Recycli: A Mobile Application to Promote the Recycling of Food Packaging

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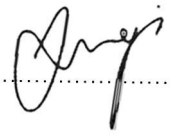
Signed  (candidate)

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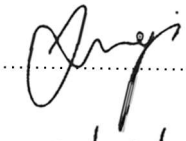
Signed  (candidate)

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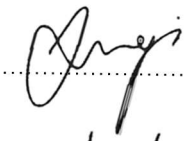
Signed  (candidate)

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Abstract

Recycling incorrectly can lead to recycling centres rejecting entire recycling loads which are then sent to landfill and incineration sites, this can negatively impact wildlife and contribute to the increase in CO2 emissions. There are many applications on Google Play Store and the App Store that have attempted to serve as support tools for recycling, however they are usually limited to be used in one location and only allow the user to search for general object.

This thesis describes the early development and testing of the first android mobile application that supports recycling in any location and provides the recycling information of specific products. This is guided by environmental psychology literature that identifies common factors that determine recycling behaviours, two of these factors are: 1) the convenience and familiarity of one's local recycling infrastructure; 2) knowledge regarding how to recycle.

The application, Recycli, allows the user to search for specific products in a database and in turn the application will display the materials each component of the product's packaging is made up of. The user can also search for their nearest recycling centres, as well as allowing the user to also add product to the database. The data in the database is crowdsourced using the latter feature, whereby, when the user recommends an addition to the database it will be moderated and verified by the administrators of the application before being put on the database accessible to the public.

The application was evaluated using a usability test, where in the participants were able to navigate through most of the tasks with ease, and the task of recycling was said to be easy through the use of the application. However, the provision of knowledge is limited through Recycli, as participants stated they would know how to recycle certain items if they needed to recycle them again, however knowledge regarding recycling was not gained through the application.

Currently, the application is limited in terms of scalability, as users are only able to see recycling centres in the Swansea area, thus making this specific feature limited, as well as this, the database is limited as it will grow upon further adoption by users. The final product serves as a good foundation to be developed further and improved upon using the feedback given from the usability tests and features from similar applications.

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2 Introduction

The recycling and responsible discarding of residual waste such as food packaging is an important and effective way individuals can contribute to working toward a sustainable society. Fortunately, there has been a gradual increase in the rate of UK household recycling between 2000 and 2011, that being said, since 2011 this incline has plateaued [1].

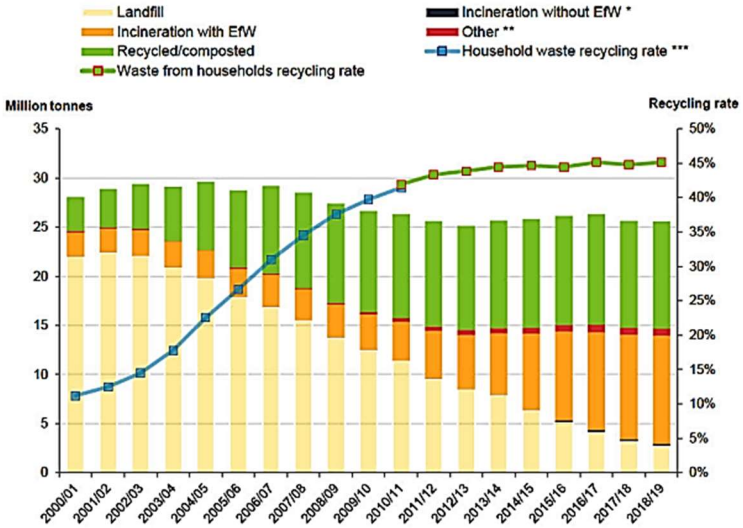

Figure 1: Management of all local authority waste and recycling rates, England, 2000/01 – 2018/19 [1].

Considering this, there have been many studies and psychology literature researching the determining factors of recycling behaviours, these factors are; a) the convenience and familiarity of one's local recycling infrastructure; b) knowledge regarding how to recycle; c) the effects of their recycling behaviours; c) social norms regarding recycling [2]–[5]. That is, people tend to act more positively when equipped with relevant knowledge.

A ubiquitous channel for delivering this information is through smart-phone devices as users usually keep this device in close range for convenient use, making access to information immediately available [6]. Whilst there are many applications on the market that have attempted to provide recycling support, they are all limited in that they are designated for use in specific locations only, thus the adoption of these products is low. Furthermore, the current applications only allow users to search for general objects such as "glass bottle", as appose to specific brands or foods.

2.1 Aims

The project described in this thesis aims to provide users with recycling guidance and knowledge through a mobile application, and in turn will encourage users to adopt positive recycling behaviours. The mobile application will do the following:

1. Utilise a cloud-hosted database that will allow users to remotely access the information within the data, as well as accommodate the crowdsourcing of data.

2. Allow the user to search for specific food products in the database. In return the application will explain what recycling bin to put specific components of the products packaging.
3. Provide the user with the location for their nearest recycling centres.

The successful completion of these aims will produce a support tool for recycling that can be used by anyone in any location as well as allowing the user to search for specific foods, unlike current recycling applications available today. The finished product will be evaluated using a usability test to ensure the product delivers in presenting useful recycling information to the user as well as providing the user with knowledge about recycling, that is the recycling of obscure products and their local recycling infrastructure.

3 Motivation and Background Research

To refine the aims of the project, an understanding of its core theme – recycling, must be understood. This chapter discusses the motivation behind the project and the relevant books, academic journals and papers, and current technologies that were analysed to define the mobile applications requirements before implementation.

3.1 Global Warming

Global warming is the long-term increase in the Earth's temperature. This has been extensively studied and proved through annual temperature measurements of the Earth's atmosphere, in fact the Earth's surface air temperature has increased by 0.06 degrees Celsius per decade since 1880, however in the past thirty years this number has doubled to 0.28 degrees Celsius per decade [7].

One of the top contributors toward this increase in temperature is widely considered to be correlated to the increase in human activity through industrialisation, and the consumption of natural resources. This is proved in a study by K Dong *et al.* that considers six regions across the world (Europe and Eurasia, Africa, Middle East, Asia Pacific, North America, and South and Central America), as seen in Figure 1 [8].

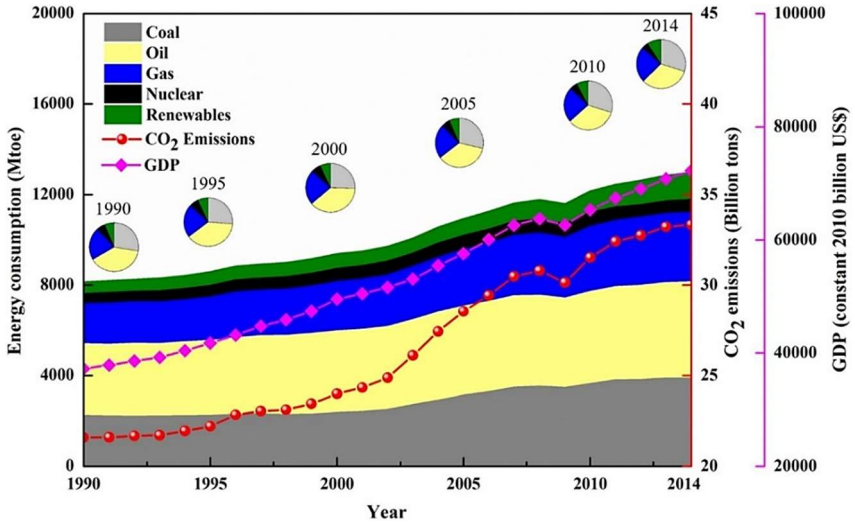

Figure 2: Global CO2 emissions, economic growth, and primary energy mix from 1990 through 2014 [8].

According to M. Maslin, the increase of the Earth's temperature will have detrimental effects on humans health, societies, agricultural and bio-diversity through the production of toxic greenhouse gas emissions and the rise in sea levels [9].

Furthermore, whilst global warming is a natural occurrence, that has been stimulated by human activity. Fortunately, studies have proved that a reduction in harmful human activity can slow it down.

One-way individuals can contribute is by recycling, it is a simple, yet effective task individuals can adopt in their everyday lives to help in the reduction of global warming. However, due to confusion people often make mistakes when recycling, for example, by discarding of materials in the wrong recycling bin. Whilst this may seem like a harmless oversight, this can lead to entire recycling loads ending up in landfill. This can be avoided through the provision of information, as will be discussed in the upcoming sections.

3.2 Recycling and its importance

When a material is recycled this means that it is reprocessed to be remade into something new, thus maximising its potential use. The more materials recycled contribute to the minimisation of waste going to landfill [1] and incineration, both of which contributes to CO2 emissions. Recycling ends up in landfill and incineration site due to contamination.

3.2.1 Contamination

In a study by A. A. Babei *et al* consisting of 2400 households in Abadan, they found that 94.3% of participants were willing to participate in separating their waste but due to the inconvenience of accessing recycling bins and the lack the knowledge on how to do so, they found that only 1.7% of the surveyed were separating their waste [2]. This lackadaisical attitude to recycling can lead to contamination.

Department of Environment, Food and Rural Affairs (Defra) defines contamination as *"people putting items in their recycling bin that are not collected locally for recycling (i.e. non-target materials); or materials which are not collected as part of dry recycling such as nappies or food waste, or from cross contamination, for example from shards of glass."* [10].

When recycling loads have too many contaminants, the entire load may be rejected at reprocessing or sorting centres and are sent to incineration or landfill sites. Moreover, materials made by recycled material that contain contaminates are lowered in quality and so the demand from producers that utilise secondary materials decrease [10]. To combat this UK law requires local authorities in England and Wales are to collect paper, metal, plastic, and glass waste separately for recycling [11].

Furthermore, in 2018, Defra, reported that only 20% of recyclable household waste was sent to landfill (Figure 3) [12], this over-achieves the EU waste targets for recyclable household waste sent to landfill to be no more than 35% by 2020. However, as seen in Figure 1, although landfill by tonnage has seen a significant decline over the past decade, waste sent to incineration with EfW has vastly increased and incineration without EfW has been introduced since 2015 [1].

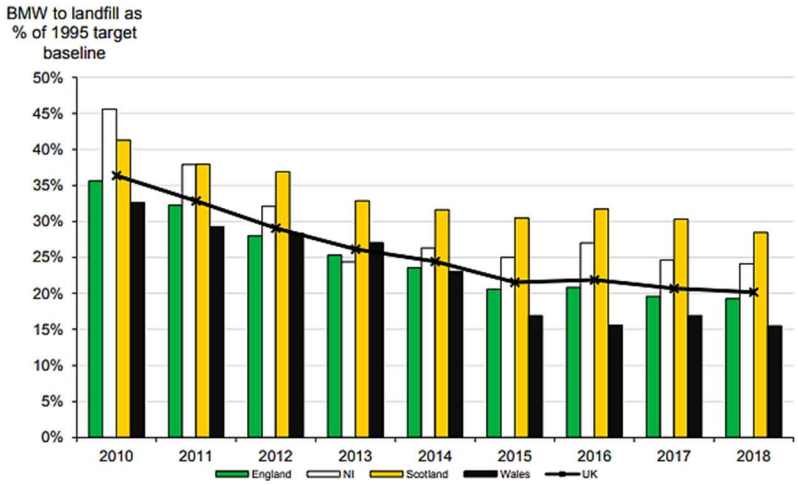

Figure 3: Biodegradable municipal waste (BMW) to landfill as a percentage of 1995 baseline, UK and country split, 2010-18 [12].

3.2.2 Incineration with Energy from Waste (EfW)

Incineration with EfW is a controversial method of waste disposal, it is argued to be a productive method as the energy produced can be utilised as electrical energy [13] and it also reduces the need for space that would be used by landfill sites[14].

However, there are many criticisms regarding the emissions produced during the incineration process, as it has been found to contain hazardous substances such as toxic metals like mercury, toxic gases such as sulphur dioxide, nitrogen oxide, hydrogen chloride, chlorine gas, harmful hydrocarbons, volatile organic compounds (VOC), dioxins, and furan[13]–[16]. The release of these pollutants can degrade the air quality and contribute to the health of communities and contribute to greenhouse gasses [14]. Thus, it is vital to encourage recycling and to ensure individuals are recycling correctly to avoid recycling loads being sent to landfills and incineration centres.

3.3 Recycling Habits and Attitudes in the UK

In 2019 WRAP published a survey regarding "*Behaviours, attitudes and awareness around recycling*" amongst households in the UK [17]. Encouragingly, the survey found that three in five households stated they recycled one or more items in the past year. This includes materials and products not accepted by their local council.

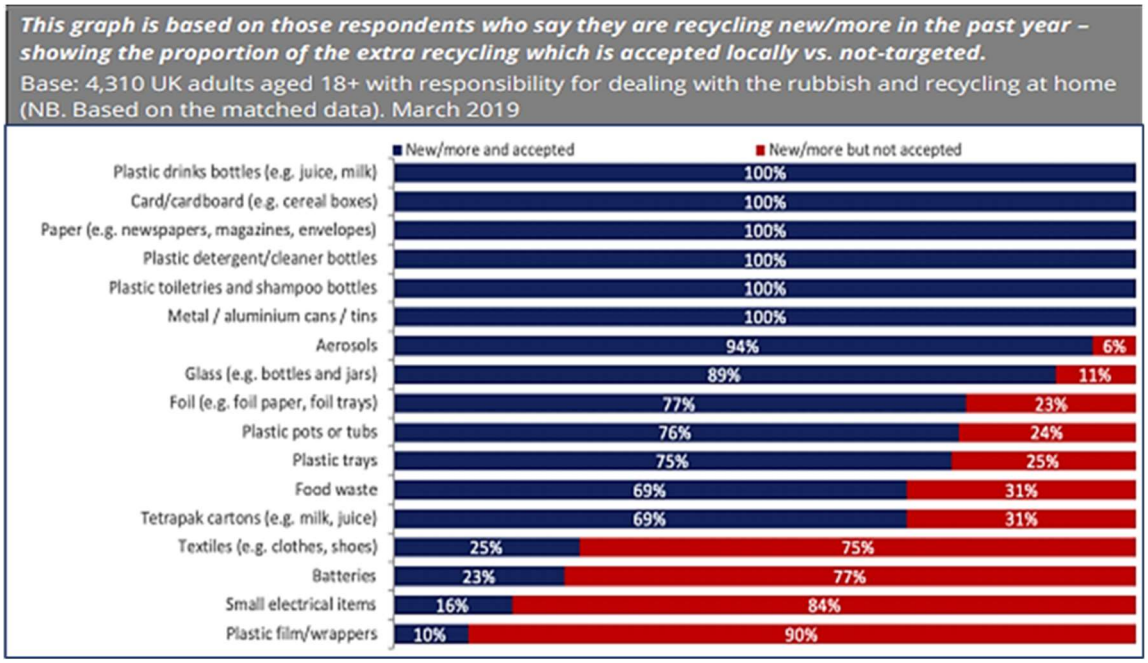

Figure 4: Extra recycling by material, separated by those accepted locally vs not [17].

Their study also revealed that 51% of households dispose of items in non-recycling that were collected for recycling by their local authorities, what's more 82% admitted to having included one or more items into their recycling bins that were not meant to be in there (i.e. contamination), this is a significant increase from their 2018 findings which was at 76%.

Those that recycled fewer items incorrectly were identified to be habitants of councils that collect at least 14 materials, have higher recycling motivations, and received information from their council about the recycling of specific recycling of items in the past year. These identifiers coincide with environmental psychology literatures factors for influencing recycling behaviours.

Furthermore in another 2019 survey by Viridor [18] found only 34% of the 2500 participants were "very confident" about what they put in the recycling bins, and less than half (46%) said the recycling information provided was proficient and 27% were frustrated about not having enough educational material available on recycling.

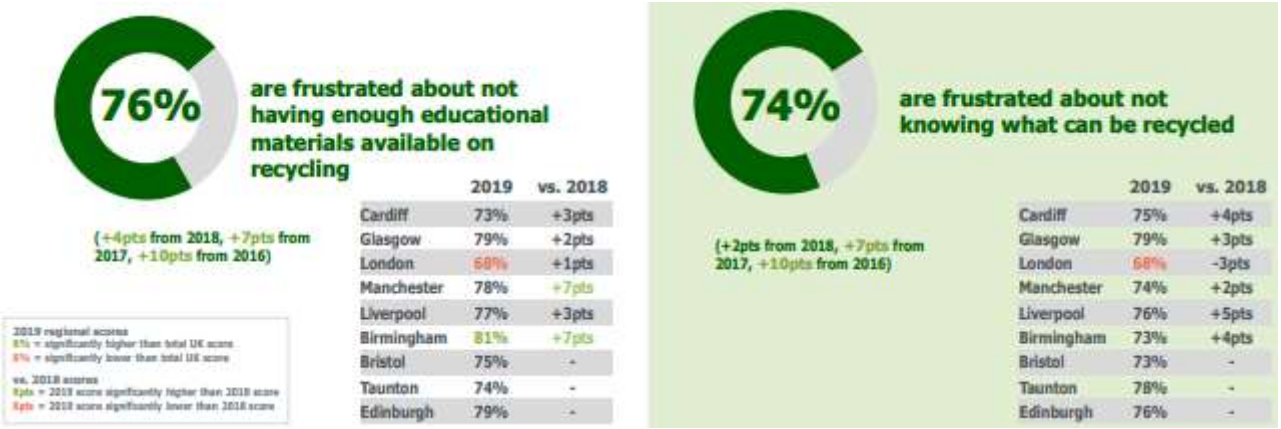

Figure 5: Viridor survey [18]

This gives further weight to research by Cezara Hulber who's findings suggest that utilising technology as a support tool, such as a mobile app, is effective when attempting to encourage environmental behaviour [6], such as recycling.

3.4 Related Works

3.4.1 Factors Influencing Households' Participation in Recycling

The paper "Factors influencing households' participation in recycling" by P. Vicente and E. Reis aims to better understand the factors influencing a household's decisions to participate in recycling programmes[19]. This study relates to this project in that the scope of the paper also focuses on citizens and their recycling behaviours (as opposed to commercial recycling behaviours for example). The findings of this paper provide a useful starting point in helping for understanding how to approach this project so that it is effective in encouraging people to recycle.

Vicente and Reis gathered their data by carrying out structured personal interviews amongst two-thousand households in the Metropolitan Area of Lisbon (MAL), Portugal. Their interviews focused on 1) attitudes toward recycling, 2) incentives to encourage recycling, 3) effects to the access of recycling information received through direct media[1] and the presence of children in the household (age < 14 years). Participant's answers were given with statements or against a Likert-scale system.

Their study concludes that personal attitudes appear to effect positive recycling behaviours over receiving incentives when participating in a recycling programme. The strongest determinant of one's attitude when recycling are social and personal norms, that is, citizens "*feel a strong obligation to recycle*" or "*feel bad if they do not co-operate with recycling*" or when it is considered a shared task for everyone.

However, households that do not partake in recycling were found have feelings of indifference toward recycling or found it to be a difficult task. The two most encouraging incentives for these groups of people were to have more information on recycling and have Ecopoints[2] that are clean and in an ideal proximity to their home.

It is highlighted that providing citizens with clear recycling information is the most compelling factor when encouraging recycling participation. This means; clarifying the separation process of items; the bin each component should be deposited in; as well as providing information for the disposal of materials that are "*less frequently used or that cannot be accepted for recycling*". Access to abundant and high-quality information were proven to make citizens consider recycling less difficult.

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[1] Direct media includes direct mail, brochures provided with their waste collection, local information provided by their local authorities, and local billboards. This is in contrast to mass media which include TV, radio, newspapers and the internet.

[2] EcoPoints: Location points for points.

Direct media is suggested to be more effective than mass media as it can be made to be more personable to the recipient, leading the household to feel that recycling is a task that requires their co-operation.

Information should also communicate the effects of positive recycling habits by showing households how their recycling contributes positively to society. The study suggests communicating this using the current figures for waste sites compared to when recycling was not part of their community. Thus, replacing indifference toward recycling with concern as it demonstrates that "everyone is a waste producer" and so everyone should be active in recycling.

The findings of this paper are very discerning for establishing the requirements of the mobile application in that the information provided will clarify what bin to put each component of the foods packaging in and to include information about how to discard obscure materials. Furthermore, the project involves creating a mobile app, which is not considered direct media, however as discussed in C. Hulber's in the previous section, a technologies, like a mobile application, have been proven to be an effective method of communicating recycling information to users as mobiles are personal devices.

3.4.2 WasteApp: Smarter Waste Recycling for Smart Citizens

The paper "WasteApp: Smarter Waste Recycling for Smart Citizen" by D. Bonino *et al*. aims to engage the citizens of Turin, Italy, in recycling through a mobile application [20]. The problem they identify is the lack of user-centred recycling tools today. The project described this paper is akin to the mobile application that will be implemented in this paper. This paper will serve as guidance for how the mobile app will be developed and tested.

The research for WasteApp compromised of a co-design methodology with Turin's social housing project and the citizens of Turin over a six-month period. Their early meetings involved gaining a comprehensive understanding about the city's waste structure and rules, and the communities recycling habits. This was done by conducting interviews with Turin's social housing projects operators (administrators, workers, technicians), and workshops with the Turin's citizens. From their interviews and workshops their findings revealed the following; people become frustrated when they can't recycle simple materials, which lead to bad recycling habits; participants also stated that they did not always know what goes where or they simply forget how to recycle something; and they are not always in tune with what materials are collected on a specific day of the week.

To address these issues through the WasteApp a set of requirements were established; 1) collection calendar and reminders, 2)recycling guide, 3) location of waste bins near a specific location, 4) locate nearby drop-off points, 5) collaborative recycling support tools with up-to-date and trustworthy information. These requirements were design in a lo-fi prototype (Figure 6) and were evaluated by HCI/Ubicomp experts to identify any weaknesses in their concept. After two cycles of revisions another low-fi prototype was created and tested in a think-aloud protocol with users that had "good experience on using mobile applications". The test resulted in the participants completing most of the assigned tasks which they used as confirmation of the initial design.

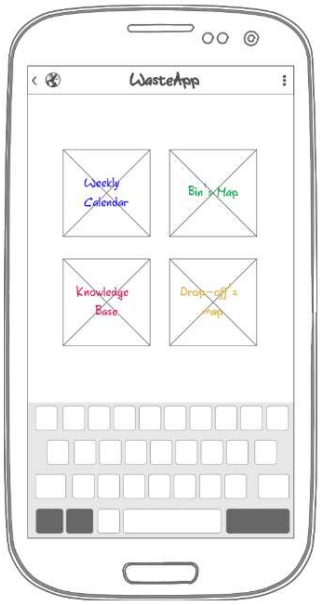


Figure 6: WasteApp's lo-fi paper prototype.

They then developed an interactive prototype android application that included the following features; a) an updated calendar for waste collection for the municipality of Turin, b) a notification system for the calendar, c) a searchable recycling guide with the option of using a barcode scanner to give back the information of a product, d) an interactive map of bins near to the user with its current fill-level, e) a map of drop-off locations and their information. Crowdsourcing is also implemented in the WasteApp for users to define new products and their waste-disposal.

Figure 7: WasteApp's home activity and recycling calendar activity.

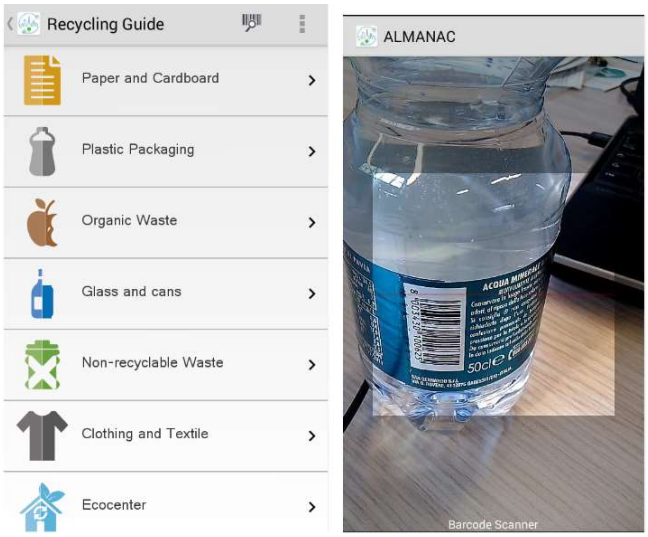


Figure 8: The WasteApp Recycling Guide and Barcode scanning feature.

In their final testing of the application, a usability study was done with six participants. The participants were first queried about their first impression of the interface and its visual appeal and were then required to perform four tasks each in a think-aloud protocol to verify their decisions to understand the usability of the application.

A Nielsen Alert box was used to calculate the success rate of the participants ability to complete all tasks. In figure 9 S indicates a success score of 100, P indicates a partial success score of 50, and F indicates a failed score of 0, the success rate is the average of the points for each user.

TABLE II
SUCCESS RATE OF THE STUDY.

User	T1	T2	T3	T4	Success Rate(%)
U1	P	S	P	S	75.0%
U2	S	S	P	S	87.5%
U3	P	S	S	S	87.5%
U4	S	S	P	S	87.5%
U5	P	S	F	S	62.5%
U6	S	S	F	S	75.0%

Figure 9: Success rate of WasteApp's usability study.

The success rate of each user is quite high, and through user feedback during this test, the were able to identify the application's shortcomings. Firstly, users said that the barcode scanning button was difficult to find, but easy to use. Secondly, participants were able to use the app to locate nearby bins, however they argued that the icons on the map were too small and "cumbersome" when trying to identify what kind of waste the bin took. On the other hand, participants praised the notification feature and the ease of use and support from the app.

The development of the WasteApp and it's features have brought to light some features that could be implemented in Recycli, such as such as the use of barcode scanning to search for a product within a database, a map to locate a user's nearest recycling points for alternative products, and a crowd-sourced database. However, from the recycling guide screen shown in figure 7, it appears that the user will choose the material the product is made of first and then search through the

products in that material category. However, food packaging is often compromised of multiple materials, or is made of materials that are often mistaken for another, therefore an exploration as to how Recycli will display it's recycling information will be done with consideration as to how it will be structured in the database whilst ensuring the information is clear.

As Recycli is focused on creating a supportive recycling tool, a usability test will also be carried out similar to WasteApp's, to evaluate its usefulness and ease of use to the user.

3.4.3 Review of Existing Recycling Applications

To further define the requirements of Recycli, this section will review five recycling applications available for download on the Google Play Store today. This analysis will also inspire the visual aspect of the interface.

When exploring the internet for applications to include in this analysis, there were many listicles that recommended various applications, interestingly when delving into these applications many of them were no longer available for download on the Google Play Store [21]. This could be due to the low adoption of recycling application as many of the application in this review have been downloaded very few times.

The apps surveyed are all available on Google Play store, these were, Recycle Nation, iRecycle, RecycleSmart, Recycle Right and Recycle Coach. A common feature amongst these applications are that they are targeted for use in a particular set of cities or one country as the information provided are location specific such as nearby recycling points or bin collection calendars. The number of downloads to the population of these locations are compiled in Table 1, this clearly displays the apparent failure of engagement by the apps targeted citizens.

Table 1: Recycling Applications

App Name	Location	Population (million)	Downloads	Rating (out of five stars)
Recycle Nation	USA	328.2	8	2.5
iRecycle	USA	328.2	10	3
Recycle Smart	Australia	24.99	45	3
Recycle Right	Western Australia	2.589	26	3
Recycle Coach	Madison, Wisconsin Jefferson County, Louisville Tacoma, Washington New Jersey San Antonio	11.432	4032	4.5

The first four apps listed Table 1 were given low rating, many of the reviews given have criticized that the recycling results given were either incorrect or out of date. In contrast, RecycleCoach, whose download rate is still comparatively low, it has been rated 4.5 stars by the users. When looking at the reviews, there are no specific features that are praised just that it is deemed a useful

recycling app, furthermore, each review left on their Google Play Store page seems to have some kind of engagement by the RecycleCoach team.

The common features provided amongst the surveyed apps were; a) a key-word searchable index that described different types of waste and at least one image is used as an example; b) waste-collection calendar for the app's target municipality with notification capabilities; c) a map to locate nearby drop-off recycling locations.

Similar to WasteApp, most of the applications allow the user to search for a product by first picking a category. However, because Recycli will only focuses on food product's packaging, this method of filtration would just be an unnecessary added step.

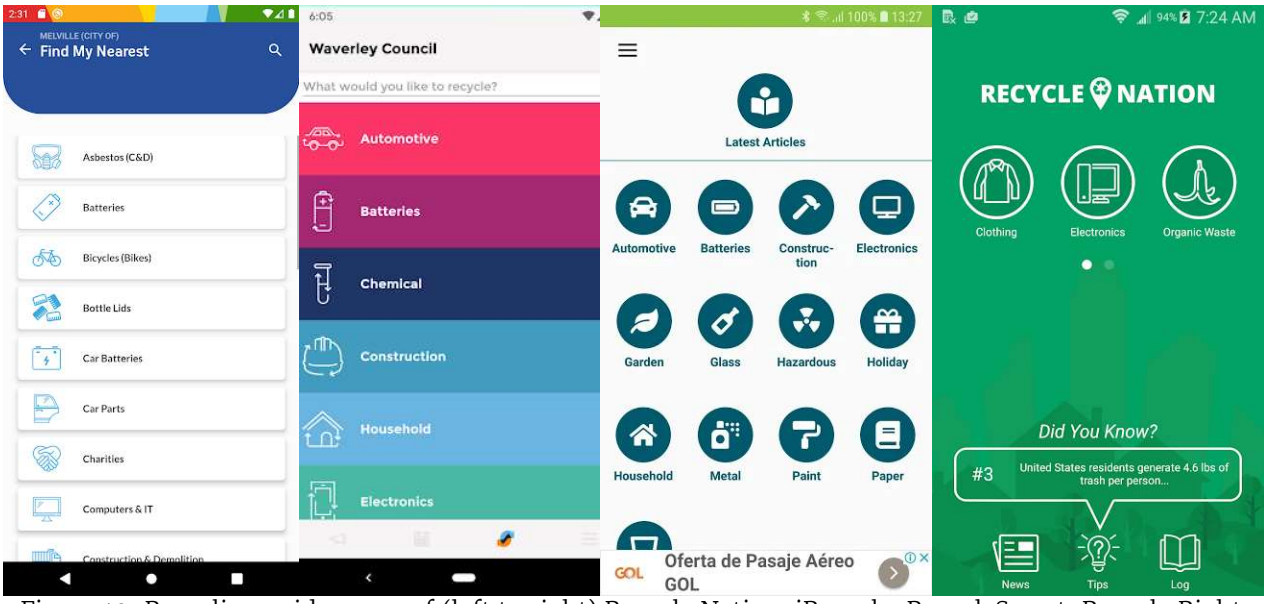


Figure 10: Recycling guide menu of (left to right) Recycle Nation, iRecycle, RecycleSmart, Recycle Right.

None of the applications allow the user to search for specific products, only general materials, or the product type, such as aluminium can. One could argue that this defeats the purpose of the recycling guide and unnecessarily over-complicates the task flow of showing the user recycling information. This goes against the one of the researched factors that encourage recycling behaviour [19], in that the information is not easily accessible. Furthermore, because search is limited to specific materials or a type of product, the problem of contamination is still present as none of these applications describe the separation of the different materials an item may be made up of.

Visually, all of the applications surveyed used simple yet attractive designs, an utilise flat and minimalist icons. This approach will be ideal for Recycli's interface, as it will be quicker to design, and the information presented will be clearer to the user.

3.4.4 Review of Barcode Scanning in MyFitnessPal

Recycli will utilise barcode scanning as a way for users to search through the database, as inspired by the WasteApp project. To gain a better understanding of how barcodes have been implemented in existing applications, this section will analyse a popular nutrition tracking app MyFitnessPal.

MyFitnessPal is a nutritional app that is free to download with freemium features. The overall aim of the application is to achieve a goal weight and two sub-aims are to reach a target calorie and increase physical activity. These goals are reached through the app by allowing the user to monitor their nutritional intake [22]. While this does not relate to recycling, the way MyFitnessPal allows its user to search for a food item in their database is not too dissimilar from the methods that will be implemented in Recycli.

The user can search for food via the search bar, or by the barcode scanner the items barcode. According to a study by D. C. Mohr *et al.* the barcode scanning feature to search for a product in a database is simpler to use than the search bar feature[23]. If the barcode scanner cannot recognise the given barcode, the user also has the option of entering the barcode manually. A study by M. Maringer scanned 700 products using the MyFitnessPal scanner and received a 99% success rate for matched barcodes in the database [24].

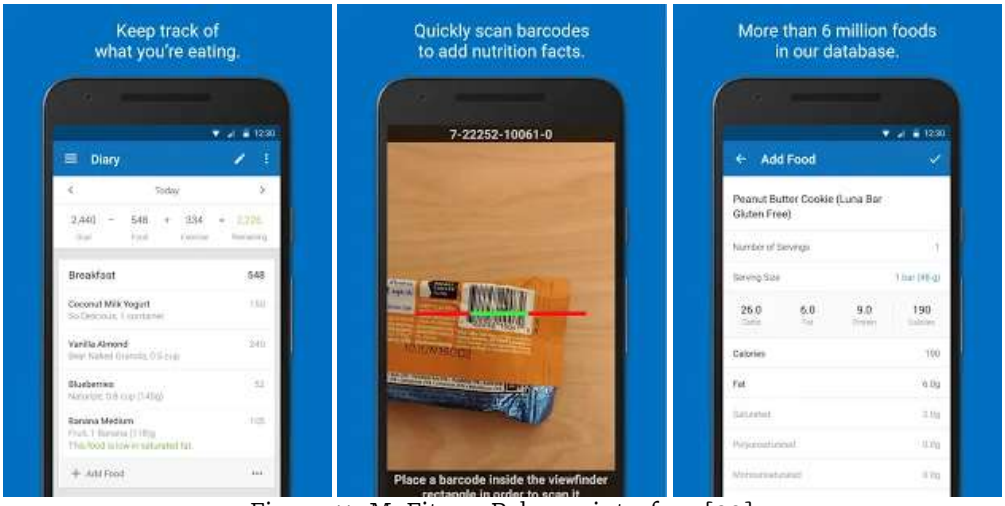


Figure 11: MyFitnessPal user interface [22]

The data was accumulated mainly by crowdsourcing where the user is able to manually enter the nutritional information of a specific food, and the entry could receive confirmed votes by other users, as many food products packaging are required to have nutritional information on its labels. As a result, they have reported to have accumulated over three-million food's data, which account for 90% of food items available in most supermarkets. However, an estimated 76% of items are said to be duplicate entries [25].

As inspired by WasteApp, the food products available in Recycli's database will also be crowdsourced however, it may not be advisable to allow other users to verify other users entries as it is not required for food packaging to have recycling symbols on them. Instead the data input by the user will be verified by moderators to ensure the information is correct to avoid overpopulating the database with redundant information which may confuse the user.

4 Project Specification

The aim at the inception of this project was to create a tool to encourage recycling amongst individuals by giving them easy to access and clear information regarding the recycling information of a product. The research allows the further definition for the requirements and features of the application, as will be outlined in this chapter.

4.1 Requirements

For successful completion of this project the requirements of the application are divided into specific primary and secondary requirements. The primary requirements are tasks that are indispensable to achieving the minimum viable product that represents the main goals of this project, and the secondary requirements are tasks that aren't essential to the success of the final project but are desirable features that may be added if there is extra time after the completion of the primary aims.

4.1.1 Primary Requirements

- Design interface that is appealing, intuitive, and allows for the clear displaying of information regarding recycling, this will be decided via a user survey.
- Implement a cloud-hosted database that will hold some information about a food product and its recycling information.
- Allow the user to search the database via search bar through the application interface.
- Allow the user to search the database via barcode scanning through the application interface.
- Query the users search to find a match in the database and retrieve the information from the database to display on the applications interface.
- If the user's search query does not match any products in the database allow the user to add an item to the database for recommendation.
- Locate the user's current position and to locate nearby recycling centres and display this on a map interface.

4.1.2 Secondary Requirements

- Extend the database to include products other than food
- Extend the database to store information of curb side recycling in different municipalities in the UK.
- Implement a calendar feature that uses the curb side recycling information to display when bin collection day is and what materials are being collected.
- Implement a feature that will notify the user before bin collection day.

4.2 Technology Choices

To reach the established requirements the chosen technologies that will be used to create the application are based on previous experience and research.

4.2.1 Software and Language

Android Studio

Android Studio is the IDE for android application development. Having taken the Mobile Application module in the first semester, using Android Studio's will be familiar territory and the knowledge gained from that module will allow for a good foundation to develop and learn further when developing Recycli. The application allows for the implementation of code and the designing of interfaces all in the same environment making it a convenient tool to use. Android studio also allows the easy installation of SDK's by Google, this will be especially useful to when implementing the map features and database.

Java

Android Studios give developers the option of coding in Kotlin or Java. Having had experience with both languages, due to familiarity and comfortability, the application will be coded in Java.

XML

XML is the language used in Android to build interfaces, it should be easy to implement as many of the interface features can be added through the drag and drop features of the interface design tool within the Android IDE.

Google Firebase Realtime Database

Google's Firebase Realtime Database is a cloud-hosted meaning that every client and device connected to it receives and the newest data in milliseconds, without the need for an application server [26]. Thus, making Firebase Realtime Database is a suitable database service for this app.

As Firebase is a NoSQL database, it is the most suitable type of database to use as connection to a server will not be needed, and in terms of longevity of the application, as the database grows it will be cheaper to expand than using an SQL database, and won't require as much storage space compared to SQLite. Also connecting this database to the application will be seamless through the Android Studio IDE.

The only downside to using a cloud-hosted database is that the user will need internet connection to receive real-time updates from the app, but once connectivity is re-established, any changes to the data will be synchronised instantly.

Mobile Vision

To implement the barcode scanning feature, Google has an API that allows for the detection of barcodes. However, having never used this API before it may be difficult to implement. Thus, I have searched for alternative tools that could implement a barcode scanner if this fails.

ZXing

If the barcode scanning feature fails to be implemented using Mobile Vision, Zxing will be used instead. It is a library for android studios that all provides barcode scanning capability to an application, without the developer having to implement the camera or identifying barcodes. It is an easy to use library that will aid in the barcode scanning feature of Recycli.

4.2.2 Hardware

Samsung Galaxy A5

Recycli will be an android application, thus for easier development and testing, a second-hand Samsung Galaxy A5 was purchased. Whilst Android Studio allows you to run your application on an emulator, from personal experience, it is not always reliable and can slow down the system.

Furthermore, to ensure the interface is functional and information is presented how intended, using an actual device will display the interface as the user might see it.

Having an actual device over using the emulator will also be beneficial when testing and demonstrating the application as it will mimic the application of the app in real life as the application requires a camera for the barcode scanning feature.

5 User-Centric Design

In order to effectively design an application that caters to the target user, an online survey was distributed to better identify the target users of the application and to gain quantitative feedback for the applications features. This chapter discusses the survey and its results.

5.1 Survey Planning and Topic Guide

The survey was created using google forms and distributed it via social media sites such as Instagram and Facebook. The survey aimed to gain information regarding the demographic of the targeted user as well as get quantitative data to validate the demand for the features that may be implemented and for the overall need for the app. The questions topics were as follows:

- Demographic: Age, Gender, Location
- Application aims and features:
    - “Main feature of the app: Search for food products in the database and in return it will tell you how to recycle the materials the product is made up of”
    - Feature 2: Search for a food product using a search bar.

- Feature 3: Search for a food product using a barcode scanner via your phone's camera.
- Feature 4: A map showing your nearest recycling centres, you will be able to click on a location to get the directions to the specified location.
- Feature 5: A form to recommend food items if no result is returned, your recommendation would be moderated and considered for addition to the database.

The user was asked how useful they thought each feature is, and could choose from four options: very useful, somewhat useful, a bit useful, not useful at all.

For those that answered anything but very useful, they were asked to give a reason as to why.

The user was also asked if they felt features 2- to 4 were easy to use

- Additional features:
  - Additional feature 1: Calendar for your local authority's bin collection days
  - Additional feature 2: Notifications from the calendar
  - Additional feature 3: Accumulation of points for every item recycled

  The user was asked to rate how useful these features would be to the app on a scale of one (not useful) to five (very useful).

- How recycling information should be searched and shown:
  - Method 1: Search using a search bar or the barcode scanner and use a picture of the item and point out the recycling information of each component.
  - Method 2: Search for a general component type and then search for the specific item. For example, if you are undecided about how to recycle a Volvic water bottle cap, you would first search for bottle caps, and then specify for Volvic using the search bar or barcode scanner.
  - Method 3: Search for an item using the search bar or barcode scanner and display the information for lid, container, label, and other, component of the item where applicable. For example, if you searched for Tesco's long-life milk, in return you would get the recycling information regarding its components, the container and lid (as these are the only components of the item.
  - Method 4: Select the material you think the component would go in, and search for the product using barcode scanning or search bar for the specific information. For example, if you weren't sure if you should recycle a plastic tray in recycling, you would select "Plastic" from a menu, and then search for the specific product using the search bar or barcode scanner.

  The participant was asked to rate how easy these features sounded to use with 1 being the very difficult and five being the very easy.

- Effects of the application on the individuals recycling
    - Would this application be useful recycling tool for you?
    - Does this application sound like it would encourage you to recycle more?
    - Does this application sound like you would learn more about recycling?

5.2 Survey Findings

The survey received 55 responses in eight days. The participants of the survey consisted of 5.5% 17 and under; 71% 18 to 38; 20% 39 to 59; and 3.6% 60 to 80. There were no participants over the age of 80. The gender percentage was 36.4% male and 63.6% female, none of the participants selected "Other" or "Prefer not to say".

Usefulness of features and overall app

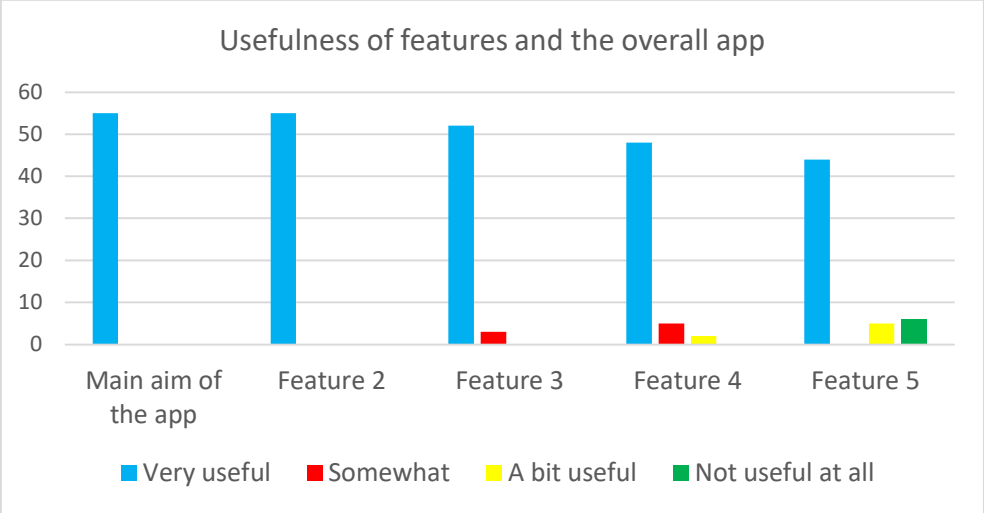


Figure 12: Survey results for usefulness of features and the overall app

100% of the participants voted that the overall aim of the application was very useful. All of the primary requirements stated in the Project Specification chapter received were considered to be "Very useful", however Feature 3, 4, and 5, received votes other than "Very Useful".

The feedback given for Feature 3 was concern over the accuracy of the barcode scanner and one person said that their phone's camera did not work but if it did, they would use it.

For Feature 4, five people voted that it would be somewhat useful, and two people voted that it would only be a bit useful. The common reason given in both categories were that they do not often visit recycling centres, and another person stated that they could just find out via Google search.

Feature 5 received five "A bit useful" votes and six "Not useful at all" votes, the reasons given by these voters was that they would expect the information to already be on the application and that it seemed like a time consuming feature especially if their recommendation doesn't make it on the app.

When asked if the features sounded easy to use, the majority vote for all the features queried were positive, however there was one "no" vote for Feature 2, and three "no" votes for Feature 5. Features 3, 4, and 5, also received a few votes for "I need more information"

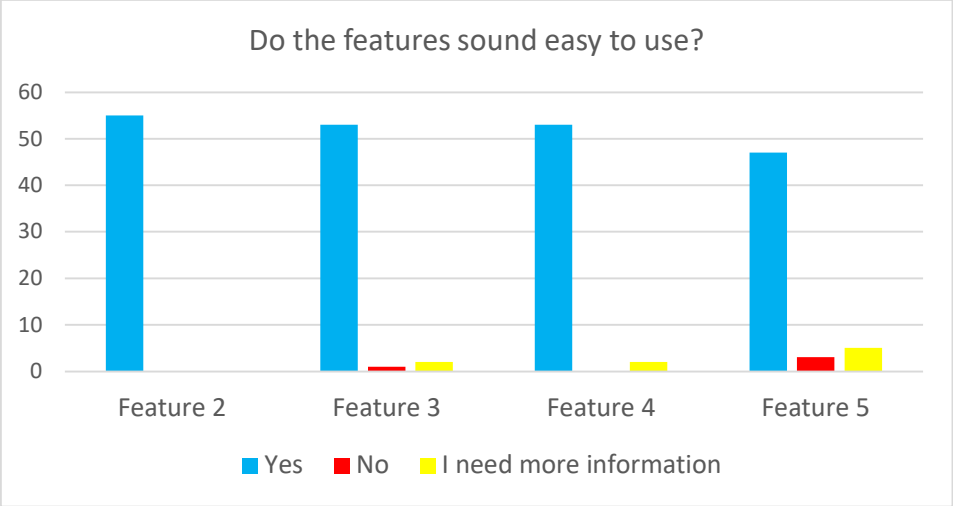


Figure 13: Survey results easy use of the features

Usefulness of additional features

From the graph it is evident that the feature (1 and 2) for a calendar that notifies the user when their bin collection day would be very popular. When asked to give a reason as to why, many stated that they often forget what bin they should put be putting out, or they accidentally miss a day.

The third feature of gamification, where the user will gain points for every item they recycle received mixed votes with a majority of twenty votes voting 3 out of five, the common reason given amongst all the votes was that they wouldn't utilise this feature. Some people stated that they would use the app for recycling information they were unsure of and would not log in all the recycling they do to receive points. If this feature has time to be implemented, it would need to be further developed so that it adds more enjoyability to the app and isn't a redundant feature.

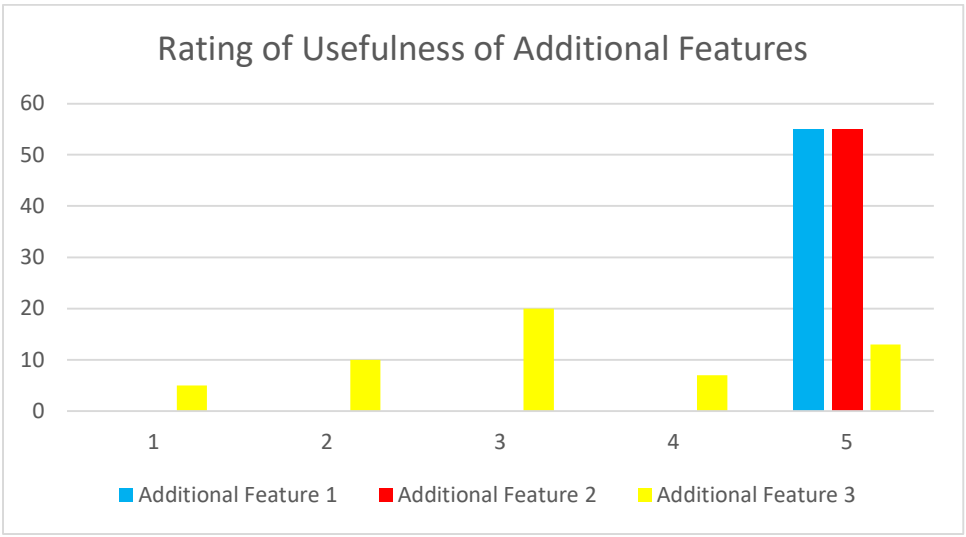


Figure 14: Survey results for usefulness of additional features rated out of 5 (very useful)

Method of showing and searching for information

Method 1 was voted the easiest method out of the four methods presented with all the participants voting 5 out of 5. This method may be difficult to implement as it would require a database to not only store all of the image of the products in the database which could be memory expensive, but it would require a custom interface for each product.

The second most popular method was number 4, as it received thirty-three 5 out of 5 votes, and seventeen 4 out of 5 votes. It would be more realistic to implement this method with regards to the time constrains given for the user interface design and would make more sense when creating the database.

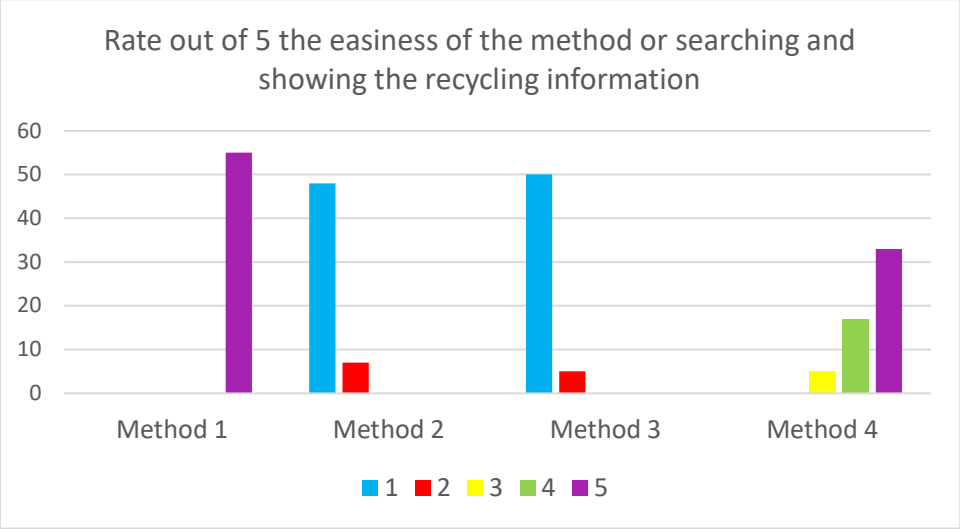


Figure 15: Survey results for ratings out of 5 for easiness for each method proposed for searching and showing the recycling information.

Methods 1 and 4 could be combined by using example images to go along with each component section to show as examples of what is meant by lid, component, and label.

Effects the application will have on the user's recycling

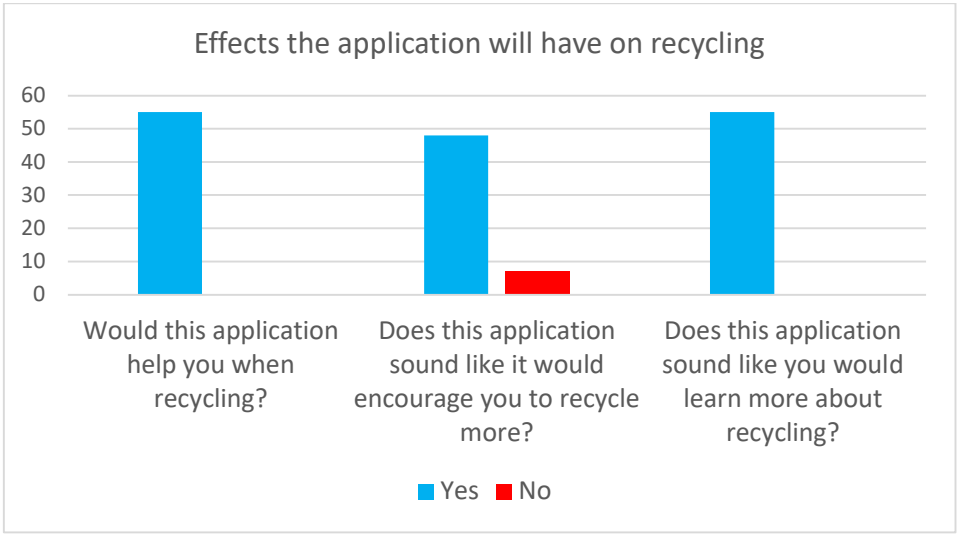


Figure 16: Survey results for the affects the application will have on the users recycling

When asked if the application would encourage the participant to recycle more, forty-eight of the fifty-five participants voted "yes", of the seven that voted "no", the reasons given were that it was dependent on if their council accepted the identified material, and if it didn't they would not seek facilities to recycle the item outside of their home. Despite this, the majority votes were positive and so the goal of encouraging people to recycle more is also fulfilled.

When asked if the application would help the user learn more about recycling, all of the participants answered "yes", this gives further weight to the research that people tend to have better recycling habits when they are more knowledgeable about recycling so this is result is encouraging.

5.3 Evaluation

The overall response for regarding the application was positive with all the participants voting that it would be a "Very useful" app and when asked how the application would affect the participants recycling behaviours, the majority of votes supported the projects motivations for creating a tool to support and encourage recycling by making the user more knowledgeable about recycling. The primary and secondary features of the application also received a majority positive votes for usefulness and ease of use. The survey was also useful in determining how the recycling information will be displayed. With the findings of this survey, the implementation phase of the application can begin.

6 Implementation

All of the primary requirements were implemented, this chapter will explain the implementation of these features with regard to the structure of the application, its graphical interface, the database connection, the implementation of the barcode scanning and the location of the users nearest recycling centres.

6.1 Methodology

The applications structure considers the MVC architecture where the interface is separate from the functionality, the components of the architecture is represented by: the Model that represents the functions responsible for handling data such as the network or database API's; the View that represents the visual aspect of the data from the Model; and the Controller that represents the functions that get notified of the users behaviour and updates the Model.

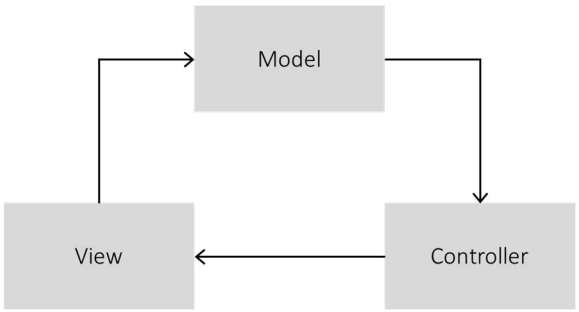


Figure 17: MVC Architechture

The logic architecture of Recycli is shown over four different layers as shown in Figure 18, from top to bottom the layers depicted are: A view layer that holds interface xml documents; an activity layer, that holds the functionality in java documents for the views; a services layer that holds the android services; and lastly the database layer that holds the firebase database.

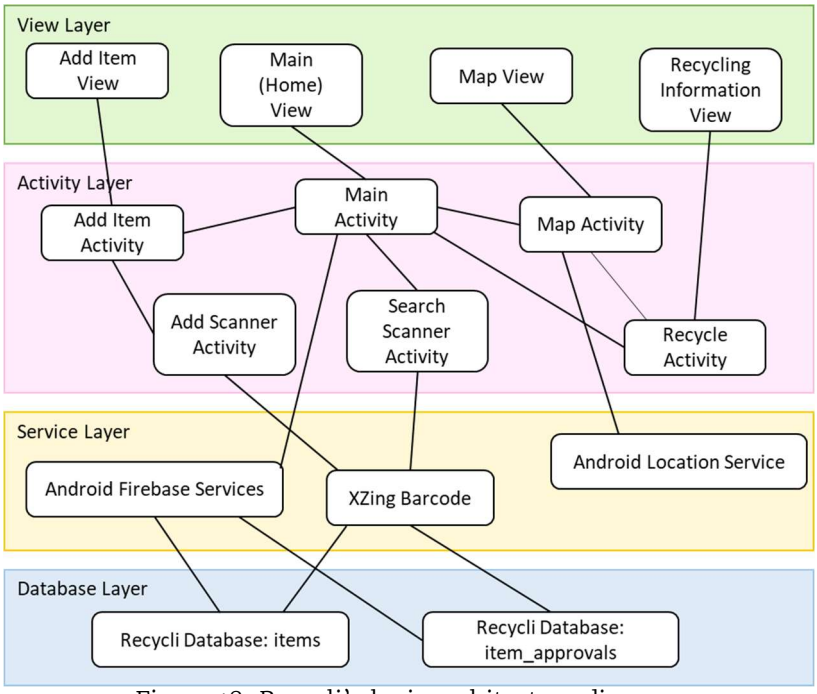


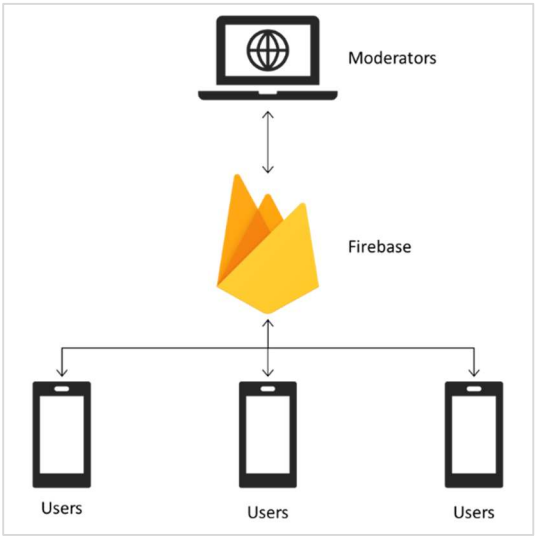
Figure 18: Recycli's logic architecture diagram

6.2 Database design

In order to gain a better understanding of the other features implemented, an understanding of how the database is structured is required. The database will store the information of the products, name, brand, weight, and barcode. As well as its information on how to recycle the lid, container and label, this portrayal of the recycling information was decided using the user survey as mentioned in the User-Centric Design chapter.

The application can retrieve information about a product upon the user's request through the search bar or barcode scanner. This information is stored in the "item" node of the Recycli database.

Information about an item can also be added to the database through the applications interface by the user. When information is added to the database, the applications moderators (currently me), will have to approve the item and add the recycling information to the database. The data added to the database will be stored in the "item_approval" node of the Recycli database, this side of the database will not be seen by the users, only moderators who have access to the Recycli Firebase Database console.



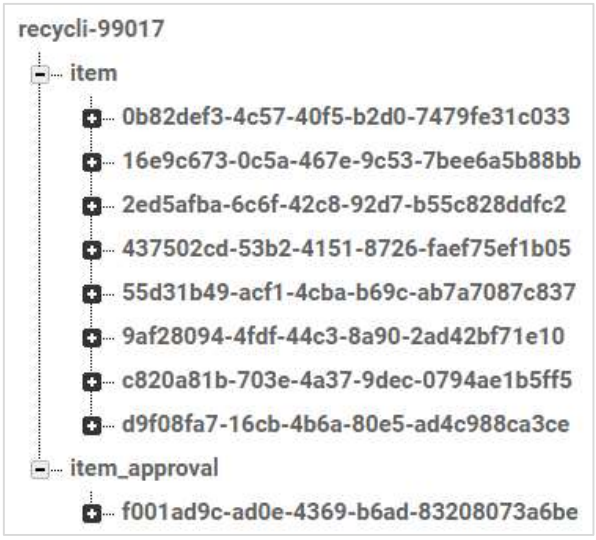


Figure 19 (right): Recycli's database flow diagram
Figure 20 (left): Structure of the Recycli Firebase Database

6.3 Features Implemented

6.3.1 User Friendly Graphical User Interface

The implementation of a graphical user interface was successful. Ensuring that the interface was appealing and intuitive to the user was determined by the analysis of current recycling application during the research phase. A common design approach was simplicity and the use of flat icons, thus inspiring Recycli's design choice, as seen in throughout the application interface. Utilising icons over text relies on the assumption that the chosen icons are intuitive enough for the user to know what the button does; this will be tested in the testing phase in a usability test.

Home Screen

When launching the application, the home screen allows the user four options of navigating through the application, these are:

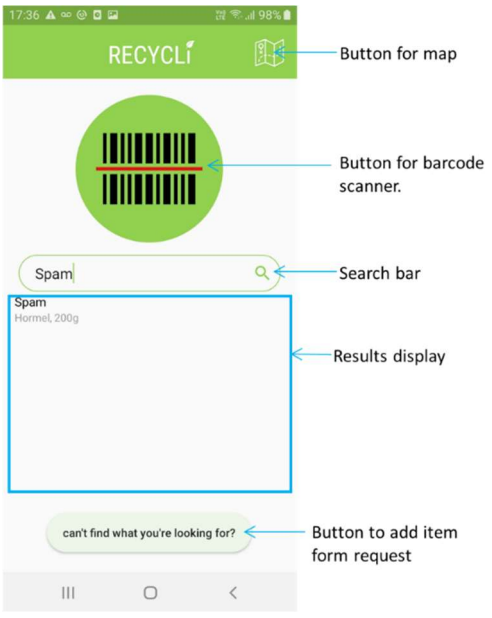


Figure 21: Home screen without and with results in the RecyclerView

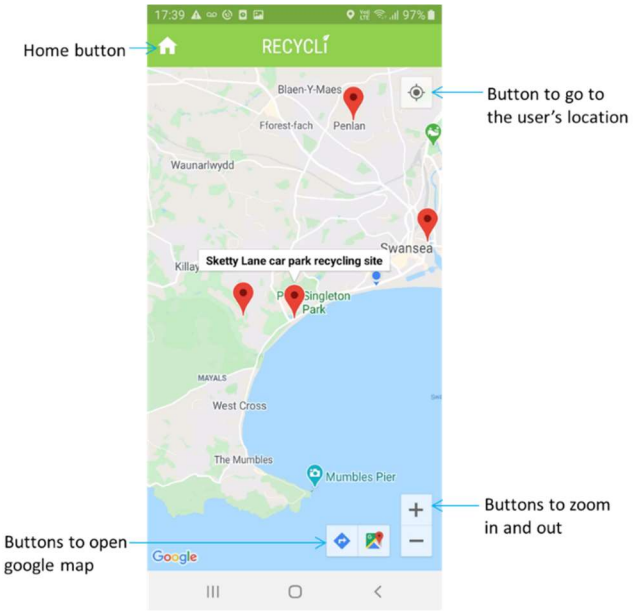
The layout file for this screen is called activity_main.xml

- A button that directs them to a map that shows them their nearest recycling centres.
- A button that opens up a camera that will scan a given barcode and search the database for a barcode match.
- A search bar that allows the user to search the database by typing in the name or brand of the product.
  - If a the typed in search query matches any items on the database, it will be displayed in the recycler view below it.

- A button that directs the user to a form they can fill out request the addition of an item to the database.

Map of Nearest Recycling Centres Screen

When the map icon is chosen from any screen, the user will be shown recycling centres near them, from this screen the user can do select the following:



- The house icon to go back to the home screen.
- Select one of the red location pins on the map to get the name of the recycling centre.
  - When a pin is clicked two buttons will appear that will open the google maps app and show them the route to the selected pin.
- A button that will re-centre the maps current view to the user's current location.
- Zoom in and out of the map either by pinching the screen or using the '+' and '-', respectively.

The layout file for this screen is called activity_maps.xml

Figure 22: Map of nearest recycling centres

Barcode Scanning Camera Screen

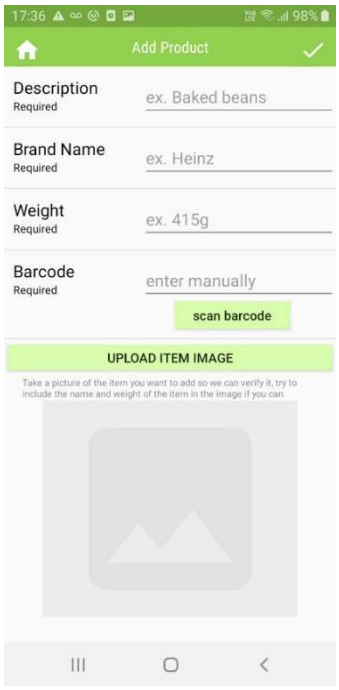
The user can reach the barcode scanning camera from the home screen using the barcode scanning icon button, and the "Scan a barcode" button in the screen to add an item to the database.

The idea behind the barcode scanner was that any 1D barcode presented in the bright square section of the camera will be detected. If the barcode matches any of the barcodes within the database, they will be directed to the recycling information page of that product, however if the scan fails the user will be directed back to the home screen and a toast notification will pop up momentarily indicating "Failed to find barcode".

Currently, the barcode scanning feature is limited in functionality and will be further explained in the "Search the Database via Barcode Scanning" section.

Figure 23: Barcode scanning screen

Add Product Screen



If the user cannot find a product in the database, they have the option of adding one to the database where it can be approved by the administrators of the application. This can be done by clicking on the "can't find what you're looking for?" button on the home screen where they will be directed to a form.

The form requests the description, name, weight, barcode, and an image of the product, when these fields are filled out the user will submit the information given using the check mark icon at in the top left corner.

Otherwise, the user can go back to the home screen by clicking on the house icon.

The layout file for this screen is called activity_additem.xml

Figure 24: Form to add a product to the database for approval

Recycling Information Results Screen

When a barcode is detected that is in the database, or when the user selects an option from the menu. They will then be directed to a page that will display the information of the product and how to recycle its lid, container, label where applicable. The page also contains diagrams to demonstrate what is considered a lid, container, and label.

The results page also has the option of looking at a map of the users nearest recycling centres for materials not commonly collected by their local authority.

A pop up will appear explaining what is meant by each component (lid, container label) when the user clicks on the ⓘ icon next to it.

The layout file for this screen is called activity_recycle.xml

Figure 25: Recycling information about the item

Interaction Flow Diagram

Below is the diagram that depicts how the application's activities are connected.

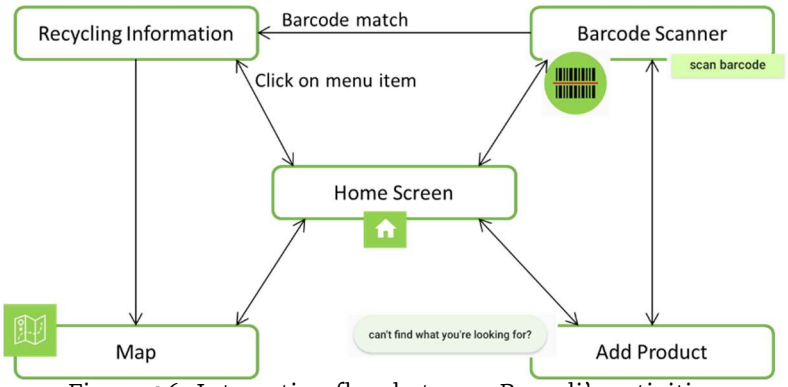


Figure 26: Interaction flow between Recycli's activities.

6.3.2 Cloud-Hosted Database

The implementation of a cloud-hosted database was achieved as Google's Firebase Realtime Database is a cloud-hosted database, further reasons for the adoption for this database are explained in chapter 3, Project Specification.

Connecting the application, the Firebase was seamless as the Android Studios have tools and guides regarding how to embed certain Google services into the application, this is done by adding dependencies to the Gradle scripts in the app/build.gradle. The dependencies needed to connect to the database were:

```
implementation 'com.google.firebase:firebase-database:19.2.1'
```

This dependency is used to connect to the Firebase Realtime Database where the data for the application is stored. This is necessary for retrieving and adding information to the database from the application.

```
implementation 'com.google.firebase:firebase-storage:19.1.1'
```

This dependency is used to connect to Firebase storage, this is where media content can be stored such as images, this will be discussed in the Adding Data section of this chapter.

```
implementation 'com.firebaseui:firebase-ui-database:6.2.1'
```

This dependency is used to connect the user interface to the database. This is necessary to show the retrieved information to the user as well as get the data input from the user through the app and adding it to the database.

Whenever the application reads (retrieves) and writes (adds) to the database a DatabareReference instance variable should be declared, and then access to a specific location can be called. In the context of the application, the information accessed is stored under the "item" child of the database.

This can be seen in two activities, the MainActivity.java when the user searches for a product using the search bar the query is searched within the "items" node of the database.

```
DataRef = FirebaseDatabase.getInstance().getReference().child("item");
```

The second activity this can be seen in is the AddItemActivity.java, when the user adds an item to the database, the data will be added to the "items_approval" node of the database.

```
dbRef = FirebaseDatabase.getInstance().getReference().child("item_approval");
```

6.3.3 Querying the Data Through the Search Bar

The feature to allow the user to search the database via the search bar was achieved. The functionality of this feature can be found in the MainActivity.java file and the interface is created within the activity_main.xml file.

The search bar is simple EditText field and the results will be shown in a RecyclerView. In order to use the RecyclerView and its functionalities, the following dependencies must be added to the app/build.gradle file.

```
implementation "androidx.recyclerview:recyclerview:1.1.0"
implementation "androidx.recyclerview:recyclerview-selection:1.1.0-rc01"
```

The results will show up in the recycler view when the afterTextChanged() method detects a string input into the text field, the loadData() will be called using the string.

When the database matches the query, the loadData() method uses the FirebareRecycler options object to build the matched items data with the ItemModel instance variable. Next the FirebaseRecyclerAdapter object is created that binds the query with the recycler view by displaying each items information in the ItemViewHolder. Finally, the RecyclerView, called resultView, is attached to the adapter and the results will be shown to the user.

6.3.4 Search the Database via Barcode Scanning

The feature to allow the user to search the database via barcode scanning was somewhat achieved in that the barcode scanner as it is able to detect and return the numbers on a given barcode, however despite many efforts the barcode scanner was unable to connect to the database and would not attempt to match the barcode to those in the database. It is able to match a barcode with a given barcode that is coded in. During the testing phase, we will test the usability of the barcode scanner using dummy data.

Google's Mobile Vision was intended to be used to implement the barcode scanner however this was difficult to implement within the time allocated for the this feature, thus the ZXing library was used instead. To use this library the dependency is added to the app level of the build.gradle file.

```
implementation 'com.journeyapps:zxing-android-embedded:3.4.0'
```

As the scanner uses the user's camera, the application will request camera permissions on first launch, this is added in the AndroidManifest.xml file

```
<uses-permission android:name="android.permission.CAMERA" />
```

The ScannerActivity.java class and the AddItemScannerActivity.java class is where the implementation for the barcode scanner is found.

To invoke the barcode scanner, an instance of the IntentIntegrator class is called, from here the barcode type can be set using .setDesiredBarcodeFormats(), for this application, the scanner will only be able to detect 1D barcodes. The scanner is then initiated using the .initiateScan() function.

When a barcode is detected the onActivityResult() method is called. In this method, the scanned barcode will be stored in the IntentResult object variable, called scanResult and will be shown in the TextView, of the UI. If the scan fails, the user will be redirected to the previous screen and a toast will indicate "Failed to find barcode" will appear.

6.3.5 Retrieve and Display the Recycling Information from the Database

The feature that retrieves and displays the recycling information from the database was achieved. This can be reached via the home screen, by clicking on one of the items shown in the RecyclerView below the search bar. This is done in the loadData() method in the MainActivity.java file, when the item is selected by the user, a new intent will be created that directs the user to the view that will display the selected items recycling information, the selected item is specified using the .putExtra() method where the item id, or "ItemKey" is passed on to RecycleActivity.java. In RecyclerActivity.java the elements of the activity_recycle.xml are established and the data from the database are set into the the variables from the ItemModel to be shown in the GUI. This happens in the onDataChange() method.

6.3.6 Allow User to Add Items to the Database

The feature that allows the user to add items to the database was achieved. If the database doesn't contain an item the user may have searched for, the user can recommend the item by filling out a short form. This is implemented in the MainActivity.java, when the user selects the "can't find what you're looking for button", the .setOnclickListener() function will be called to direct the user to the form.

The code that handles this is called AddItemActivity.java, and the activity_additem.xml, handles the user interface. The user will be asked the add the name, brand, weight, and barcode using a text field, the barcode can also be inserted using the barcode scanning feature. An image of the product will also be required.

This feature will require the user to allow access to their devices camera and internet, which have already been established at the conception of the database.

As the images of the product will be used by the moderators for supplementary evidence of the information provided, the image will require storage in the database so the in the app/build.gradle file, the firebase storage dependency is implemented.

```
implementation 'com.google.firebase:firebase-storage:19.1.1'
```

When the user adds the image to the database, the image will be added to the database storage named "item_approval_images". This takes place in the uploadImageToFirebare() method using the putFile() function. When an image is taken, the method dispatchTakenPictureIntent() will add the call the createImageFile() method to give the image file consisting of a unique id and time stamp. This unique id can be used to identify the image in the storage to the entry in the database.

When the user fills out all the information, they will simply select the check mark at the top-left corner of the interface and the information will be submitted to the "item_approval" node of the database.

6.3.7 Location of Nearest Recycling Centres

The feature that locates the user's current position to and their nearby recycling centres displayed on a map interface was somewhat achieved. The map is able to locate and show the users current location but getting the information to show nearby recycling centres only was not achieved. In testing the data will be hard coded in to give an idea of how the interface will look and how the user can interact with this information.

In order to get the users location, permission will be required.

```
<uses-permission android:name="android.permission.ACCESS_FINE_LOCATION" />
```

In order to use Google map services, the dependencies to use the map and location services are added to the app/build.gradle file.

```
implementation'com.google.android.gms:play-services-maps:17.0.0'
implementation 'com.google.android.gms:play-services-location:17.0.0'
```

The files responsible for the functionality of this feature is MapsActivity.java, and the file that depicts the GUI is called activity_maps.xml.

The activtity_maps.xml file consists of a title bar and a fragment of the map. The map is declared in the java file as mMap. The user's location is detected in the enableUserLocation() method by the setMyLocationEnabled() function.

When the map is loaded the onMapReady() method will set up the location pins for the nearest recycling centres and will show the name of the location when selected by the user. When the user selects a pin, they will also have the option of selecting button to open google maps to show them the directions to the selected pin. This is enabled using google maps UiSettings object.

7 Testing

To test the application, Usability Tests were used to gather data regarding the visual appeal of the product, the ease of use, and to find out if the application achieves the goals of providing quick and accessible recycling to the user to simplify the task of recycling.

7.1 Methodology

Five participants were recruited for this study: 4 females and 1 male, aged between 20 to 26. All of the participants own a smart phone in their every daily life to complete daily tasks, however none of them work or have experience in roles that require them to have an in depth understanding of technology or user-experience. As well as this, all of the participants live in cities around the UK and have experienced curb-side household recycling.

The usability test asked each participant to achieve the following tasks within the app:

- Task 1: Getting recycling information through the search bar tool.
- Task 2: Getting recycling information through the barcode scanning tool.
- Task 3: Adding something to the database.
- Task 4: Getting the directions to a recycling centre.

The participants were interviewed individually and to reduce any ordering affects, the order of the tasks asked were not given in any identical order. The questions this test aimed to answer were:

1 How easily and quickly can users navigate through the application to achieve the tasks?
2 How understandable is the recycling information page?
3 How does the user feel about the look of the app?
4 Would you use this application to help you recycle?
5 Would this application help you become more knowledgeable about recycling?

After briefly introducing the app to the participant they were asked to give their first impressions about the application. After this the participant was asked to say how they would navigate through the application to achieve each task using a screen recording of the task being performed. The recording was paused before each answer was given when the user chose an incorrect navigation, they were asked to expand on their choice and how it could be made clearer to them. The participant was also encouraged to use a think-aloud protocol during the test, to add to the qualitative data.

Question 1 was evaluated using Nielsen's Alertbox [27], the success rate of each participants ability to carry out each task was calculated. For successful completion of tasks with no errors the task was given a 100% rating, for tasks that were performed with some errors the task was given 50%, and for failed tasks were the participant was not able to achieve the desired outcome of a task, the

task was given a 0% success rating. The average success rate for all tasks completed by each user can be seen in Table 2.

Question 2 and 3 was evaluated by asking the user to rate the system against a Likert-Scale (1 to 5) as well as any comments given by the participant. For question 2, the higher the rating given out of 5 the more understandable to recycling information page is to the user. For question 3, the higher the rating given out of 5 the more appealing the visual aspect of the application is.

Due to the COVID-19 pandemic, testing could not be done in person, and was instead carried out through Skype. Each task was screen recorded and played for the user via screen share.

The optimum flow the tasks can be seen in the Figure 27.

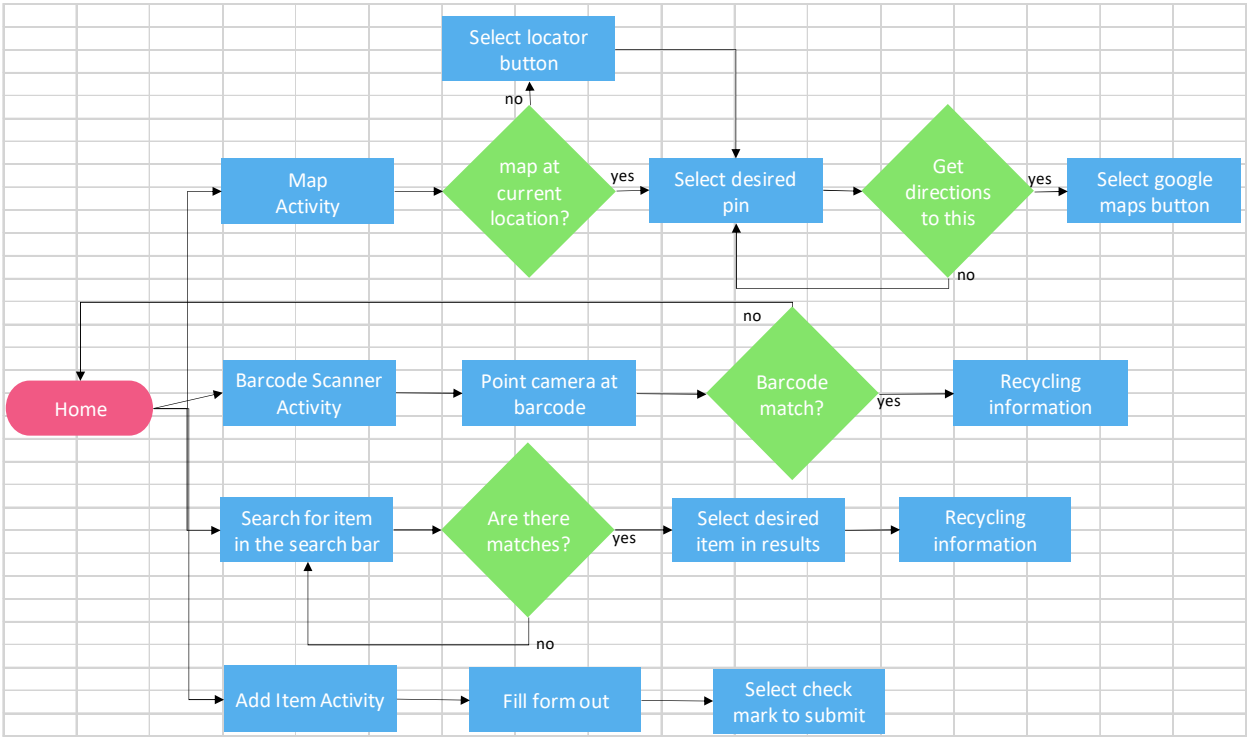


Figure 27: Optimum flow of tasks for testing.

During the interview, notes were taken, and the Skype call was recorded[3]. However, for two of the participants, the recordings did not seem to pick up their voice clearly, but because notes were taken during the interview, this will be used in the analysis of the results.

7.2 Findings

Using Nielsen's Alertbox, the success rate of each participants ability to carry out each task was calculated. This can be seen in Table 2 where each task is given either an S, P, or F score. S denotes successful completion of a task with 100% score, P denotes partial completion with a 50% score,

[3] See appendix A for the recorded interviews.

and F denotes a failed completion with a 0% score. The success rate was worked out by calculating the average of the tasks ratings.

Table 2: Success Rate of the Applications main features					
User	Task 1	Task 2	Task 3	Task 4	Success Rate (%)
U1	S	S	S	S	100
U2	S	P	S	S	87.5
U3	S	S	P	P	75
U4	S	S	S	P	87.5
U5	S	S	F	P	62.5

The results success rates were quite high although, a little lower than anticipated. Integrating this quantitative data and the comments made by the participant during the interview, two main issues were clear regarding the design of the application.

Firstly, for task 3, for users that had some or complete failure in finding the button to start the task, they commented that the wording on the button was unclear and could be improved by changing the sentence used. Those that were able to identify the button, they stated that it was because they had seen this used in a similar application, MyFitnessPal. This application and the particular feature were what inspired the wording of this button.

The second issue relates to task 4, whereby the two of the participants could not easily identify the map button as it looked to be part of the logo. A recommendation was made to fill out the map instead of using just the outline. Another improvement for the map feature was to add the opening times and contact details of the recycling centre, as it would let the user know before getting the directions if the site was open and if they needed to contact the centre for more details beforehand.

There was one comment made by one user regarding the barcode button, they initially thought it was just an image, however they also stated that upon first use of the application, they would experiment with the interface and that the button was identifiable after that.

When asked to rate the understandability of the recycling information provided, 100% of the users gave a rating of 5 on the Likert-Scale. All the participants comments stated the segregation of the components made sense and the information shown was clear. However, one person did comment that there should be a label to state that the images shown for the examples are just examples.

When asked to rate the visual appeal of the application, 100% of the users gave a rating of 5 on the Likert-Scale. The general comments regarding the look of the application was that it felt very simple, intuitive, had easy learnability, and produced what was needed.

A gamification feature was suggested by one of the participants as they said it would make them want to use the app more if they could collect points or streaks for each item they recycled. This

contrasts with comments that were made in the user survey, however in the survey it was only briefly described.

When asked if they would use the application to help them recycle, 100% of the participants said yes, and that it was a good idea and the information provided was useful. When asked if the application would help them learn about recycling, 80% of the participants said that it would help them learn more about the recycling of certain products as they would know how to recycle the product after using the app for another time, as well as learning about local recycling centres. But general recycling knowledge would not be gained from the app, one participant suggested to add a page that listed all the recycling and waste symbols found on food packaging.

Overall, the comments regarding the application were positive, with the feature being highlighted by the participants as making the search process simpler. Moreover, all participant said they felt it would be a useful recycling tool that fulfilled their needs for support in recycling.

8 Discussion

Using the factors identified by environmental psychology literature, this project aimed to develop an early iteration of a mobile application that supports and encourages users' recycling behaviours by providing the user with access to and clear information about how they can recycle their food products packaging.

8.1 Testing Results

The results from the usability test verify that the aims outlined in the introduction were achieved in that users felt the interface was intuitive and appealing, and the information provided was presented clearly and in line with their expectations. Furthermore, the users also stated that they would use the application as a support tool for recycling and the information about the different materials of a products packaging would be useful to know for the next time they need to recycle that product.

In the usability testing for a similar application, WasteApp, their Nielsen Alertbox rating resulted in an average of 79.2% (Figure 9), this is lower than Recycli's average success rating of 82.5%. However, each application has different features and tasks that were analysed in the usability test, but two features that are similar included getting the recycling information of an item, this is identified as T1 in WasteApp's usability test and Task 1 and Task 2 for Recycli, and locating the users nearest recycling locations, this is identified as T3 in WasteApp's usability test and Task 4 for Recycli's usability test.

The average success rate for getting the recycling information of an item for Recycli is 95%, whereas WasteApp scores an average of 75% for this task. Some of the comments given by the participants of WasteApp's usability study were that the barcode scanning button was difficult to

find, this can be seen in Figure 8, where the barcode scanning button is located on a secondary screen and is quite small. Whereas on Recycli's interface, the barcode scanning button is located on the home page, and takes up about 30% of the page, as can be seen in Figure 21.

The average success rate to locate nearest recycling locations for Recycli is 80%, whereas the WasteApp scored an average of 41.2%. The comments given by the WasteApp participants stated that the icons on the map were too small when identifying what kind of waste a bin took. This feature is difficult to compare as the Recycli locates nearest recycling centres to the user which are far apart, and WasteApp locates bins in the streets of Turin, which are closer. Therefore, Recycli has the advantage of distance to display each recycling centres location clearly. WasteApp could benefit from utilising a filtering feature to allow the user to select what kind of bin they would want to see.

There are some desirable features implemented in WasteApp that could be implemented into Recycli such as a notification feature for bin collection days.

8.2 Feature Achievements

The overall outcome of the project was successful in that all of the primary features were implemented fully or were implemented with a good basis to be developed further.

The user is able to search for products in the database via the search bar and when selected from the menu, the data in the database is retrieved to show in the recycling information page. Furthermore, users are also able to add products to be moderated before addition, when the user submits an item, the database updates in real time.

Furthermore, the barcode scanning feature is able to identify a barcode and retrieve the information to the interface, however it is currently only able to match a given barcode in the code and not the database. The time allocated for this feature was lost due to difficulties when trying to implement it using the Mobile Vision API, thus ZXing library was used, however it is unable to connect to the database.

Another feature that was partially implemented is the location of the users nearest recycling centre. This feature is able to identify the user's current position, however, only recycling centres in the Swansea area are able to be located

8.3 Limitations

Information regarding the recycling of packaging is limited due to the fact that it is not required by law to display the recycling information of a product on its packaging, thus there is no database that Recycli can utilise. This is why crowdsourcing and moderating is used to build the database for this app, however this limits the application as the database is sparse and can only grow with user input.

Furthermore, if the application becomes more popular and more users input product recommendations, more moderators will be needed and a better system of moderating will have to be implemented as currently, the moderation is done by looking at the database itself which can be confusing.

Another scalability issue is that the application only displays the recycling centres in the Swansea area, thus this specific feature is limited by location.

8.4 Future Works

The application has the potential to be developed further and reach the aims of the project, first by implementing the requirements that were not fully implemented such as connecting the barcode scanner to the Firebase Database and expanding the locations of recycling centres across all regions.

The barcode scanning feature could be improved by spending more time looking at Mobile Vision to get it correctly implemented.

The application could be improved further using the feedback given by the participants of the usability test. Such as displaying information about recycling centres and a guide that provides the information about different recycling symbols, or even using image recognition to identify recycling symbols.

Another feature that could enhance the user's knowledge of their local recycling infrastructure is to allow the user to set a notification for bin collection days.

An interface for the moderators could also be implemented to present the data clearer for verification of suggested items.

Furthermore, further long-term field testing could be done to find out how successful and supportive the application is in daily use. Moreover, a beta version of the application could be deployed amongst several users in a field test to identify any bugs or improvements for the application, as well as, an early deployment amongst limited users will help the expansion of the database.

8.5 Project Management

At the start of the project a Gantt chart[4] and risk analysis table was created for better organisation throughout the development of the project whilst maintaining other university obligations. The progress of the application aligned mostly with the Gantt chart predictions, however due to the

[4] See appendix B

COVID-19 pandemic that started in March that put most parts of the world under lockdown, there were some interruptions to the schedule and alterations that needed to be made for the project.

Firstly, because no one was allowed to leave their house for unnecessary reasons, this had a significant effect on productivity levels. Furthermore, some deadlines for coursework's were pushed back, therefore time that was planned to be used for dissertation writing were also occupied with working with these deadlines. However, because sections of this dissertation were written throughout the development of this project it was easy to adjust the schedule.

The testing phase of the application was impacted the most by the lockdown. As the initial plan was to carry out usability tests in person with fellow students, instead digital resources were used which took less time to carry out which was ideal due to time constraints, however there because there the tests weren't carried out in person it was difficult to gage the participants reactions over Skype as they were not able to see the application in person.

9 Conclusion

This thesis explained the motivations and implementation of a mobile application to support and encourage recycling behaviours amongst individuals by clearly presenting the information about what the materials a food products packaging is made up of, easy searching of this information on the application, and the locale of nearby recycling centres. The qualitative data provided through usability testing suggests that the outcome of the application was successful in providing knowledge about recycling and knowledge of one's local recycling infrastructure, both of which are recommended factors to consider when attempting to influence pro-environmental behaviours. The application provides a solid foundation to be built upon for further development and implementation.

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Appendix

A Recordings of Usability Testing

Test 1: https://youtu.be/dh4rwifDTZs

Test 2: https://youtu.be/Edzjw4X_hfM

Test 3: https://youtu.be/oL3-rZAHKfY

B Gantt Chart

https://1drv.ms/x/s!AqVxnfFSQ0LChIcbqMaDrK4J-Zy5Og?e=yn10TL