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Data Transmission Using RFID System on Smart Shopping Carts for Checkout Process Efficiency in Supermarket at Indonesia

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Abstract

A lengthy queue upon entering the checkout process in supermarkets is an undesired situation for the customers and can possibly cause the number of customers to decrease as well as their loyalties. Therefore, rendering the checkout process efficient is necessary as saving time can help the customers to do other activities in their lives. The purpose of this research is to create a System that consists of Smart Shopping Carts, a smartphone application as an interface, an application for the cashier integrated with the server and database to support data transmission, that enables people to do self-scanning of items and the cashier only has to perform payment. This System is developed using the Waterfall methodology and involves tools such as Arduino Uno, RFID, Visual Studio Code, Flutter, PostgreSQL, REST, React dan Node.js. By simulating the process with various variables from observation, the result is efficiency that grows with increasing number of items and customers.

Keywords: Smart Shopping Cart, RFID, Supermarket

1. Introduction

Through the years, the improvement of technology that we could find in Indonesia's Supermarket is remain the same. There are still more rooms for improvement in the supermarket business. In order to acquire our data, we conduct 2 observations in Ranch Market and Food Hall, located in Grand Indonesia. Within 3 months period, starting from November 2019 - January 2020. We usually observed during the lunch break (11.00 - 13.00) and after office hour (17.30 - 18.30).

Based on our observations within almost 3 months, these are several points needs to be highlighted: most of the customers are using carts during the shopping and there are always queues in the cashier range between 3-10 customers in line. In addition to that, the time consumed are vary between 5 - 25 minutes until the customers completed the

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transaction. The average number of customers found during our observations are about 50 customers. Moreover, the time consumed may vary due to the situations occurred during the checkout:

(a) The time consumed of using barcode around 3-10 seconds. The problem of using Barcode observed are the product is wet, thus makes barcode hard to read. In addition, the condition of barcode may be broken and some placements of barcode is quite hard to find.

(b) The speed of the cashier counted, starting from picking up the products and align with the barcode scanner.

(c) The quantity of items purchased

(d) The time consumed during the payment. Most of the people observed using cashless method.

In addition to that, we also conducted a questionnaire to 104 people. This aims at enhancing our data requirements from observation. Through the questionnaire, 52.9% people spent 30-60 minutes in one time shopping, 48% people usually queue about 10-20 minutes during checkout. Moreover, we also asked what factors that could lead to the long queue, there are 2 options that reach above 50%: the quantity of the purchased items around 76.2% and the long waited scanning process around 66.3%. Furthermore, 81.2% agreed that the long waited queue is one of the problems that needs to be fixed.

A lengthy queue upon entering the checkout process in supermarkets is an undesired situation for customers in a retail business and can possibly cause the number of customers to decrease as well as their loyalties. As the survey conducted by Technologies [1], 86% of the respondents tend to avoid stores with a lengthy queue, where 70% of them admits not going back to the store they are aware they would be faced with a queue. It is believed that it happened because customers find frustration in not being able to achieve what they wanted to do with ease and do other activities in their lives [2]. A supermarket queue can be solved by rendering checkout process efficient.

Based on the problems found in our observations and questionnaires, this work aim at reducing the queuing time starting from when the customer enter the supermarket until finish the checkout process. Therefore we implement an RFID system on the cart that connected to mobile application and Point of Sales in the cashier. Additionally, we show that our workflow could reduce the processing time during the checkout process. Furthermore, the implementation of Smart market application has several benefits [3], one benefit to the owner side such as the automated price tag reconfiguration could be achieved within this research.

2. Previous Works

The idea of smart carts could be found quite a decent numbers in the literature review. The term ”smart” has made some creative approach in it. Research shows starting from the implementation of the sensor using such as RFID on the cart and the integration with the mobile application, the implementation of the Zigbee system. An innovative research is done by Tang et al. [4], shows the advanced of the smart cart that could follow the customer during the shopping time. Their specific customer is the elderly people aged 65 or older, this could be a tool aim at Independence shopping. To be more precise, our research aim at reducing the queuing time during the shopping in the supermarket. Therefore, the idea of making a self driving cart is not the solution to our objective.

Hove et al. [5] introduced context-aware shopping list in order to reduce a frustration that may occur when the items you need could not be found in the supermarket as well as improving the task performance. They installed a tablet into child seat then web display the current location of the cart as well as the location of each item needs to be purchased based on the selected amount of products during the experiments. The result shows the duration to get all the products improve 2 times faster than the paper shopping list.

Subudhi and Ponnalagu [6] implemented so called an intelligence shopping cart by mounting finger print to authenticate the user, RFID sensor to identify each RFID tag attached on each product and LCD Screen to display the amount of transaction should be paid. The weight sensor is also being installed to ensure the RFID tags corressponds with correct item. In addition to payment process, OTP based is proposed. Once the customer finish shopping, then interaction through the keypad attached to confirm that they are finished. Subsequently, the OTP is sent to through sms that proposed to be linked with the bank account. On the other hand Ezhilazhagan et al. [7] also used RFID tag and mobile application in order to display each scanned RFID tag. The reader is mounted on the cart, however the communication between the data is through Li-Fi technolgy that could transfer the data locally around ¿10 Gbps.Mekruksavanich [8]

3. Material and Methods

Figure 1 illustrates how Smart Shopping Cart is implemented along with the Smart Shopping Assistant application that is connected to the database and server, as well as the web application used on the cashier.

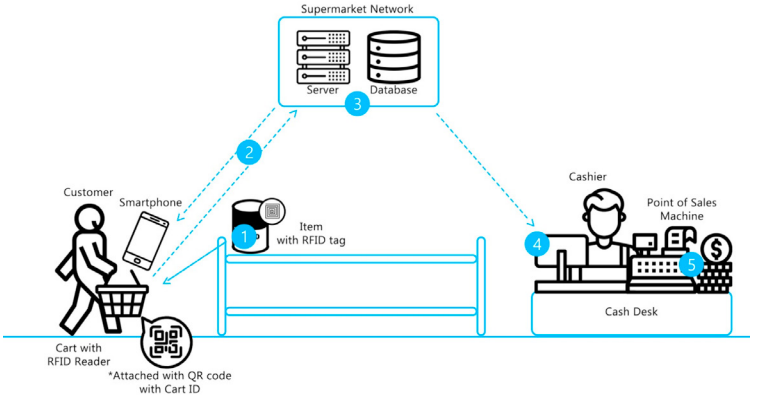


Figure 1: Smart Shopping System Schema)

The flow could be described as follows:

(a) All products in the supermarket will be tagged with an RFID tag containing information of the item ID as well as the price, as signified in number 1 in the illustration.

(b) As the customer taps the RFID-tagged product to the RFID reader in smart shopping cart, it will transmit the data in the tag to the server as signified in number 2 in the illustration. The application will continuously inquire for updates of information regarding the transaction in the smart shopping cart, so that all products that has been scanned can be monitored in their mobile application.

(c) Figure number 3 illustrates the database and the server. The database contains all information about all smart shopping carts as well as the transactions made in the supermarket using the system. It is synchronized with the help of the server that accepts the transmission from smart shopping cart. The server will also synchronize the data to each active transaction by responding to the continuous inquiry the application sends, allowing to give an accurate list of goods that has been scanned and total price.

(d) When customer is about to finish an active transaction, they are obliged to head to the cashier to proceed with checkout process as shown in number 4 in the illustration where they show the one-time password that is shown on their application. Cashier will input the said code on the web application to retrieve the corresponding transaction list to do a final check process.

(e) Customer proceeds to payment process with a payment method of their choice or choose to cancel the transaction with the cashier's help. Once the process is finished, the cashier clicks the finish button on the web application to inform the server that the transaction has been finished, and the server synchronizes the information to the database.

3.1. Radio Frequency Identification System

Radio Frequency Identification (RFID) is a technology that uses radio frequency to recognize an object from several distance. RFID technology uses automatic data capture system for process efficiency. It consists of a reader and tag combination to make it work. RFID tag is a small electronic device that contains microchip and antenna so that the information inside it can be sent wirelessly[9]. There are two types of RFID tags:

(a) Passive RFID Tag
Passive RFID tag is a tag that does not require a power supply. This type of tag retrieves power from the corresponding RFID reader as it sends electromagnetic wave that will produce electric current in RFID tag's antenna, which the RFID tag will reflect as a transmission signal and adding information on it to RFID reader.

(b) Active RFID Tag
Active RFID tag is a tag that has its own power supply. Active RFID tag has a longer reading distance. It is able to send a signal containing tag information that will be captured by RFID Reader.

In this work, passive RFID tag is used and RFID reader that works in 13,56 MHz frequency with one meter of reading distance, medium transmission speed and low interference.

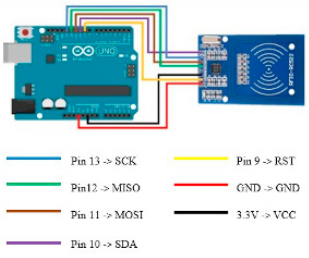
3.2. Arduino Modules

Arduino is an open-source electronics platform which possesses both hardware and software components, where inputs coming from a sensory hardware can be used to give instructions to the microcontroller on the board to be later processed into a certain output.

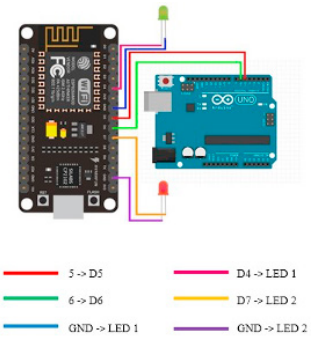
In order to deliver instructions to the Arduino machine, a script is required. The script is developed using the Arduino programming language that is based on Wiring and compiled in an Integrated Development Environment (IDE) owned by Arduino, the Arduino Software. With the set of instructions that are compiled and deployed in an Arduino machine, it will be execute and process inputs as defined in the instructions.

The Arduino hardware is highly customizable. With this capability, the instructions that are given and deployed in an Arduino system can be very versatile. A few other notable Arduino qualities are its cost-effective, wide-connectivity, a customizable hardware and software, and easy-to-learn programming language for beginners.

There are various types of Arduino, where each type is distinct by the number of inputs and outputs that it could receive and send, as well as the variety of built-in modules attached to the Arduino machine. For example, Wemon D1 Mini has a small module to provide a wireless connection capability. In the development of the Smart Shopping Cart, the Arduino used is a generic type, which is Arduino Uno.



(a) Arduino RC522 Schema



(b) Arduino ESP8266Mod Schema

Figure 2: Arduino Modules

The RC522 module that is attached to the Arduino Uno in Smart Shopping Cart works as the place where customers are able to scan the RFID tag attached in the item, so that the item information could later be sent out to the server. Its power is supplied from a VCC pinout that is connected to the 3.3V pin on Arduino board which implies that the RC522 uses 3.3-volt power supply. The GND pin serves as a connector between Arduino board and RC522. The module is controlled by Arduino board using Serial Peripheral Interface (SPI) protocol, which is a protocol that has the capability to enable data transmission between Arduino and RC522. The SPI Protocol needs 4 signal bus schemata for communication, such as MISO (Master In Slave Out), MOSI (Master Out Slave In), SCK (Serial Clock), and SDA. MISO and MOSI serves a role as data carrier, SCK as signal synchronizer for data transmission between MISO and MOSI, and SDA as input signal when SPI Protocol starts.

ESP8266Mod is a module that enables wireless connectivity over WiFi; in Smart Shopping Cart, it is used to send the information from item with an RFID tag scanned by RC522 to the server. ESP8266Mod is yet another independent module attached to the Arduino Uno on Smart Shopping Cart that needs its own power supply. ESP8266Mod uses serial communication to communicate with Arduino. In this system, the 6 and D6 pin are used as data transmission enabling pins, while the 5 and D5 pin are used as receiver pins. For notification purposes, ESP8266 is also connected to LED1 and LED2 through the GND pin, D4 pin and D7 pin as power supply pins.

3.3. Cart

The Smart Shopping Cart has a QR code that is printed and plastered on it that acts as an identifier. The QR code is first generated using any QR Code generator such as an online QR code generator by entering the desired value of Cart ID then clicking generate. Once generated, the QR code is printed and attached to the Smart Shopping Cart where it could be scanned by the interface application that has a ZXing library implemented for cart booking purposes. Figure3 shows the cart with implemented QR code.

Figure 3: Smart Shopping Cart

3.4. Application

In order to support our workflow, then we implemented 2 applications, respectively for customer and cashier. The application for customers is built using Flutter framework on Android, while the cashier web application is developed using NodeJS. All the scanned items with RFID tags attached could be listed on the Android application to track what kind of item purchased as well as the total price of the transaction. Subsequently, the customers could press the Checkout button in the app to complete the shopping process where an OTP shows in the app. The OTP will be shown to the cashier who revalidates all the purchased item and the total that should be paid by the transaction's corresponding customer. In this work, the primary concern is to reduce the queuing time, not for the security. The details of the app used in this work could be described in figure 4.

4. Experiments and Results

Based on problems deduced from the observations and questionnaires mentioned in section 1, IoT is implemented in order to reduce the queuing time by improving efficiency of the checkout process. As it is mentioned in section 3, there are 3 parts we will focus on in our experiments: RFID, Arduino, Cart, and the application.

4.1. RFID

For the implementation, we use passive RFID tag because of several reason as follows:

(a) The range that needs to be read is lower than one meters distance.

(b) The price of passive RFID tag is cheaper than active RFID active so we can reduce implementation costs

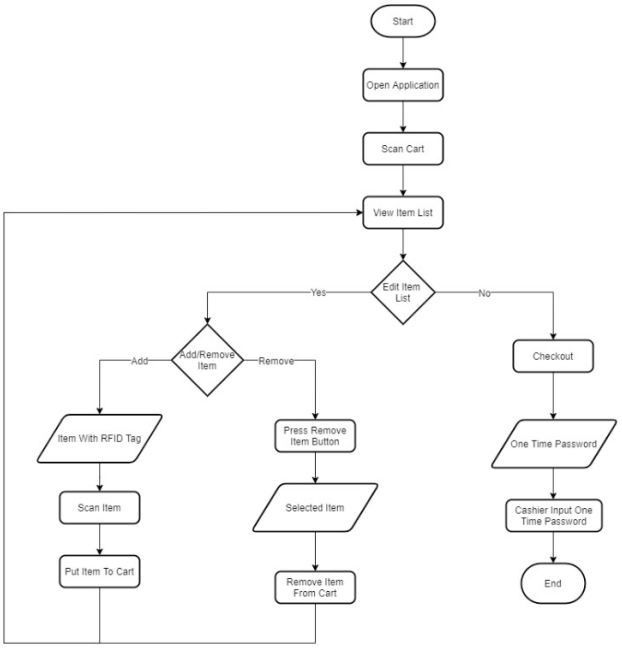


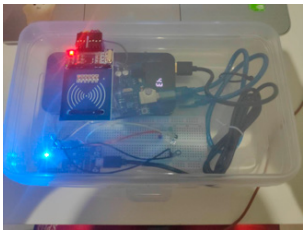
Figure 4: Flowchart Smart Shopping Cart Schema

(c) Passive RFID tag doesn't need a power supply to make it work.

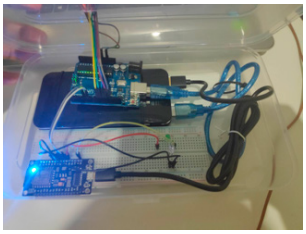
Item ID is inserted to the tag using a program made using C language and Arduino IDE. After the data is inserted to the tag, the reader can read it within the reader's read range.

4.2. Arduino Setup

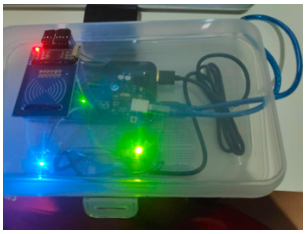
We used arduino as our main processing hardware in order to manage the data being sent to our server through wifi network.



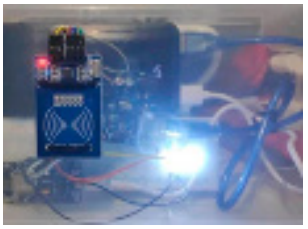
(a) Shopping Cart Modules that attached into the Cart



(b) Arduino's components used



(c) Green LED as notification of sucessfully inserted product



(d) White LED as notification of failed inserted product

Figure 5: Arduino modules attached to the cart

4.3. Smart Shopping Cart and Smart PoS

Every item in the supermarket is expected to be attached by a passive RFID tag that has the item ID information embedded in it. The Smart Shopping Carts in the supermarket will each have the Arduino system attached on it, where the power supply is enough to boot the system up, the compiled source is implemented in the Arduino, including

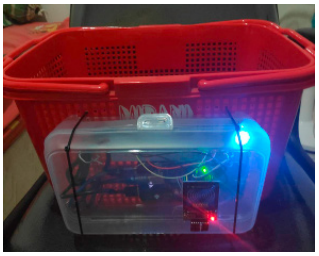


Figure 6: Smart Shopping Cart

the configuration of the supermarket's own network to be connected over WiFi. The cart can only have one open transaction. When a customer scans the QR that is attached on the cart, the app will ask [TransactionID] from the server. Server will search for any open transaction for that cart, if there is no open transaction, the server will create a new transaction and return the transaction id. The transaction will remain open as long as the customer does not close or cancel.

In the shopping process, the customer will tap the item's RFID tag to the reader located in the Smart Shopping Cart. The reader, as programmed in the Arduino that is connected to it, will retrieve the information of the item ID, then ask the interconnected Esp8266Mod module to transmit a request with the parameters [ItemID, TransactionID] to the server via WiFi network that has been previously configured. As a return to the inquiry, the server updates the list of items in the corresponding open TransactionID; this ensures the accuracy of the scanned items to exclusively be placed in the transaction ID that had been inquired.

When the app requests the server for an update on the TransactionList in a secondly interval, the phone sends a request with the parameters [TransactionID], and in return, the server sends [TransactionList] that consists of the most recent list of items and the information of the items to the requesting app. The process is repeated until the customer is done with scanning the items in the supermarket, and the customer decides to press "Checkout" in the shopping screen which sends a signal to the server in the network with the parameters of [TransactionID, Status] where the status signifies that the TransactionID is closed and ready for checkout as a validation that the cashier may help with the checkout process anytime soon.

4.4. Results

By transferring the effort of scanning barcodes in the cash desk by the cashier to a self-scanning done by every customer in their own carts, the time taken to scan items during checkout is eliminated during a checkout process. The remaining activities that must be done in the checkout process is packaging and proceeding with payment. Assuming there is a queue of 10 people in the cash desk that want to do checkout process and there are several conditions of item's barcode that make the scanning process took several times according to observation as follow:

(a) 50% item with barcode sign that is easy to scan (need 5 seconds).

(b) 30% item with barcode sign that is hard to find (need 8 seconds).

(c) 10% item with wet barcode sign (need 8 seconds)

(d) 10% item without barcode sign, remember that barcode is one type of price card that commonly exists for each product, but there is a chance where a product doesn't have a price card (need 10 seconds).

(e) 3 seconds needed to put each item in package. item Average time consumed to finish the payment process is 7 minutes or 420 seconds

With several conditions above, we make a comparison between the barcode system and the smart shopping system. We assume if customer put 10 items in the cart, so according to conditions above there will be 5 items of category a, 3 items of category b, 1 item of category c, 1 item of category d. With all the condition as describe before, the formula to calculate the times needed to finish the checkout process is:

(a) Scanning process :
(5a x 5) + (3b x 8) + (1c x 8) + (1d x 10) = 67 sec

(b) Packaging process :
10 items x 3 sec = 30 sec

(c) Payment process :
7 minutes = 420 sec

(d) Total time :
67 sec + 30 sec + 420 sec = 517 sec

With the same formula as above, we simulate the checkout process time with various total items as illustrated in the figure 1

Table 1: Queue Time with Barcode System

No	Total Item	Scanning Process [Second(s)]	Packaging Process [Second(s)]	Payment Process [Second(s)]	Total Time for Checkout process [Second(s)]
1	10	67	30	420	517
2	20	134	60	420	614
3	30	201	90	420	711
4	40	268	120	420	808
5	50	335	150	420	905
6	60	402	180	420	1002
7	70	469	210	420	1099
8	80	536	240	420	1196
9	90	603	270	420	1293
10	100	670	300	420	1390

With smart shopping system, we can remove scanning process by transferring the effort of scanning barcodes in the cash desk by the cashier to a self-scanning done by every customer in their own carts, the time taken to scan items during checkout is eliminated during a checkout process. The remaining activities that must be done in the checkout process is packaging and proceeding with payment and total time for checkout process can be optimized and it is described in figure 2.

Table 2: Queue Time with Smart Shopping System

No	Total Item	Scanning Process [Second(s)]	Packaging Process [Second(s)]	Payment Process [Second(s)]	Total Time for Checkout process [Second(s)]
1	10	0	30	420	450
2	20	0	60	420	480
3	30	0	90	420	510
4	40	0	120	420	540
5	50	0	150	420	570
6	60	0	180	420	600
7	70	0	210	420	630
8	80	0	240	420	660
9	90	0	270	420	690
10	100	0	300	420	720

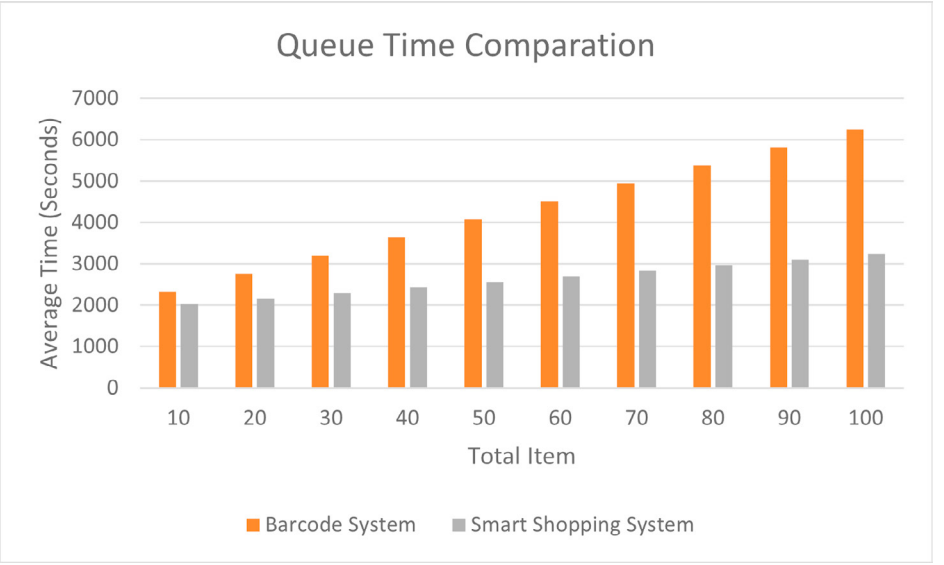


Figure 7: Differences Queue Time Efficiency in a 10 Customer Queue

Table 3: Queue Time Efficiency in a 10 Customers Queue

No	Queue Length	Total Item	Average Queue Time (Barcode System) [Second(s)]	Average Queue Time (Smart Shopping S) [Second(s)]	Differences (Second(s))	Differences (Minute(s))
1	10	10	2326.5	2025	301.5	5.025
2	10	20	2763	2160	603	10.05
3	10	30	3199.5	2295	904.5	15.075
4	10	40	3636	2430	1206	20.1
5	10	50	4072.5	2565	1507.5	25.125
6	10	60	4509	2700	1809	30.15
7	10	70	4945.5	2835	2110.5	35.175
8	10	80	5382	2970	2412	40.2
9	10	90	5818.5	3105	2713.5	45.225
10	10	100	6255	3240	3015	50.25

The result is significance of the efficiency in this process grows proportionally with the increasing number of items and customers, as illustrated in the figure 3

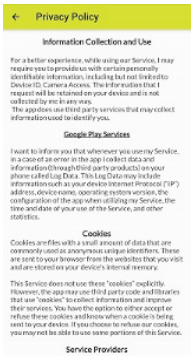
5. Discussion

In our work, we conducted observations and questionnaires. The observations has been done through 2 supermarkets within 3 months starting from November 2019 - January 2020. The observations results are described in details could be found in section 1. The main findings in this observation is the queuing time that could be improved in several process. In addition to the queuing time, the results in the questionnaire also shows on each transaction usually takes 10-20 minutes during the checkout. There are 2 prominent factors that could impact the queuing time: the quantity of items purchased and the long waited scanning process.

6. Conclusion

This paper regarding development of Smart Shopping System using Smart Shopping Carts shows that it is able to reduce queue time by eliminating the barcode scanning process during the checkout process as the process of scanning items to be shopped has been independently done in the shopping process by the customer. RFID shows a high capability, durability, and efficiency. Although the capability of an RFID system can be explored more for further use or development such as the other types of RFID, higher frequencies, longer read distances.

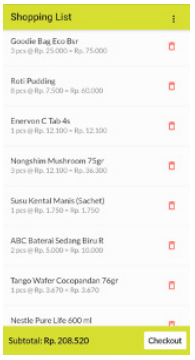
(a) Boarding Pages



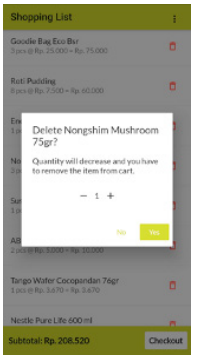
(b) Privacy Policy Page

(c) Green LED as notification of sucessfully inserted product

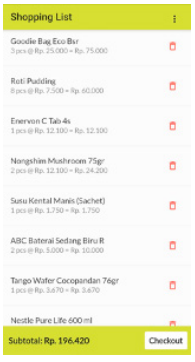
(d) White LED as notification of failed inserted product



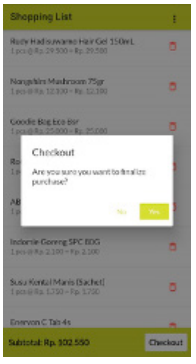
(e) White LED as notification of failed inserted product



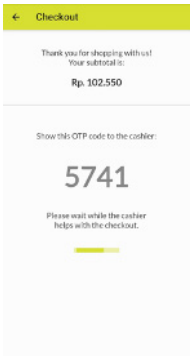
(f) White LED as notification of failed inserted product



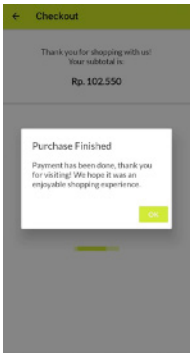
(g) White LED as notification of failed inserted product



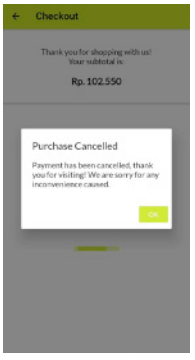
(h) White LED as notification of failed inserted product



(i) White LED as notification of failed inserted product



(j) White LED as notification of failed inserted product

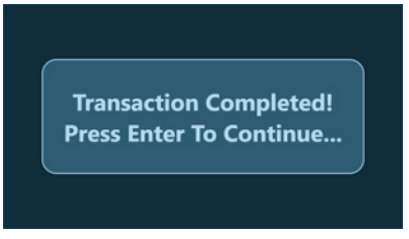


(k) White LED as notification of failed inserted product

(l) White LED as notification of failed inserted product

(m) Shopping Cart Modules that attached into the Cart

(n) Arduino's components used



(o) Green LED as notification of sucessfully inserted product

Figure 8: Smart Shopping Assistant UI

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