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Digital Receipt System

Paperless proof-of-purchase solution

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Abstract
The continued production and use of paper receipts is to not only wasteful in both terms of squandered resources used in their production, but also the waste that results in their disposal as the vast majority of customers dispose of them immediately. Unknown to many is also the potentially harmful health effects to both the customers and especially retailers as a result of exposure to chemicals contained in paper receipts. Research shows while people were initially reluctant, once informed of the potential health risks involved with coming into contact with paper receipts, the majority were willing to consider using a digital receipt system. If the results of the research in this project are substantially extrapolated, it shows that there could be a massive reduction in the resources consumed and the waste produced from the use of paper receipts.

Keywords
Receipt, digital, paperless, waste, environment, Android

1. Introduction

Human society produces too much waste. The world generates at least 3.5 million tons of solid waste a day, 10 times the amount a century ago. If nothing is done, researchers estimate that figure will grow to 11 million tons by the end of the century (1). One substantial contribution to this is paper receipts, considered by many to be an unnecessary nuisance, if not a relic of a bygone age. The paper receipt, while may seeming to be an innocuous annoyance, presents and significant drain on resources and may pose a significant health risks to customers and retail staff alike.

This project aims develop a system that digitalizes the use of receipts in retail environments. This system will provide the customer with a mobile application that stores receipts in a remote database that a retailer can access by scanning a QR code generated by the customer. In this prototype the receipt for the purchase is generated by the retailer and sent directly to the customer's database using a program created in JavaFX. This system or one like it could be implemented on a large scale and significantly reduce resource consumption used to generate paper receipts.

Background

Receipts for the sale of goods and services are an essential part of commerce. They contain information including the date of supply, details on the product or service, the price, any taxes applied and the method of payment, and are a legal requirement for businesses to provide in several countries. Swedish law (Law 2007: 592, Section 9) states specifically:

At each sale, a receipt made by the cash register shall be produced and offered to the customer.

However, in every day life neglible thought is generally given to the volume, production and disposal of paper receipts. Research indicates that around 80% if the US populace (261 million people) is given one to three paper receipts per day, 11% of which are disposed of at the point of sale (2). As a result, over 3 million trees and 34 billion litres of water are consumed each year in the creation of paper receipts, generating 137 billion kilograms of solid waste and 1.81 billion kilograms of carbon dioxide. Paper products fill over one quarter of all solid waste in landfills, including receipts (3).

Additionally, an estimated 93% of paper receipts are coated with Bisphenol S (BPS) and Bisphenol A (BPA), the same chemical banned from plastic bottles, and should not be recycled. Heavy exposure to BPA, which is absorbed into the body through the skin, is particularly concerning as the chemical interacts with estrogen and thyroid hormone receptors, causing a cascade of biological effects. Even low doses of BPA have been found to impact fetal development and may contribute to reproductive impairment, ADHD, autism, obesity, and type-2 diabetes (4)(5)(6).

The goal of the project is to assist industry and customers to adopt a less wasteful and more environmentally friendly proof-of-purchase option in the form of a digital receipt system.

Aim and Purpose

Research Questions

Our research has shown that the production, use and disposal of paper receipts not only consumes a vast amount of resources, but can be a potential health hazard. Yet, whether this is generally considered or even known to the general population remains undetermined. Before considering whether a digital receipt system could be considered an alternative, this must be examined.

As such, the ultimate question proposed in this project is:

If made aware of the environmental consequences and potential health risks, would people be prepared to adopt a digital receipt system?

Following from this, other research questions can be potentially asked from the extrapolated data, namely:

What volume of resources could be potentially saved by using a solely digital receipt system?

Limitations

As stated, the digital receipt system consists of two parts: the retailer's program and a mobile application for the customer. If the customer does not have a smart phone or if they do not use applications from the marketplace, they will not be able to use the system. Additionally, for this level of development, the customer's application will only be available for devices running Android operating systems.

This project will primarily be focused on a retail environment, meaning other paper-based proof-of-transactions such as within the banking sector, will not be considered in this project.

We understand that most retail environments use a proprietary or off-the-shelf sales processing system that automatically prints a receipt after each purchase. Each company may have their own requirements for information contained in a receipt, but for the purposes of producing a working model of a digital receipt system, we have used JavaFX for the retail end of the system and Android Studio to create a mobile application for customers.

2. Method

Literature Review

The literature review for this project generally consisted of two distinct parts: research regarding the paper receipts and research concerning the adoption rates of digitalization of previously analog technologies.

Articles regarding research on paper receipts is concentrated primarily on the resource consumption and environmental consequences of production and disposal. As stated, research shows that in the US alone, over 3 million trees and 34 billion litres of water are

consumed each year in the production of paper receipts, generating 137 billion kilograms of solid waste and 1.81 billion kilograms of carbon dioxide. Paper products fill over one quarter of all solid waste in landfills, including receipts (3). More academic research still focused especially on the chemical compounds Bisphenol S (BPS) and Bisphenol A (BPA) uses to coat thermal receipts and the potential health hazards they present. (4)(5)(6).

Articles concerning the adoption rates of digitalization suggest that populaces have been generally increasingly ready to embrace the advent of new technology over time, especially in the replacement of analog technologies with digital systems. This is especially true for Organization for Economic Cooperation and Development (OECD) countries (7). Although this isn't without some reservations mainly concerning privacy and corporate transparency (8), experts forecast this appetite for digital replacing analog systems will only increase in the future (9).

Case Study

Our proposed application has two parts: the customer mobile application and the retail program.

The mobile application created in Android Studio serves as both the interface for the customer to access their receipt database and for the retail program to identify the user's account and send the customer's receipts to the correct database. The is achieved through the application creating a unique QR code when an account is created which serves as a key to the customer's database.

When a customer makes a purchase and requests a digital receipt, the retail program created in JavaFX generates a PDF receipt. The customer's unique QR code is scanned by the retailer, which identifies the customer's account, and the receipt is sent the customer's database.

Using this system, no paper receipt is produced, thus eliminating the use of resources and any potential waste products, while still adhering the retailer's legal requirement to produce and offer a receipt. Additionally, neither the retailer nor the customer comes into contact with any product containing BPS or BPA.

Interviews and Surveys

Initially, a simple survey was conducted in a retail environment in which a paper receipt was automatically generated for every purchase made in which the number of customers who accepted versus the number of who declined their paper receipt was tallied. A total of 100 customers were surveyed.

Second survey was conducted in three parts. In each case, twenty people were asked:

1. 'Would you consider using a mobile app-based digital receipt system that replaced paper receipts?'
2. 'Are you aware that 93% of printed receipts contain chemicals that may contribute to reproductive impairment, ADHD, autism, obesity, and type-2 diabetes?'
3. 'Knowing this, would you consider using a mobile app-based digital receipt system that replaced paper receipts?'.

Working Process

Regarding to our project and the four key principles of 'eXtreme Programming (XP)':

Simplicity

Trying to keep our application simple has proved a challenge. In the planning stages of development, and even when coding is well underway, it is an almost irresistible to temptation to add a new feature or new component to the design. In order to maintain a healthy velocity, we set aside these suggestions as later priorities to be done once the main functionality of the two applications have been completed and successfully tested.

Communication

The interaction within the group has been generally very good, with frequent in-person meetings as well as online meetings, chat and document exchange using Discord. One particular aspect of communication that all members of the group were particularly sensitive to in this project was honesty. This is primarily due to each member of the group having worked with people in the past that were less than honest in stating where they were regarding their responsibilities, in some cases severely undermining the project. In this regard we have strived to be as honest as possible and this has promoted a sense of real trust between team members.

Feedback

This aspect of the project proved to be a challenge as the opportunities for feedback were limited to short sessions with different 'customers' once per week rather than the 'tight coupling' as advocated in XP. As such, it was frequently difficult to know whether we were on the right footing in design and development.

Courage

We were forced to change directions in our development after our initial planning stage was completed and programming had begun. The initial plan was to have the retail program provide a QR code containing the receipt for the customer to scan and store into their database. This had to be refactored primarily due our unfamiliarity with QR codes and the limitations on the amount to information they can provide. While an advanced QR code can provide the necessary amount of data for a receipt in PDF format to be generated, the complexity of the QR code would be increased significantly (this is expanded upon further in the Discussion section). Thus, we reserved the transaction so that the retailers scan a QR code provided by the consumer to allow the retailer to send the receipt directly to the consumer's database.

Regarding the use of story cards, these proved to be useful in the initial planning phase when calculating how much work each aspect of the project plan would take, or the group's 'velocity'.

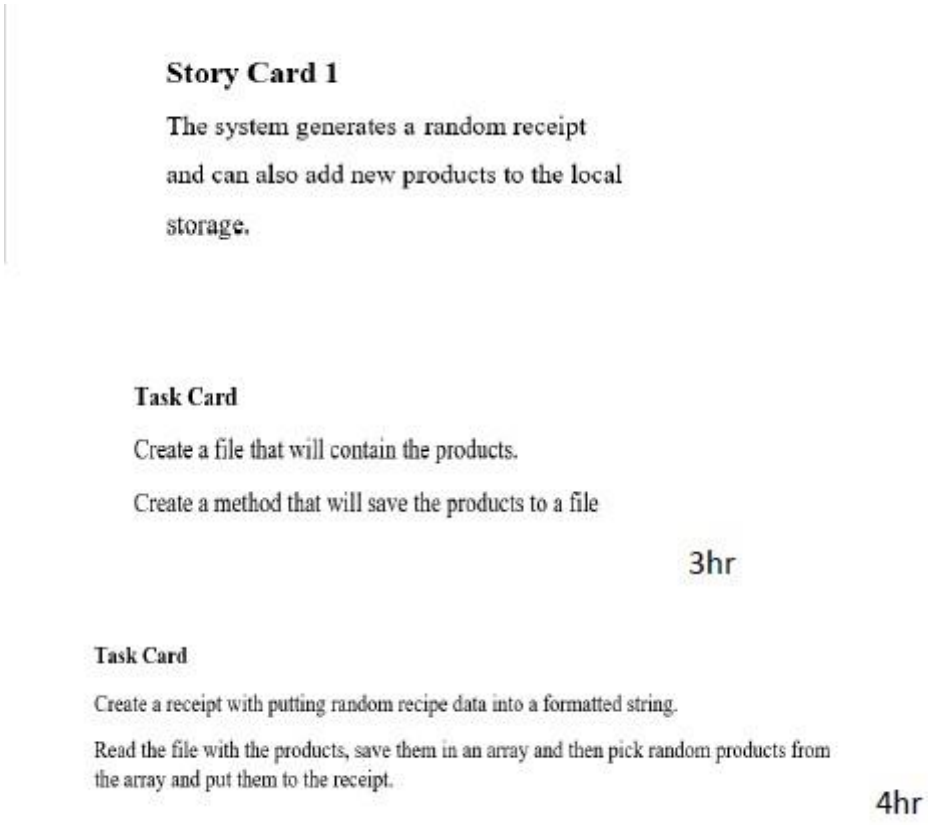

Figure 1: A sample of story cards and task cards for Iteration 1.

Links to GitHub:

- Digital Receipt System JavaFX:
  - https://github.com/matzab/ReceiptGeneratorApp
- Digital Receipt System Android app:
  - https://github.com/matzab/DigitalReceiptApp

Velocity

Table 1. Velocity

Velocity	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Average Velocity	
Student 1	0.79	0.71	0.83	0.78	0.71	0.76	
Student 2	1.00	1.25	0.75	0.86	0.75	0.92	
Student 3	1.00	1.00	1.00	1.20	1.20	1.08	
Student 4	0.79	0.95	0.91	0.72	0.71	0.82	
Total Velocity	0.88	0.94	0.87	0.85	0.84	0.90	*(Average team velocity here)*

3. Results

The academic research conducted as part of this project clearly shows that the production of paper receipts consumes a significant amount of resources, the vast majority of which cannot be recycled due the chemicals contained therein (3)(4)(5)(6). Additionally, studies indicate these chemicals may be harmful to human health even at low exposures (4)(5)(6).

The initial survey conducted showed that the vast majority of these resources are wasted, with the preponderance of paper receipts being discarded immediately. Out of 100 customers:

- 18 kept their receipt
- 11 took their receipt when offered but discarded it in the nearest bin, and
- 71 did not take their receipt when offered.

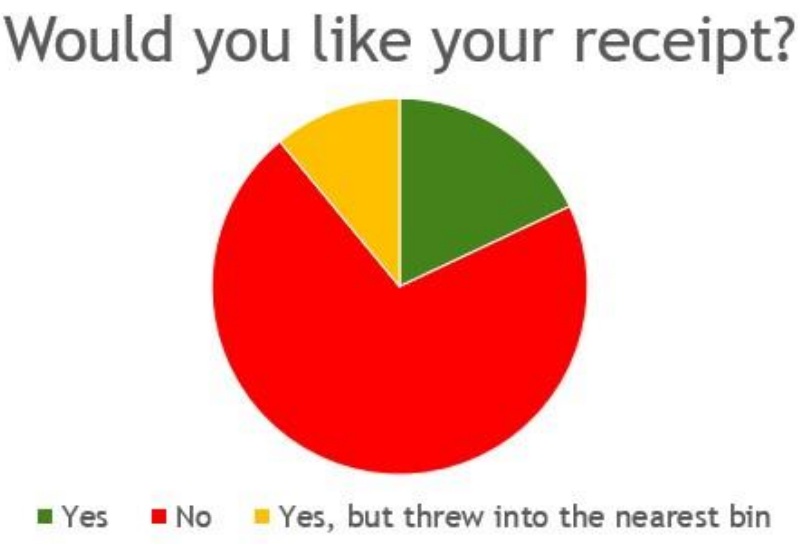

Figure 2: Results of a survey of 100 people when making a retail purchase.

This led to the development of our research question, namely concerning if people would be prepared to use a digital alternative to paper receipts. The second survey was conducted in three parts. In each case, twenty people were asked:

'Would you consider using a mobile app-based digital receipt system that replaced paper receipts?', to which 35% responded positively, 65% negatively.

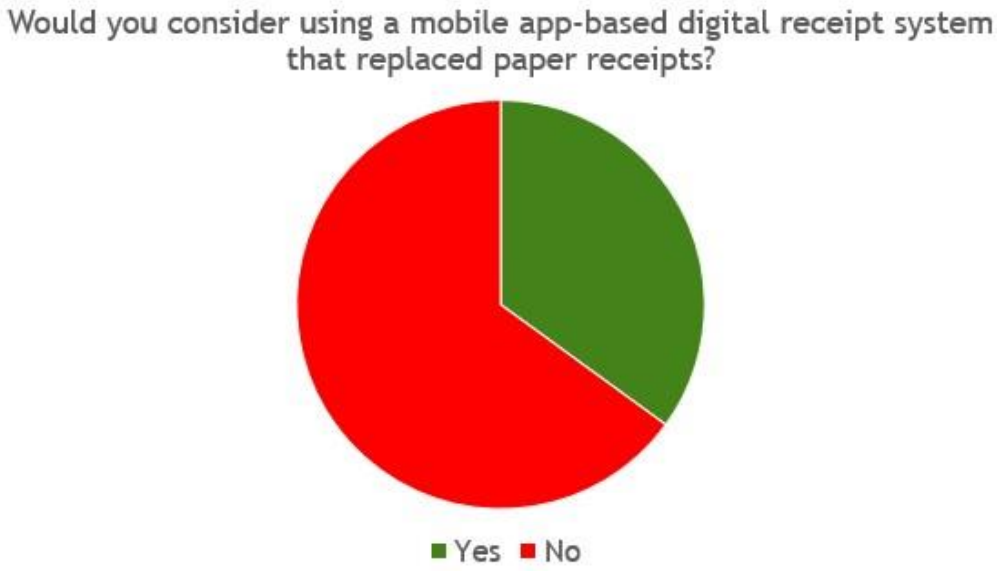

Figure 3: Results of a survey of 20 people regarding the use of a digital receipt system.

'Are you aware that 93% of printed receipts contain chemicals that may contribute to reproductive impairment, ADHD, autism, obesity, and type-2 diabetes?', to which 15% responded positively, 85% negatively.

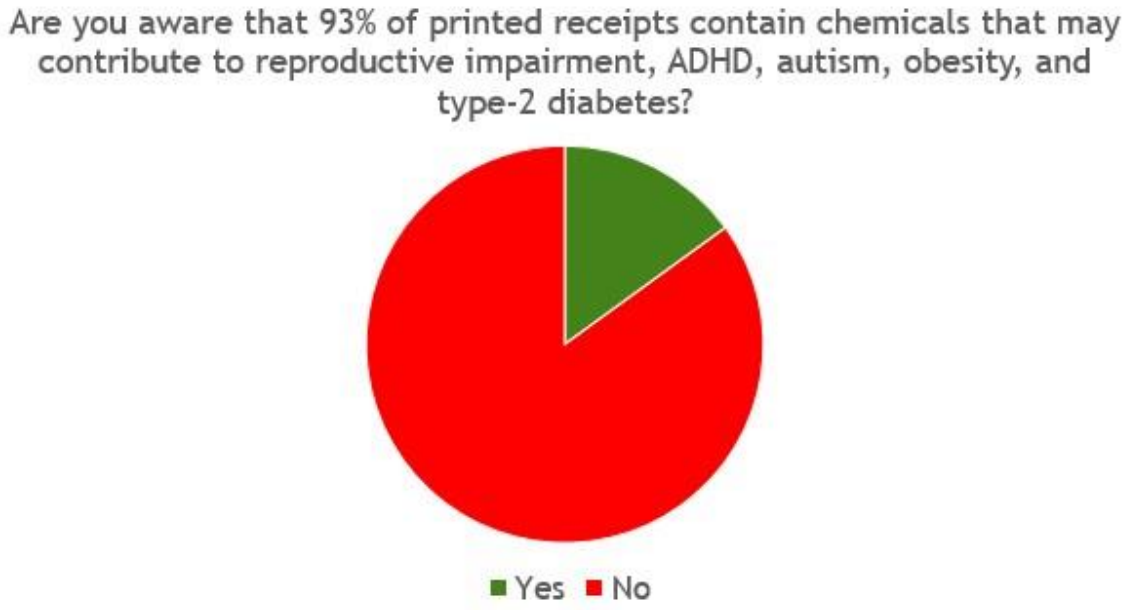

Figure 4: Results of a survey of 20 people regarding the awareness of the use in potentially harmful chemicals in paper receipts.

'Knowing this, would you consider using a mobile app-based digital receipt system that replaced paper receipts?', to which 75% responded positively, 25% negatively.

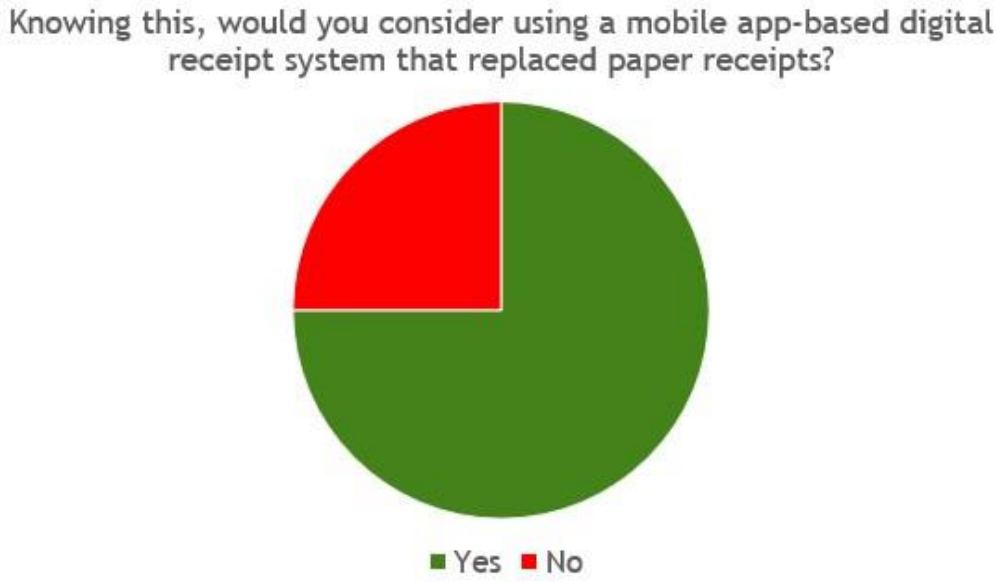

Figure 5: Results of a survey of 20 people regarding the use of a digital receipt system having been given additional information.

To this end, our project provides a solution to this needless waste of resources by providing that alternative.

The digital receipt system consists of two parts: an application created in Android Studio for customers and a program created in JavaFX for retailers:

- The application created in Android Studio provides an interface that allows customers to:
    - create an account
    - login to an existing account
    - create a one-time QR code that provides a link to their receipt database, and
    - view and download receipts from the database
- The program created in JavaFX provides an interface that allows retailers to:
    - create a receipt in PDF format containing the particulars of the purchase as required by law
    - scan the QR code provided by the customer, and
    - send the receipt directly to the customer's database once the login details are scanned.

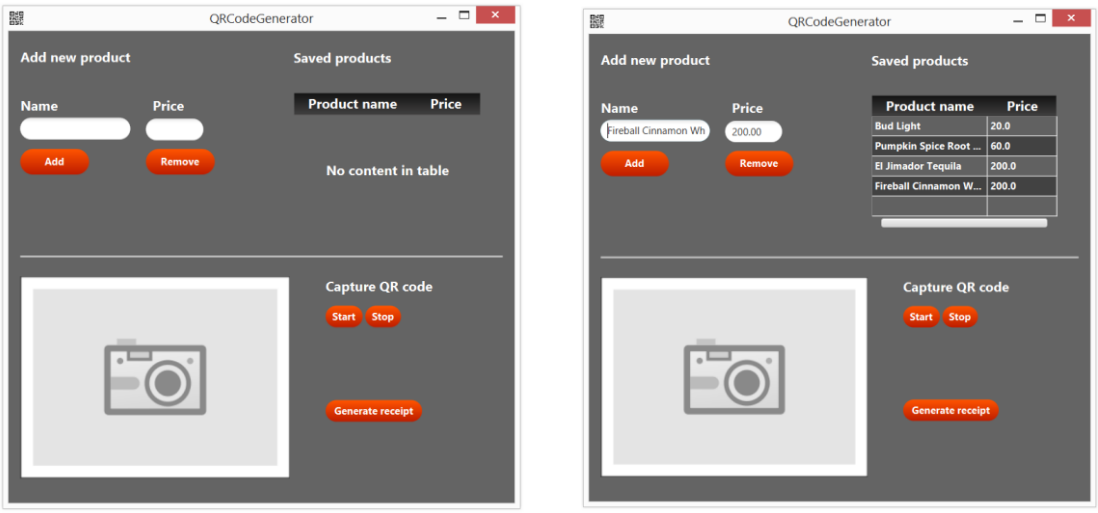

Figure 6: Example of the receipt generator application built in JavaFX

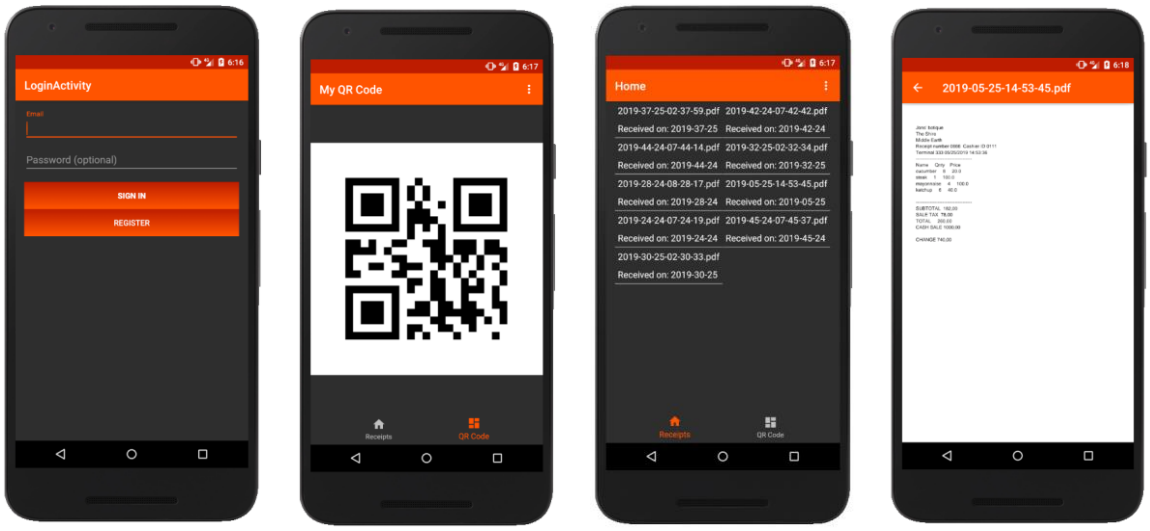

Figure 7: Examples of the Android application showing the login screen, the user QR code, the customers stored receipts and an example of a receipt.

Regarding the second research question concerning the amount of resources that could possibly be saved, some substantial extrapolation of the collected data is required. From the academic research, in the US alone 3 million trees and 34 billion litres of water are consumed each year in the creation of paper receipts, generating 137 billion kilograms of solid waste and 1.81 billion kilograms of carbon dioxide (3). If the data from the second survey indicating that 75% or respondents would be prepared to use a digital receipt system is extrapolated, this could mean, in the US alone, a potential annual saving of:

- 2.25 million trees
- 25.5 billion litres of water
- 103 billion kilograms of solid waste, and
- 1.36 billion kilograms of carbon dioxide.

These figures are only the result of substantially extrapolated numbers from a small survey. They do, however, highlight the potential that exists for the reduction of resource consumption and waste production that exists as a result from digitizing the proof-of-purchase system.

4. Social and Ethical Aspects

The reduction of resources consumed and waste produced as a potential result of the implementation of the system this project suggests is beneficial to the environment. If the system is implemented on a large scale, the positive impacts on the environment could be substantial. Even if the digital receipt system were used by only 10% of the population worldwide, the reduction in resources consumer and waste produced would still be considerable.

As mentioned, the vast majority of paper receipts contain BPS and BPA, which has many adverse effects on human health. If digital receipts could replace paper receipts, it would greatly help to reduce the interaction between BPA and humans, especially workers at cashiers who come into contact with these chemical in every single transaction.

There may also be negative aspects of a digital receipt system that must be taken into account. One example would be the elderly who may have issues in adapting with new technology. Another could be the potential loss of jobs that may result of the reduction of paper processing and printing industries if the system were adopted in a wide scale.

5. Discussion

The idea for this project was developed in a brainstorming session in the HKR cafeteria. The group watched as, over and over again, receipts automatically printed from each purchase was refused by the customer and disposed of immediately. This was the seed of the idea for some alternative digital proof-of-purchase system.

In regards to academic research, there is a plethora of information regarding pollution and the amount of waste human society generates. However, when it came to specific figures, these tended to vary wildly between sources where these were sourced independently. Many more articles tended to all draw from the same source (1) when quoting specific numbers. When dealing with the specific issues of paper receipts and the volumes of resourced consumed and waste produced, these proved extremely hard to find, especially figures that could be verified. However, academic research regarding the use of BPS and BPA in paper receipts was comparatively easy to find.

The idea from its inception was for a digital receipt system that would have to consist of separate components for retailers and customers. As mentioned previously, this concept was initially for the retailer to make the customers receipt available via a QR code which the customer scans with using an application made in Android studio, downloading the receipt into the database. Our research on the use of QR raised the question of how much information QR codes can carry and whether this would be sufficient to send a receipt containing all the details required by law and in a user-friendly format. This research showed that a QR code can hold up to 1,264 characters of ASCII text in its most complex form (10). However, the complexity of this form makes it unsuitable for most consumer-grade mobile phone camera capabilities used for QR scanners, as shown in Figure 2. This was given particular regard considering the implications this slow-down of process could

have in a busy retail environment, not to mention on peoples' patience when standing in a queue behind someone struggling to scan a complex QR code.

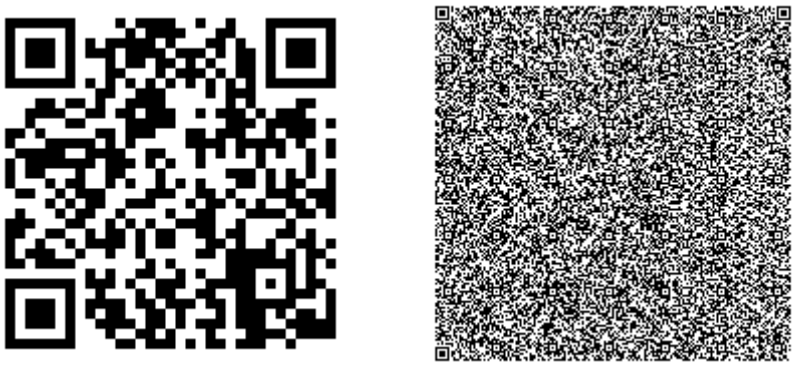

Figure 8: The most commonly used QR code Version 4 (33×33) containing up to 50 characters of ASCII (left) compared with the most advanced QR code Version 40 (177×177) containing up to 1,264 characters of ASCII text (right).

This resulted in a refactoring of the application. In the second iteration of the implementation we reversed the interface so that the customer presents QR code in the commonly used Version 4 format containing a link to the customer's receipt database. The retailer scans this one-time generated code and the receipt is sent directly to the consumer.

A challenge encountered in implementation of the application in Android studio was the use of Dalvik Executable (DEX) files working in conjunction with minSdkVersion 15. Android application (APK) files contain executable bytecode files in the form of DEX files which contain the compiled code used to run the application. The DEX specification limits the total number of methods that can be referenced within a single DEX file to 65,536. Android 5.0 (API level 21) and higher uses a runtime called ART which natively supports loading multiple DEX files from APK files. Therefore, if the minSdkVersion (the lower bound for the application) is 21 or higher, the MultiDex support library is not required. Since the project application uses minSdkVersion 15, the MultiDex support library had to be imported in order for the application to work.

Another challenge was the implementation the Firebase Databae into the JavaFX system. This required the implementation of a build automation tool for declaring the Java FX project configuration. Gradle was attempted initially but this did not work for reasons that could not be absolutely fathomed. Speculation was that this was either due to the including path to the source directory not being configured correctly, or because Gradle uses a Groovy-based domain-specific language instead of the XML used by Apache Maven, which was implemented successfully.

One unexpected challenge encountered came in the use of number variables in JavaFX, namely that variables such a doubles do not round fractions of numbers in the expected way. While this may go unnoticed the sense of losing fractions of whatever currency is applied in smaller transactions, the ramifications on larger purchases or when considered over a large time scale, the consequences or not rectifying this by using a different variable such as a float, could be substantial.

As mentioned previously, there were some aspects of working in XP that the group found challenging, in particular the key aspect of XP that involves working closely with the customer. Having project meetings once per week with different 'customers', it was difficult to receive and make use of feedback – an essential part of XP development. Perhaps this can be viewed as one of the limitations of XP in that it is not ideally suited to situations where the customer and the developer are not in frequent contact.

6. Conclusion

The continued production and use of paper receipts has been shown to not only be wasteful in both terms of squandered resources and the waste that results in their disposal, but also potentially harmful to the health of retailer and customers alike. Research shows while people were initially reluctant, once informed of the potential health risks involved with coming into contact with paper receipts, the majority were willing to consider using a digital receipt system. If the results of the research in this project are substantially extrapolated, it shows that there could be a massive reduction in the resources consumed and the waste produced in the use of paper receipts.

7. Suggestions for Further Work

As mentioned, information regarding the volumes of paper receipt used worldwide was difficult to find. Further research regarding this may be useful in the context of the report, whether it be more intensive academic research or finding information outside the academic sphere, such as seeking data from paper receipt manufacturers or distributors.

On improving the application specifically, it is difficult to suggest improvements for the retail side of the application as it is a model built in JavaFX solely to demonstrate the functionality of the mobile application. As mentioned previously, retailers typically have their own proprietary or off-the-shelf sales processing software and this functionality would have to be implemented as part of or in addition to this. As the mobile application is our own proprietary application, there is potential for substantial further development:

- Currently the application uses the free version of Firebase database which does not update in real-time. In a release-iteration of the application were developed, real-time database updates would be essential
- Currently there is no security measures beyond customer log-in with password. In release-iterations, further security features would need to be implemented
- Encryption of customer data
- Sorting of receipts in the customer's database either by retailer name or timestamp
- Development on other platforms, such as iOS

8. References

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References used in application development

https://firebase.google.com/docs/firestore/

https://firebase.google.com/docs/storage/

https://docs.gradle.org/current/userguide/

9. Appendix

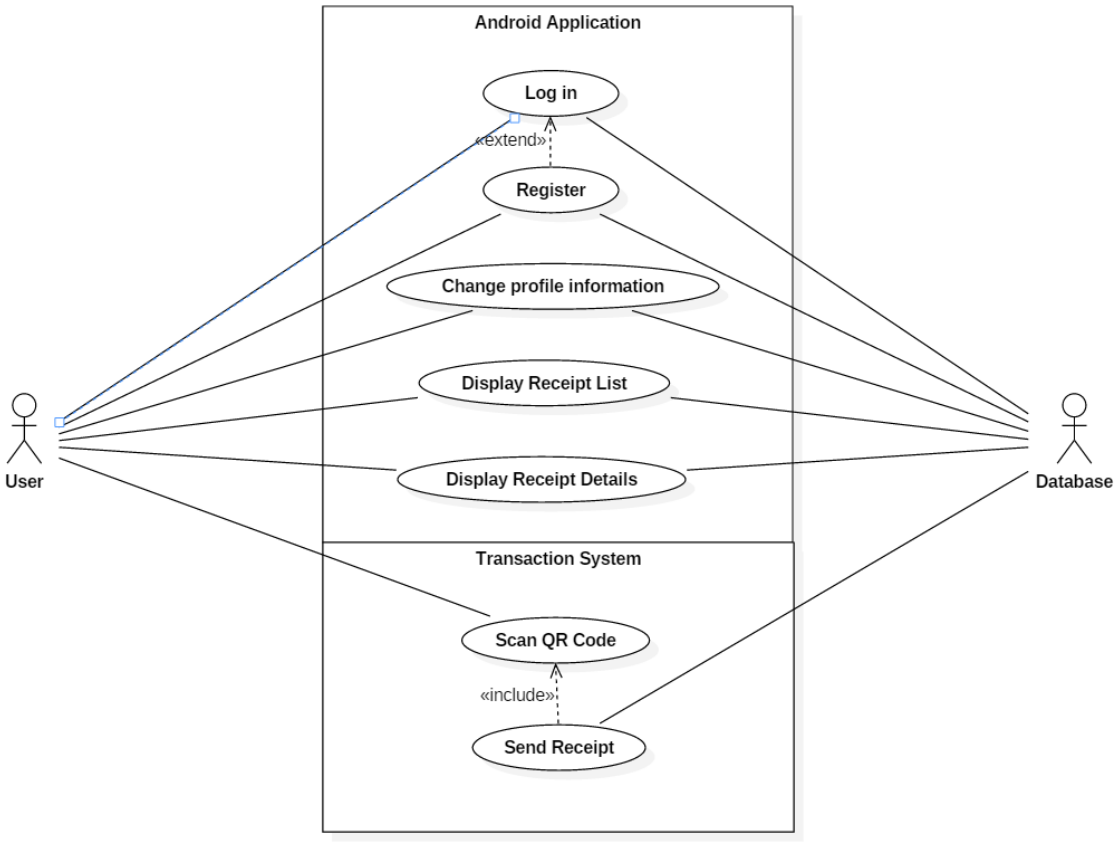

Figure 9: Use case diagram for the Digital Receipt System

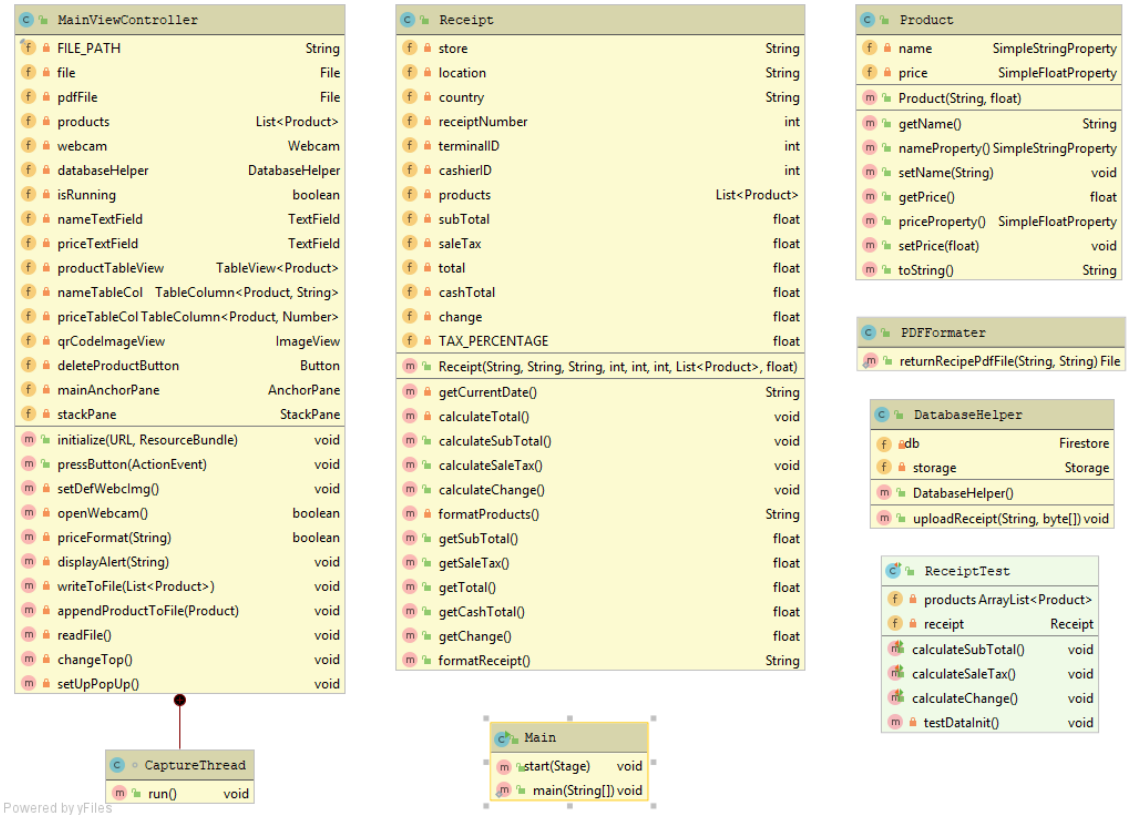

Figure 10: Classes for the retail-end receipt generator built in JavaFX

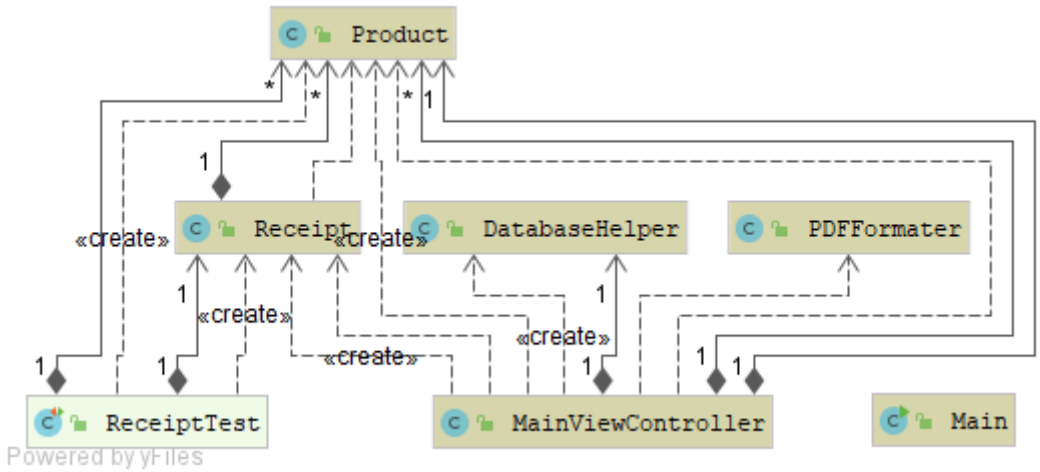

Figure 11: Condensed class diagram showing dependencies for the retail-end receipt generator built in JavaFX

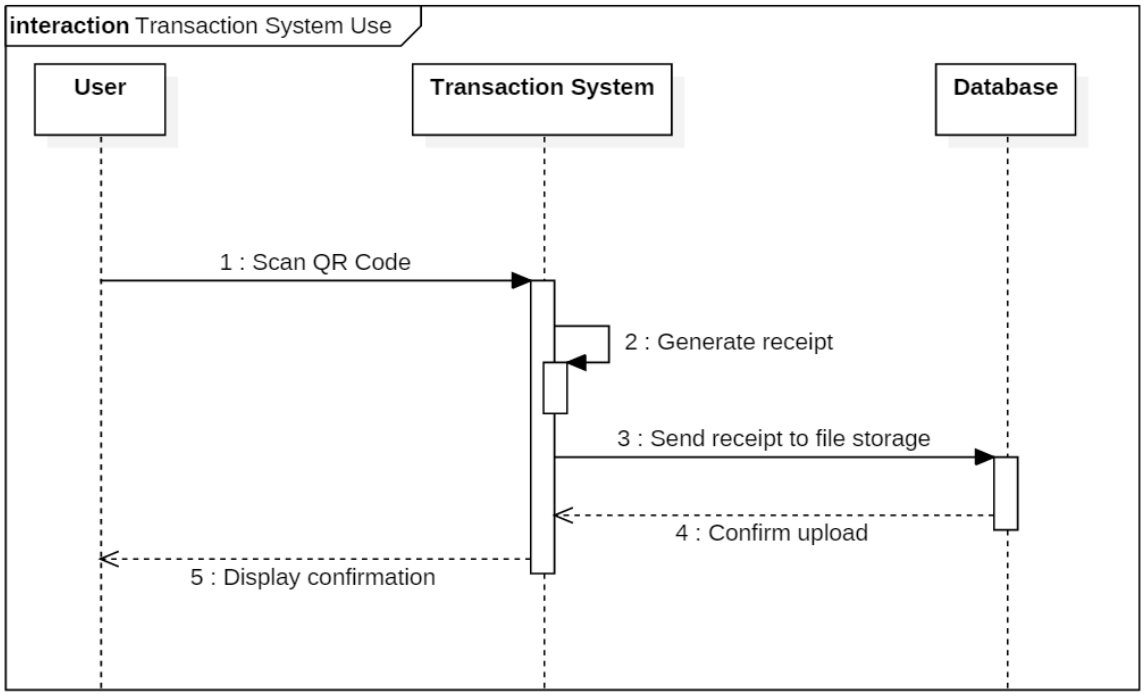

Figure 12: Sequence diagram for use of the application

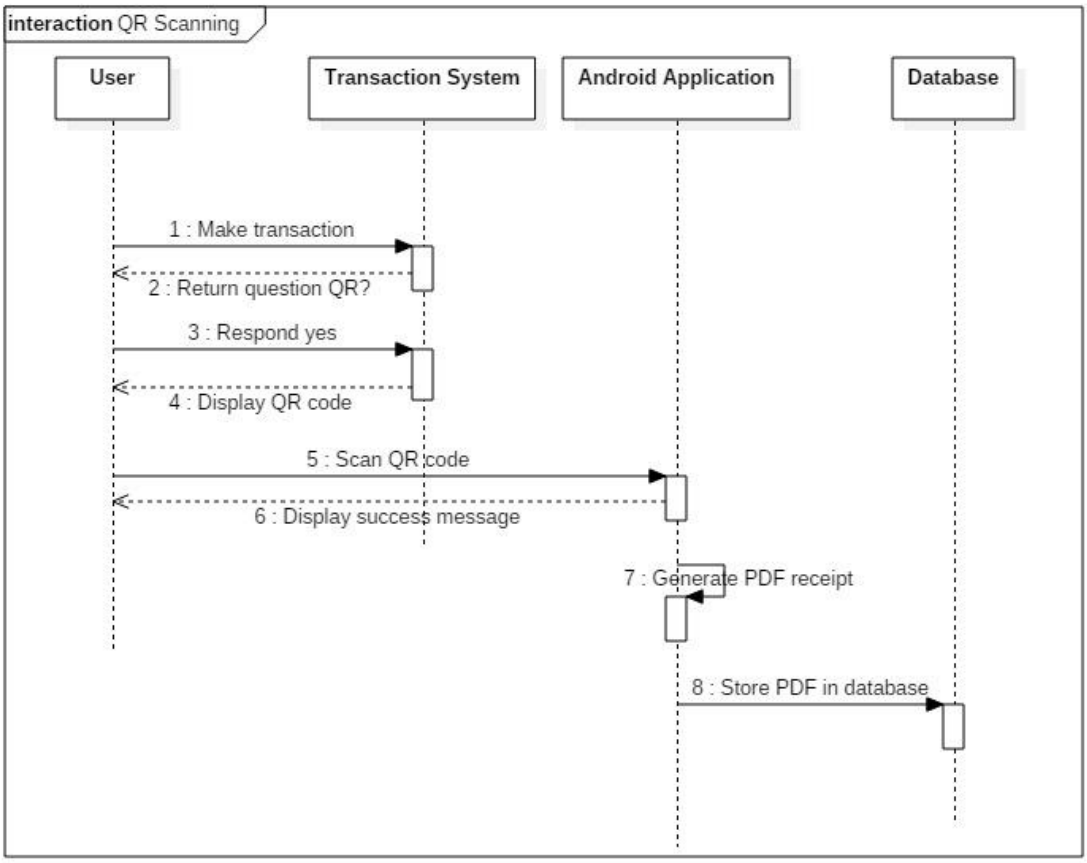

Figure 13: Sequence diagram for QR code scanning