for waste merchants to login, which requires them to fill the phone number and password that they already registered, and after they login successfully, they may go to the following screen, which is known as the home page. But if they forget their password, they may recover it by clicking on Forgot password and entering their phone number. The system will send them a verification SMS message, which they can confirm.

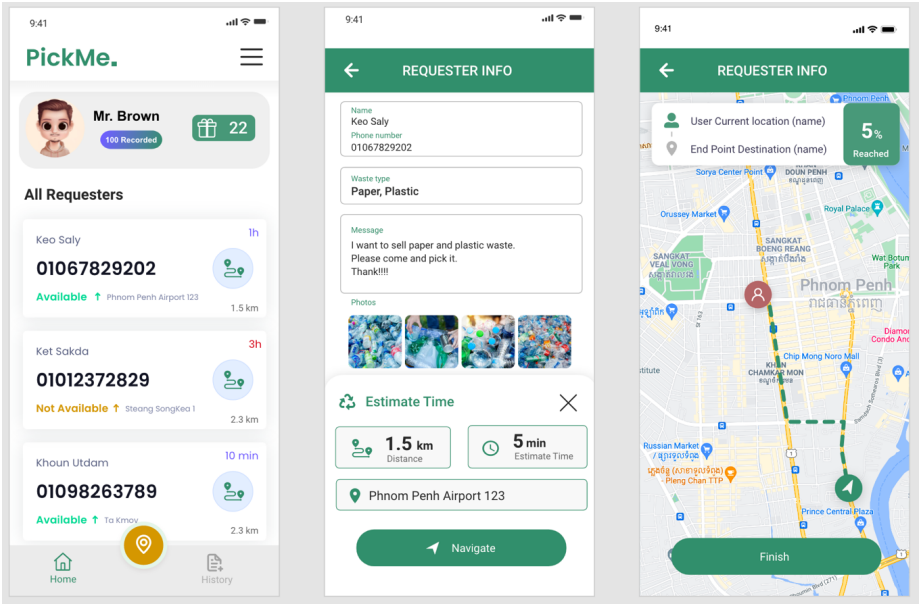



Figure 22. Home Page & Requester Information

As shown in Figure 22, this page was created to serve as the home page and to check the requester's information. Waste merchants may see all of the requesters' information on the main page, including their name, status, phone number, estimated hours, estimated direction, and the number of points they earned. They may accept a requester directly from the home page, or they can examine the user's details in depth before making a connection.

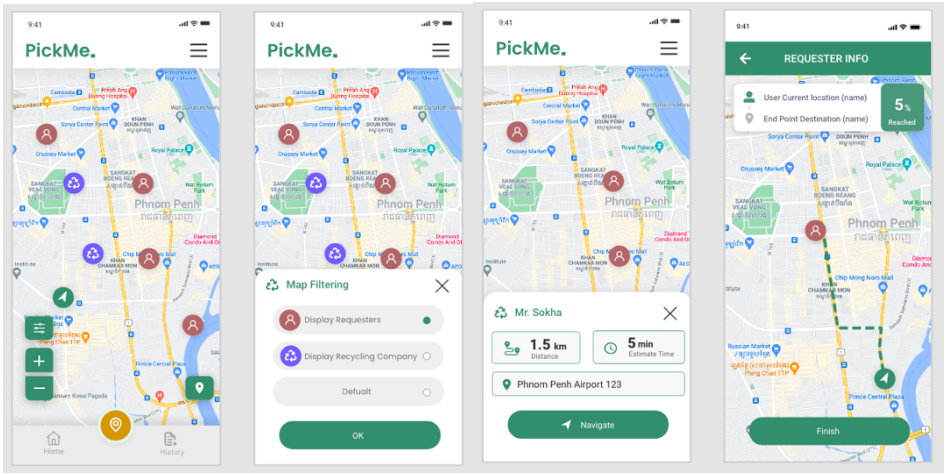



Figure 23. Map View

As shown in Figure 23, this page was designed for a waste merchant to look for a waste collecting company, depot, and all requesters. The waste merchant can click on each element to see the information, and also, they can click on filtering to sort for only waste recycling companies or only the requester's list.

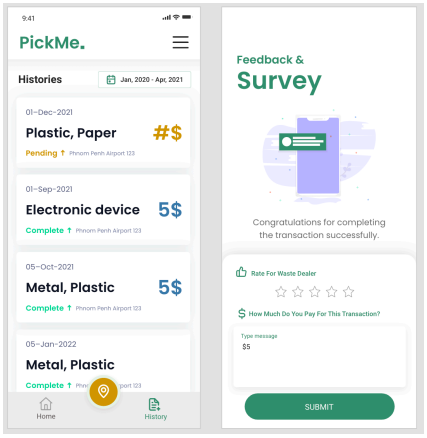



Figure 24. Survey & Rating

As shown in Figure 24, this page was designed for waste merchants to fill in the survey information, input the amount of money they received for that transaction, and rate the interaction services with the waste dealer.

# Chapter 5. System Evaluation

The main findings related to the research topics are summarised in this chapter, as are general conclusions based on the findings of the investigations reported in this thesis. In addition, we also addressed and explored the thesis's strengths and limitations.

## 5.1 Questionnaire

### 5.1.1 Theory

The design of a questionnaire should begin with examining the survey's goals and the expected output, followed by developing a list of questions that will provide reliable information. In this study, the survey questionnaire was created as a primary information source to provide evidence as to whether or not utilising a mobile application for recycling activity is possible to deploy in Cambodian society.

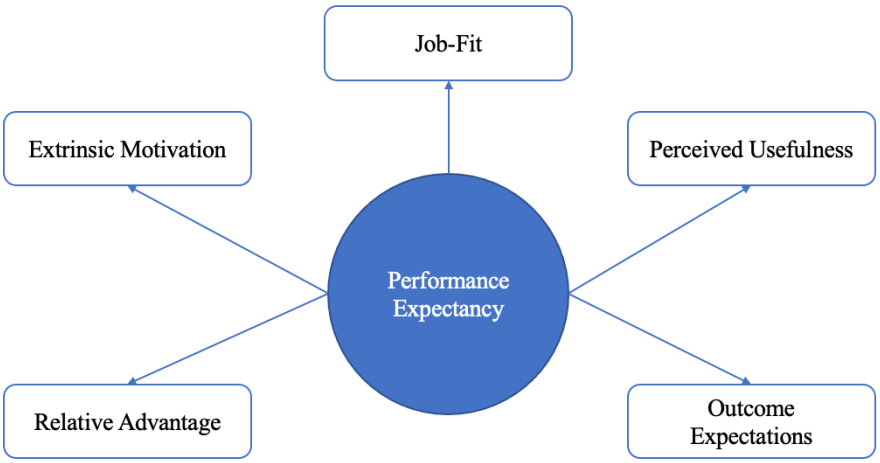
Knowing the people's point of view was especially important since they were the potential users of the proposed mobile technology recycling solution. Two kinds of questionnaires were developed to acquire information about people's perspectives: one with questions targeted at the common citizen's viewpoint and another with questions targeted at the expert's perspective. For our first step, we created a

presentation that covered the whole process of Cambodia's current recycling efforts, as well as our proposed solutions and application characteristics. Finally, after the conclusion of our presentation, all participants were asked to complete our survey form, which they did.

Regarding (Sun et al., 2013), another popular theory that attempts to explain why people adopt new technologies is called the unified theory of acceptance and use of technology, or UTAUT. The comparison of the eight important theories was discussed in that study. Therefore, based on the Theory of Reasoned Action, the technology acceptance model (TAM) was further expanded by reframing the ideas used in prior research and introducing enabling factors as an additional predictor of intention. Performance expectation, effort expectancy, and social influence are three new words that express perceived usefulness, perceived ease of use, and subjective norm, respectively. Another study, The Unified Theory of Acceptance, which is specific on the performance expectancy and effort expectancy, was discussed in the research of (Juaneda-Ayensa et al., 2021).

#### 5.1.1.1 Performance Expectancy

Regarding (Venkatesh et al., 2003), the performance expectancy, which describes the degree to which a person feels that employing the system will assist him or her in improving work performance is defined as Performance Expectancy, as shown in Figure 25. Perceived Usefulness: The extent to which a person feels that implementing a certain system would improve their work performance. Below is the list of the items which refer to perceived usefulness:




*Source: Adapted from (Venkatesh et al., 2003).*

Figure 25. Performance Expectancy

1. Using the system at work would allow me to complete jobs faster.

2. Using the system would help me perform better at work.
3. My productivity would rise if I used the system at work.
4. The system's use would improve work productivity.
5. It would be simpler for me to complete my work if I used the system.
6. In my job role, the system would be beneficial.

Extrinsic Motivation: The belief that users will want to do something because it will help them achieve valuable outcomes that aren't directly related to the activity, such as better work performance, compensation, or promotions.

1. Extrinsic motivation is measured using the same criteria as perceived utility. As can perceived usefulness (list no. 1 through 6 above).

Job-fit: How a system's capabilities improve an individual's work performance.

1. Using the system will have no impact on my work performance.
2. The technology can help me save time on some of my most

crucial work obligations.

3. The technology has the potential to improve the quality of my work dramatically.
4. The system's use may improve the efficiency with which work activities are completed.
5. For the same amount of work, use may enhance the quantity of output.
6. The overall amount to which the system might help in the work, taking into account all duties.

Relative Advantage: The extent to which employing an invention is seen to be superior than using its predecessor.

1. I am able to do work more rapidly when I use the system.
2. The technique helps me increase the quality of my job.
3. It is simpler for me to accomplish my work when I use the system.
4. Using the system improves my productivity at work.
5. I am more productive when I use the system.

Outcome Expectations: The repercussions of the conduct are the subject of outcome expectations. They were divided into job-related performance expectations and personal expectations based on actual data (individual goals).

1. I'm going to improve my efficiency at work.
2. I'll spend less time on mundane office activities.
3. I will improve the quality of my work production.
4. For the same amount of work, I will raise the quantity of production.
5. My colleagues will see me as capable.
6. I'm going to improve my chances of being promoted.
7. I'll improve my chances of receiving a promotion.

#### 5.1.1.2 Effort Expectancy

Regarding to (Venkatesh et al., 2003), The degree of ease associated with using the system is known as effort expectancy. The idea of effort expectation is captured by two current constructs: complexity, and ease of use, (Thompson, Higgins and Howell, 1991). The construct definitions and measurement scales are quite similar, as seen in Figure 26.


*Source: Adapted from (Thompson, Higgins and Howell, 1991).*

Figure 26. Effort Expectancy

Complexity: The degree to which a system is seen to be difficult to comprehend and utilise. Using the system takes too much time away from my regular responsibilities.

1. Using the system takes too much time away from my regular responsibilities.
2. Working with the system is challenging since it is so complicated.
3. Using the system requires too much time spent on mechanical tasks (e.g., data input).
4. Learning how to utilise the system takes much too long to be worthwhile.

Ease of Use: The degree to which implementing an idea is seen to be challenging.

1. My engagement with the system is simple and straightforward.
2. I feel it will be simple to get the system to perform what I want.
3. Overall, I think the system is simple to use.
4. I find it simple to learn how to use the system.

### 5.1.2 Development of Questionnaire

#### 5.1.2.1 Questionnaire for Citizen

In our study, the questionnaire that we designed to apply to Cambodians, as shown in Table 12, considers the performance expectancy and effort expectancy of using the application. We began by giving a presentation to all participants about our solution and goal in order to elicit responses from them. The survey questionnaire was then sent using Google Form.

However, the questionnaires that were developed have mostly been adapted from previous research and published works. The Unified Theory of Acceptance, which is specific on the performance expectancy and the effort expectancy, was adapted from (Juaneda-

Ayensa et al., 2021) and (Oliveira et al., 2019). We modified those questions so that they refer to the context of Cambodia.

Table 12. The adapted of questionnaire for citizens

| Var | Question | References |
|---|---|---|
| Effort expectancy | Do you think this mobile application should be easy for you to use? | (Juaneda-Ayensa *et al.*, 2021) |
| | Do you think this mobile application doesn't need any technical person to guide you to use it? | (Juaneda-Ayensa *et al.*, 2021) |
| Performance expectancy | Do you think this mobile application must be useful for recycling? | (Juaneda-Ayensa *et al.*, 2021) |
| | Do you think this mobile application should save your time in waiting for the waste merchant to come and buy it (recycling waste)? | (Juaneda-Ayensa *et al.*, 2021) |
| | Do you think this mobile application will help you to recycle waste properly? | (Juaneda-Ayensa *et al.*, 2021) |
| | Do you think this mobile application will allow you to understand which kinds of waste that you can recycle? | (Oliveira *et al.*, 2019) |
| | Do you think this application will be beneficial to citizens? | Own elaboration. |
| | Do you think this application will be beneficial to waste merchant? | Own elaboration. |
| | Do you think this application will encourage people to participate in waste | (Oliveira *et al.*, 2019) |

| | | |
|---|---|---|
| | recycling activities? | |
| | Do you think this application is contribute to collection and separation the waste? | (Oliveira *et al.*, 2019) |
| | Do you think this application is contribute to environmental protection? | (Oliveira *et al.*, 2019), (Juaneda-Ayensa *et al.*, 2021) |

#### 5.1.2.2 Questionnaire for Experts

The survey questionnaire was designed as a major information source to offer evidence as to whether or not employing a mobile application is feasible to deploy in Cambodian society. The importance of understanding the people's point of view was particularly crucial since they were the prospective users of the suggested mobile technology recycling solution.

However, the questionnaires for the interviews, which are specific on the performance expectancy and the effort expectancy, were adapted from (Tremblay, Hevner and Berndt, 2010) and (Oliveira et al., 2019). We modified those questions so that they refer to the context of Cambodia. To gather information regarding experts' perspectives, we produced the questionnaire as shown in Table 13.

Table 13. Questionnaire directed to professionals

| Var | Questions |
|---|---|
| Performance expectancy | How useful do you think this mobile application solution will be with respect to existing solution? Why (not)? |
| Performance expectancy | In which situations do you think the framework will be most/least useful? Why (not)? |
| Effort expectancy | Let's discuss about how simple it is to adopt and utilize this mobile app |
| Performance expectancy | Do you think this application will encourage people to participate in waste recycling activities? Why (not)? |
| Effort & Performance expectancy | What did you like most in this mobile application? |
| Effort & Performance expectancy | What did you like least in this application? |
| Performance expectancy | Do you think this application is contribute to environmental protection? |
| Effort & Performance expectancy | What other comments do you have related to future improvements? |

## 5.2 Analysis

This research summarises some of the findings from the system usability study and the results from the user's perspective, which refer to performance expectancy and effort expectancy, and are described in depth in the subsections below.

### 5.2.1 Responding from citizens

The survey questionnaires were created as a primary source of data to determine whether or not using a mobile application is practical in Cambodia. There were 27 respondents in the sample population.

#### 5.2.1.1 Effort expectancy

Table 14. Effort expectancy

| Effort expectancy | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| Q1 | Do you think this mobile application should be easy for you to use? | NA | 3.7% | 7.4% | 59.3% | 29.6% |
| Q2 | Do you think this mobile application doesn't need | NA | 11.1% | 29.6% | 37% | 22.2% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | any technical person to guide you to use it? | | | | | |

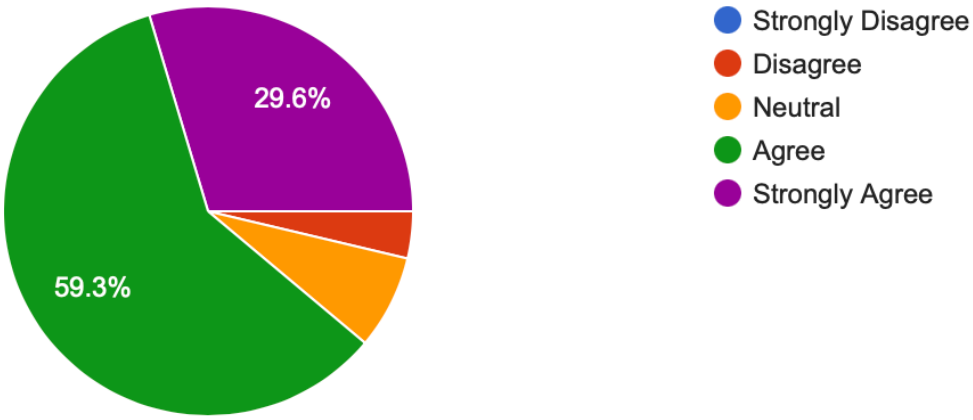



Figure 27. Effort Expectancy Q1

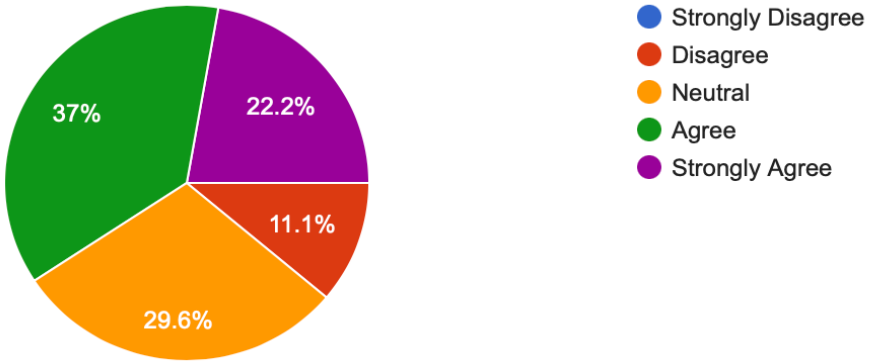



Figure 28. Effort Expectancy Q2

Regarding our data from the survey, as shown in Table 14, we found that 59.3% of the sample population agreed that the mobile application prototype should be easy to use. The other 29.6 % strongly agreed, and 7.4% responded neutrally. Only 3.7% responded by disagreeing.

Another question asked was, “Does this mobile application not require any technical person to guide them to use?” With the response data, we can see that 37% agreed that no technical person was needed to guide them to use the mobile application. The other 22.2% responded strongly agreeing, followed by 29.6% responded as neutrally, and only 11.1% responded disagreeing that they need a technical person to guide them to use this system.

#### 5.2.1.2 Performance expectancy

Table 15. Performance expectancy

| **Performance expectancy** | | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|---|
| Q1 | Do you think this mobile application must be useful for | 3.7% | NA | 7.4% | 70.4% | 18.5% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | recycling? | | | | | |
| Q2 | Do you think this mobile application should save your time in waiting for the waste merchant to come and buy it (recycling waste)? | NA | 3.7% | 11.1% | 63% | 22.2% |
| Q3 | Do you think this mobile application will help you to recycle waste properly? | 3.7% | NA | 3.7% | 81.5% | 11.1% |
| Q4 | Do you think this mobile application will allow you to understand which kinds of waste that you can recycle? | NA | NA | 7.4% | 48.1% | 44.4% |
| Q5 | I think this application will be beneficial to citizens. | NA | NA | 3.7% | 63% | 33.3% |
| Q6 | I think this | NA | 3.7% | 14.8% | 63% | 18.5% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | application will be beneficial to waste merchant | | | | | |
| Q7 | I think this application will encourage people to participate in waste recycling activities. | NA | NA | 15.4% | 50% | 34.6% |
| Q8 | I think this application is contribute to collection and separation the waste. | NA | NA | 14.8% | 66.7% | 18.5% |
| Q9 | I think this application is contribute to environmental protection. | NA | NA | 8% | 52% | 40% |

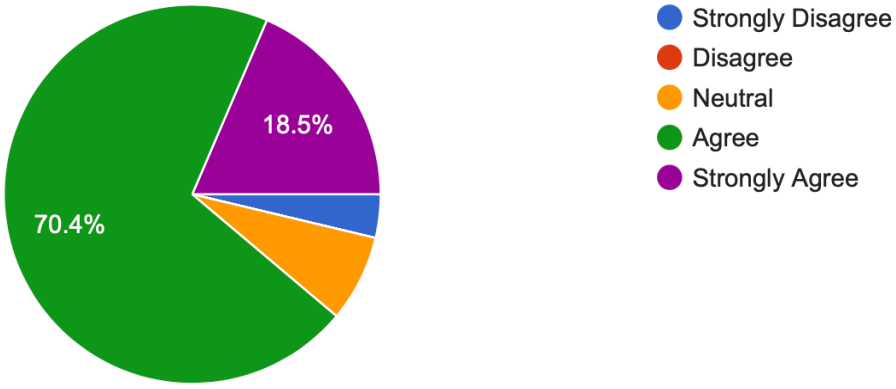



Figure 29. Performance expectancy Q1

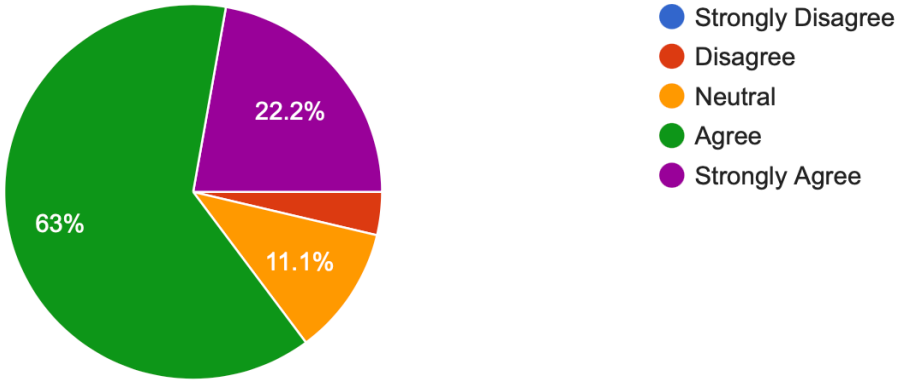



Figure 31. Performance expectancy Q2

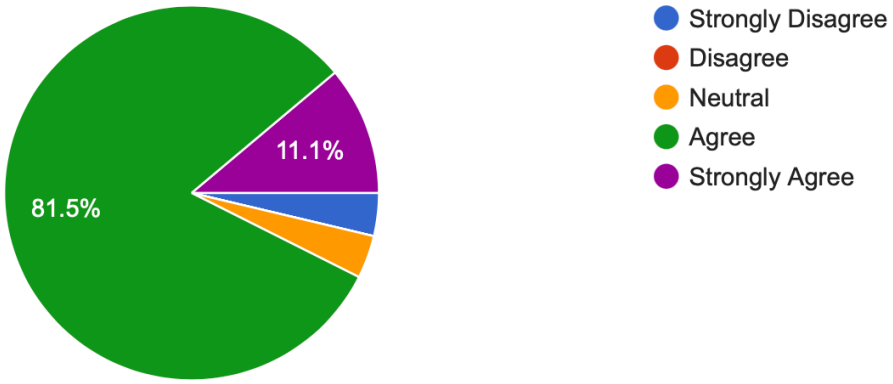



Figure 30. Performance expectancy Q3

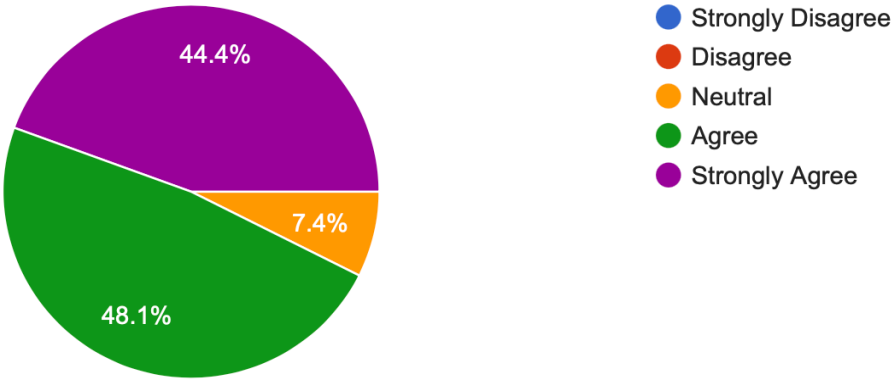



Figure 32. Performance expectancy Q4

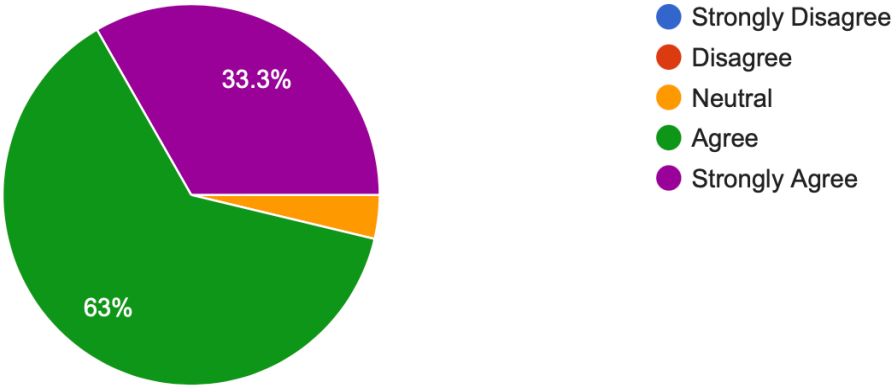



Figure 33. Performance expectancy Q5

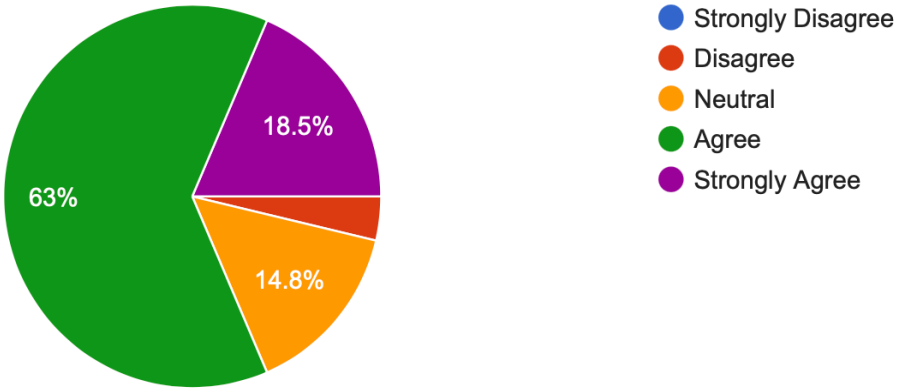



Figure 34. Performance expectancy Q6

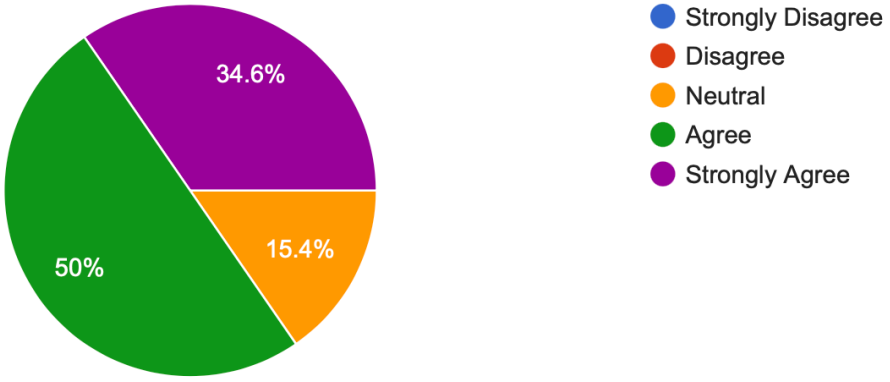



Figure 35. Performance expectancy Q7

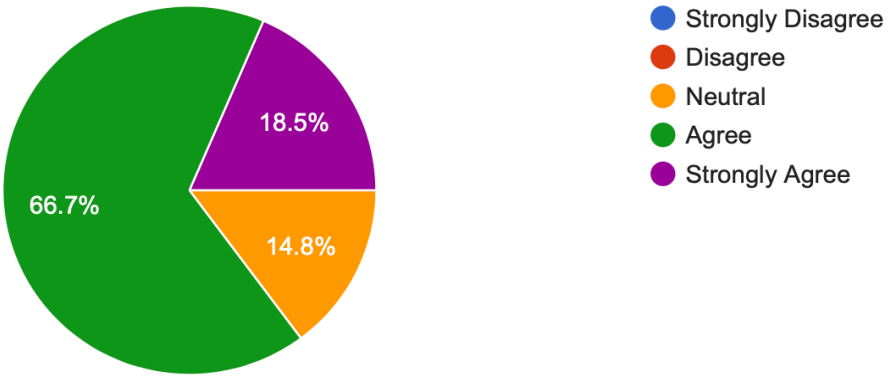



Figure 36. Performance expectancy Q8

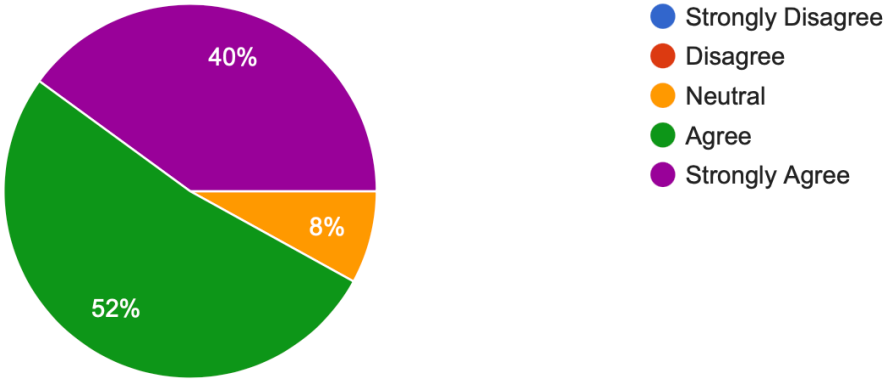



Figure 37. Performance expectancy Q9

Q1 concerned the performance expectancy and asked if the mobile application must be useful for recycling. So, regarding our data from the survey, as shown in **Table 15**, we found that 70.4% of the sample population agreed that the mobile application prototype must be useful for recycling activities, followed by 18.5% strongly agreeing with that. And another 7.4% responded as neutrally, and 3.7% responded

strongly disagreeing about that.

Q2 asked if using a mobile application could save them time waiting for a waste merchant to come and buy the recycling waste, and we also received 63% responded that mobile technology solution is helping them to save time in waiting for the waste merchant to come and buy the recycling waste, followed by 22.2% strongly agreeing with that. Only 11.1% responded as neutrally, and 3.7% responded disagreeing with that.

Q3 was asking about if the mobile application will help them to recycle waste properly, and with the number of responders, we found that 81.5% responded agreeing with that and followed by 11.1% who responded strongly agreeing. Only 3.7% of both responded neutrally and strongly disagreed.

Q4 was about if the mobile application will allow them to understand which kinds of waste they can recycle, and 48% responded agreeing, followed by 44.4% responding as strongly agreeing, and only 7.4% responded as neutrally.

Q5 was about whether they think that application will benefit citizens, with 63% of responders agreeing, followed by 33% strongly agreeing. And another 3.7% responded neutrally about this.

Q6 asked if they think this application will benefit waste merchants, and 63% agreed with that, followed by 18.5% strongly agreeing. Another 14.8% responded they disagreed and only 3.7% responded disagreeing.

Q7 was about if they think this application will encourage people to participate in waste recycling activities. Based on the survey data we received, 50% of responders agreed with that, followed by 34.6% responding strongly agreeing, and only 15.4% responding neutrally.

Q8 asked if they think this application contributes to collecting and separating waste. We found that 66.7% agreed with this, and another 18.5% strongly agreed. And only 14.8% responded neutrally.

Q9 asked if they think this application contributes to environmental protection and 52% responded agreeing, followed by 40% strongly

agreeing, and only 8% responded neutrally.

### 5.2.2 Responding from Experts

For each of the metrics proposed in the study, Performance Expectancy and Effort Expectancy were presented. The qualitative data were summarised for perceived usefulness, extrinsic motivation, outcome expectations, job-fit, and relative advantage. Then, rich descriptions were given using quotes from the focus group participants to corroborate the results. In this section, we give partial results for one of the metrics, information volatility. Table 16 provides an example of the summary results from our interviews.

Table 16. Responding result from Experts

| **Performance Expectancy** | | |
|---|---|---|
| Metric | Evidence | Comments/Observed Changes |
| Perceived Usefulness | Yes | Connection facilitates and optimize the time; Direct connection with the stakeholders; Make request anytime; More efficiency and it raises the incomes; It's faster, it's optimized the process. |
| Extrinsic Motivation | Yes | Save times; Gain money; More efficiency and faster; Get Rewards; Convenience; Easy |

| | | |
|---|---|---|
| | | to use; Job creation; |
| Outcome Expectations | Yes | Save times; More efficiency and faster; Convenience; |
| Job-fit | Yes | Direct connection with the stakeholders; Connection facilitates and optimize the time; It's faster, it's optimized the process. |
| Contribute to environmental problems | Yes | Yes, definitely agreed; Facilitate to environment; |
| Relative Advantage | Yes | Make request anytime; More efficiency and faster; Save times; More efficiency and faster; Convenience; |
| **Effort Expectancy** | | |
| Metrics | Evidence | Comments/Observed Changes |
| Simple to use/ Easy to use | Yes | Multiple language; The user Interface looks good and easy to understand. |

Additionally, we can provide evidence by using passages from the focus groups, for example, this quote from the participants that showed evidence of Performance Expectancy & Effort Expectancy as below:

*"I think it's very useful for society because it brings me as a society with the waste buyers. So, it makes me easier to recycle my waste."*

*"The same thing it is useful and it facilitates the recycling. If I can easily exchange my recycle waste without worrying being there. Because sometimes you have to be on your home, around your house or your residential area whenever these west collectors come knocking your door. If you have any recycle waste to sell or not. If you are not available or you are not there so you are going to miss that opportunity and you are going to be filled with garbage again. So, using this application is helpful. I can contact the waste buyers to be disposed while I'm working, while I'm traveling. So, it's good."*

*"It gives more efficiency and it raises the incomes for the sellers and it is good for the environment. It's faster, it's optimized and it's more given to the process is more efficiency if compare to the traditional process."*

*"Yeah, I think it's very useful because simply based on my experience I never experienced a system which does this functionality so only we dispose waste like our traditional way of doing things but this one is like a shortcut and besides add value for both sides (waste seller &*

*waste buyer). So, I think it's very useful."*

*"So, in these kinds of frameworks will be more helpful than anything like we have here (Korea). It's more helpful in the developing country than in developed country."*

*"I like the user interface of this application, because the design very clearly to understand and the good thing is it has multiple languages, so people easy to select their preference language"*

*"It seems very simple to use and attractive, yes I like it"*

*"It's motivating the Cambodian citizen to use this application because they are selling their garbage and they gain time very easily and in an optimal manner. And each time they gain money, of course, it's encouraging them to get involved."*

## 5.3 Result

As we mentioned in the methods section, we first created a presentation that described the entire process in the current state of

recycling actions in Cambodia and explained in great detail our proposed solutions and application features. Finally, after the conclusion of our presentation, all participants were required to complete our survey questionnaire. According to the respondents, this mobile application was typically efficient, easy to use, navigate, attractive, and engaging.

Here, we would like to provide the information that could answer our research questions based on the data that we received from our survey and focus group discussion.

Our first research question: “How useful will the mobile application solution be with respect to existing solutions in the context of Cambodia?”

So, to answer this question, we can conclude that based on our results, we found all of the responders responded in a positive way, which indicates that they found the application to be quite helpful as Cambodian citizens. Because this application could provide a lot of benefit to society and especially to waste merchants and waste sellers in term of making the connection facilitates and optimising the time,

users can make a direct connection with the stakeholders, users can make the request anytime, it is more efficient, it raises the income, it's faster, and it optimises the process. Both the waste dealer and the waste merchant will be able to connect more easily and save time. Compared to the transitional method, where waste dealers must wait for the waste merchant to arrive at their residence address before selling their garbage, it will be much easier for waste dealers to submit a request to waste merchants whenever they have recyclable waste and wish to sell it.

Our second research question: "How will the mobile application solution facilitate communication between waste dealers and waste merchants for waste recycle activities?"

Based on our results, which showed the communication between waste dealers and waste merchants would be more convenient and more efficient because the users can make a direct connection with the stakeholders, they can make requests anytime, and the application will notify that information to the waste merchant quickly, and waste merchants will be able to reach more customers and receive direct

connections from requesters, which will save them time and money by allowing them to explore areas that have potential users due to the waste merchant's transitional way of doing business, where they do not have the information, address, or contact information for the waste dealer, and they will have to travel anywhere to find someone who has recycling wastes.

Furthermore, as indicated in Table 19, based on expert opinion, it increases efficiency and profits for businesses while also leading to greater environmental protection. The communication between the waste dealer and waste merchant will be easier. It will be helpful in terms of connection facilitates and optimise the time, direct connection with the stakeholders, users can make requests anytime when compared to the old process, it is quicker, more optimised, and gives more attention to the process.

## 5.4 The Limitations & Recommendation

We observed some limitations in the use of focus groups in the evaluation. We discovered the potential of integrating bank payment services into mobile applications. This issue, however, is not addressed in this research study. For future research, we suggest that

the possibility of utilising online payment using this application be considered. It would be more beneficial to handle the report, money transactions, and the company model's flow.

Furthermore, the online waste recommendation price was not included in this study; nevertheless, it would be very beneficial if we could give this function to waste dealers so that they can better understand how much money they should make by recycling that kind of garbage. Consequently, it is recommended that future research studies take this characteristic into consideration.

# Chapter 6. Conclusion

The main goal of this study is to examine Cambodia's present solid waste management status and limits, as well as the performance of the informal recycling activities, local government agencies, and contractual garbage collection services, in order to develop methods and strategies for an alternative approach to recycling which proposes a new solution to enhance the efficiency of the recycling implementation process in Cambodia. Furthermore, linking the waste dealer and waste merchant for recyclable waste items through a mobile application.

The mobile application received extraordinarily high acceptance ratings based on our findings. We can assume that all the respondents were favourable, suggesting that they considered the application very useful as a Cambodian citizen. Because of this application's potential benefits to society, particularly waste merchants and waste sellers, in terms of facilitating and optimising time, users can establish direct connections with stakeholders, users can make requests at any time, it is more efficient and increases revenues, it is faster, and it optimises the process. Since the mobile application is expected to contribute to

the sustainability of the recycling market, it will encourage and mobilise the economy in this area.

For future research, we suggest activating to consider utilising this application to make online payments. So, handling the report, money transactions, and the firm model's flow would be preferable. Furthermore, the online waste recommendation price was not included in this study; nevertheless, it would be very beneficial if we could give this function to waste dealers so that they can better understand how much money they should make by recycling that kind of garbage. Consequently, it is recommended that future research studies take this characteristic into consideration.

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# Abstract in Korean

## 캄보디아 환경에 적용할 수 있는
## 모바일 기반 폐기물 재활용 프레임워크 제안

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폐기물 관리는 개발 도상국이 해결해야할 주요 문제이다. 아시아의 신흥 개발도상국에서는 환경 및 공중 보건 위험이 존재하며, 배출 결과에 대한 후속 대책 없이 도시의 쓰레기를 공공 장소, 도로, 하수구, 수로에 폐기하고 있다. 이와 관련하여, UN의 지속 가능한 개발 목표(SDGs)는 전 세계 폐기물 감소를 위한 명확한 목표와 지표를 제공하고 있으며, 쓰레기 수집율 증가, 쓰레기 안전 배출 촉진, 쓰레기 재사용 및 재활용율 증가 등을 제시하고 있다. 2020년 기준으로 1,672만 명의 인구를 보유한 캄보디아는 다양한 고형폐기물을 처리해야하는 문제에 직면한 상태이다. 캄보디아 전기통신규제국(TRC)에 따르면, 2020년까지 휴대전화 가입자 2000만 명을 달성하고 1,500만 명이 인터넷에 연결될 것이라 예상하였다. 휴대전화 및 인터넷의 확산은 다양한 당사자간의 연결을 가능하게 하는 여건이 된다.

성공 사례에 기반한 결과는 사람들의 재활용 활동을 촉진할 수 있으며, 나아가 캄보디아의 쓰레기 재활용을 위한 모바일 기술 사용 가능성을 증진시킬 수 있다. 본 연구의 주요 목표는 캄보디아의 고형 폐기물 관리 현

황 및 한계를 검토하고, 비공식적인 재활용 데이터와 지방 정부 기관 및 쓰레기 수집 대리 서비스의 성과를 분석하여 재활용에 대한 대안적 접근 방법을 제시하고 전략을 수립하는 것이다. 또한, 본 연구는 모바일 기술을 활용하여 캄보디아 내 재활용 과정의 효율성을 높일 수 있는 새로운 솔루션을 제안하고, 모바일 애플리케이션을 통해 재활용 가능한 폐기물 제품의 수요와 공급을 연결하여 캄보디아 내 모바일 온라인 폐기물 시장의 실행 가능성을 연구한다.

**키워드:** (폐기물 관리, 재활용, 감축, 재활용 어플리케이션, 모바일 어플리케이션, 캄보디아)

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