Medical Supplies Vending Machine

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Abstract: In this paper, a novel development of a Medical Supplies Vending Machine is described for solving recent emerging problems. In the recent COVID-19 pandemic, demand for round-the-clock and urgent supply of medical supplies have surged to a point that is difficult to serve by the conventional supply chain, which largely relies on shops and pharmacy outlets to sell them during restricted opening hours only. As a result, many consumers are deprived of the supplies they need and succumb to their ailments. Therefore, a smart healthcare solution for these predicaments is urgently needed. A project to address this need is presented in this paper. The goal of the project is to design a vending machine system that can deliver medical supplies at anytime and anywhere with a secure cashless payment system, security access system and ability to send restocking alert message. The vending machine is developed by using an Arduino Mega and a NodeMCU ESP8266 Wi-Fi module as the microcontrollers. The hardware components include I2C serial LCD display, RC522 RFID module, push buttons, LEDs, resistors, 360° servo motors, metal springs, IR sensors and buzzer while the software required are Arduino IDE, Telegram and ME-QR website. Testing of the prototypes reveal that the system fulfills its intended functionalities including cashless payment, security access, ability to select multi-items for a single payment and also ability to send restocking alert message. However, there are limitations such as the feature of purchasing limit could not be implemented as Arduino Mega has only one processor. Nevertheless, this paper also suggests some areas of improvement on the functionalities for future development.

Keywords: Medical supplies vending machine, Arduino Mega, NodeMCU ESP8266

1. Introduction

Over the years, we have seen the innovation of vending machines for various products [1]. The product could be dispensed to customers without the involvement of staff. Food and snack vending machines are very common. Vending machines bring many benefits such as convenience and time-saving on the purchasing process. From the owner's perspective, it also saves on overhead costs by not hiring staff.

Medical supplies are items for medical use that are suitable for use in a health care facility or at home [2]. Over-the-Counter (OTC) medicine is a type of medical supplies to treat minor symptoms. They are non-prescription medicine, so users can buy them at stores without doctor's prescription. They are safe and effective if the user follows the directions on the label and as directed by a healthcare professional [3]. First aid product is a medical supply that can help us respond effectively to common injuries and emergencies [4]. Due to the pandemic, face masks and COVID-19 rapid antigen test kits are needed by the public to protect us from the spreading virus.

In our routine, the problem arises when the need for some medicine is urgent but the pharmacy or clinic is out of the business hours as the cost to open a store 24/7 is high and manpower is lacking. Besides, the pharmacy or clinic is too far away such as at remote areas. As the total number of people within the store is limited due to the pandemic, people are required to queue first before purchasing so it will take a longer time. Even though vending machine delivery model has been widely successful for food and beverages market, its potential usage for health market segment has not been exploited that much to meet the demand and solve the access problems. Its use during the COVID-19 pandemic is hardly seen, if not available at all. Thus, to overcome the existing problems and promote the exploitation of the vending machine concept, a "Medical Supplies Vending Machine" for typical OTC medicine and first aid products is designed, developed and tested for its functionalities. This idea is to let people access medicine through vending machines easily when the need is urgent. As people are moving to cashless lifestyle nowadays, a vending machine with cashless payment method will be more convenient for consumers.

This paper proceeds as follow. Section 2 describes the review of history and recent development of the medical supplies vending machine concept, highlighting and comparing their strengths and limitations as the gaps to be addressed. Section 3 elaborates on the methodology for designing, developing, testing and evaluating the prototype of the machine. For section 4, the prototype of the project is shown and its functionalities are validated and explained. The limitation and the future development for the project is also discussed. Lastly, section 5 summarized the overall project.

2. Literature Review

The basic knowledge and development of vending machine is discussed in this section. Some related works for medical supplies vending machine is reviewed and compared.

2.1 Vending Machine

A vending machine is an automated machine that dispenses a range of products upon payment by money, credit card or other specifically designed card. Typically, the products include canned or bottled drinks, beverages, and other packaged food. Referring to [5], the first completely commercially automated vending machine was developed by Thomas Adams, selling Adams gum on train station. The mechanism of dispensing the product involves releasing it so it would fall into a compartment located below the product display once payment is made. Today, the most recent innovation of vending machines is the term of payment accepted. In the past, it only accepted coins. However, as fewer people carry coins nowadays, the machine with cashless payment system is developed. There are many types of cashless payments, including bank cards, mobile wallet applications, QR codes and contactless payments.

2.2 Related Works

Vending machines that dispense the required medicine as per the user's choice were also developed by researchers as in [6] – [9]. Before using the vending machine, all users must be registered to avoid drug abuse. The users are identified using the technology of Radio Frequency Identification (RFID) in [6] – [9]. RFID is a form of wireless communication that uses electromagnetic fields to uniquely identify and track tags attached to objects. The database for patients is uploaded to cloud storage for the reference of doctors or patients in [8]. Moreover, the machine uses the smart card system instead of coins. The digital payment system is built using RFID [6]. A single RFID tag is given to each user of the system and it can be recharged using a master card by the person in-charge. A display such as Thin Film Transistor (TFT) display or Liquid Crystal Display (LCD) is used to display text message to communicate with the system easily [6] – [9]. Medicine restocking alert message will be sent to the authorized person if the stock is out [8] [9] in order to restock immediately. However, the users may abuse medicine as there is no clear direction for them in the previous works. Besides, if the buyer forgets to collect the purchased item, the kids may collect and misuse it.

After reviewing the related works, user identification is one of the important additional features for the medical supplies vending machine. As people are moving to a cashless lifestyle nowadays, cashless payment should also be implemented in the proposed system. Furthermore, an alert message should be sent to the owner to restock immediately if the stock is running out. Aside from these functions, the detailed directions on how to use or consume the medical supplies should be explained to the buyer to avoid drug abuse. Purchase limit should also be set for medicine sold on the machine. A buzzer for alerting the buyer if he or she forgets to collect the purchased item is also proposed to be added to the system to prevent kids from collecting it. An additional feature of selecting multi-items for a single payment is also proposed for the system to save the user more time if he or she wishes to buy more than one item.

The aim of this project is to design a vending machine system that can deliver medical supplies to people at any time including night and over the weekend and at anywhere such as remote areas or the places where public turnover is lower. Not only that, the objectives are to configure the vending machine with security access, cashless payment and restock alert functionalities as well as to test and evaluate the functionalities of the vending machine system.

3. Methodology

In this section, the process of developing the vending machine is presented. In the early stage, a survey was conducted to help us understand more about the user needs and demands, marketability and public concern about our product. The analysis of this survey has proved fruitful to provide the clear picture on design specifications needed to compliment user preferences and to address public concern. The next phase is to design the complete system based on the design specification. The system consisted of a main program and three subsystem which are stock checking subsystem, security access subsystem and cashless payment subsystem.

3.1 Survey Analysis

A survey was conducted to ascertain the preferences and opinions of end users regarding the availability and use of Medical Supplies Vending Machine. A total of 107 respondents participated in the survey. The age range of the respondents are between 19 and 59 years old. Most of them (72.90%) are between 19 and 25 years old while the least (8.40%) are between 26 and 35 years old. The percentage for the age range from 36 to 45 years old and from 46 to 59 years old are the same (9.30%). 21 respondents are health workers while 86 are not. Health workers include doctors, pharmacists, medical store workers and others related to the healthcare sector such as nurses.

From the survey, most of the respondents agreed on the idea of Medical Supplies Vending Machine as it is easier to get medicine when the need is urgent, reduce contact with people, no need to wait for long queue at medical stores, can get medical supplies at anytime and anywhere. The top four in-demand medical supplies that should be sold in the machine is paracetamol, face mask, COVID-19 rapid antigen test kit and bandage. On the other hand, 30% of 107 respondents voiced out their concerns. There are two aspects that concern the majority of the respondents. First, the direction on how to use the purchased items is not clear. People are not sure on how to use and may misuse the product due to lack of dosage information. Second, the buyer may abuse the medicines for non-therapeutic purposes. Excessive consumption of medicines can lead to death.

3.2 Design Specification

To tackle the drawbacks of the existing method, a Medical Supplies Vending Machine will be developed using Arduino Mega to provide medicine to the people all the time. In our design, besides selling medical supplies in the vending machine, there are some additional features as listed below:

• Prevent kids from purchasing medical product using card verification.
• Pay the item using cashless payment method.
• Display text messages to communicate with consumer on the purchasing process.
• Select multi-items for single payment.
• Show the detailed direction on how to use or consume the medical supplies, such as COVID-19 rapid antigen test kit, by scanning QR code on the product item.
• Alert the buyer if he or she forget to retrieve the purchased item.
• Send an alert message to the owner when the item is out of stock.
• Purchase limit to one unit per customer per day.

3.3 Components Requirement

The components required in this project and its function are listed in Table 1.

Table 1 - Components name and its function

No.	Name	Function
1	Arduino Mega	To control the activities of main program.
2	NodeMCU ESP8266	To send message to the owner via Telegram by connecting to the Wi-Fi.
3	I2C Serial LCD Display	To display text message to communicate with the buyer.
4	RC522 RFID Module	For user identification and to make payment.
5	Push Buttons	To select the desired item and to proceed to the next function.
6	Light Emitting Diodes (LED)	To indicate whether the respective item is chosen or not.
7	Resistors	To control the amount of current flowing through all the LEDs.
8	360° Servo Motors	To rotate the spring attached to it to vend the requested item.
9	Metal Springs	To hold the medical products in place.
10	Infrared (IR) Sensors	To detect whether the item has collected by the buyer and to detect whether the item is out-of-stock.

11	Buzzer	To alert the buyer to retrieve their purchased item.
12	Arduino IDE	To write the program code of the system.
13	Telegram	To send a notification message to the owner when the item is out of stock.
14	ME-QR Website	To generate QR code for showing the detailed direction on how to use the product.

3.4 Block Diagrams

In this section, the block diagrams of the Arduino Mega microcontroller and NodeMCU ESP8266 Wi-Fi Module are constructed in Figures 1 and 2 respectively to represent the working principle of both systems. As the microcontroller of the main program, Arduino Mega receives input from five push buttons, a RFID reader and an infrared (IR) sensor. The outputs of the microcontroller include LCD display, four LEDs, a buzzer, and four servo motors. For the stock checking system, NodeMCU ESP8266 Module is used as the main controller to detect the availability of the items in the vending machine. It receives input from four IR sensors and sends the data to Telegram over the Internet.
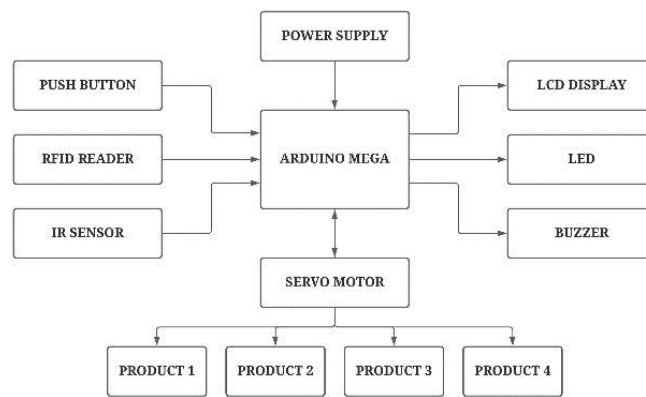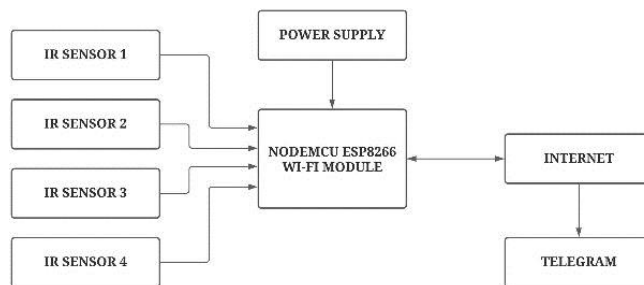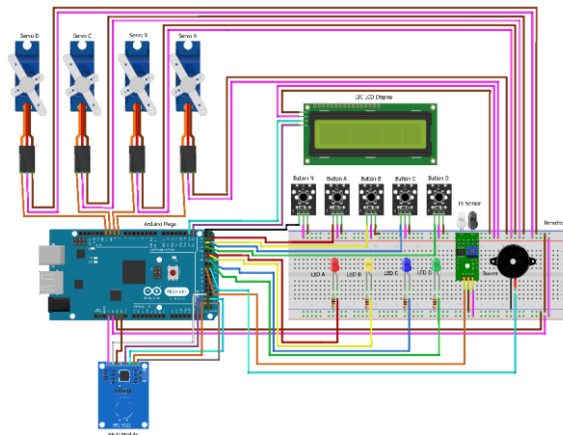

Fig. 1 - Block diagram of Arduino Mega

Fig. 2 - Block diagram of NodeMCU ESP8266
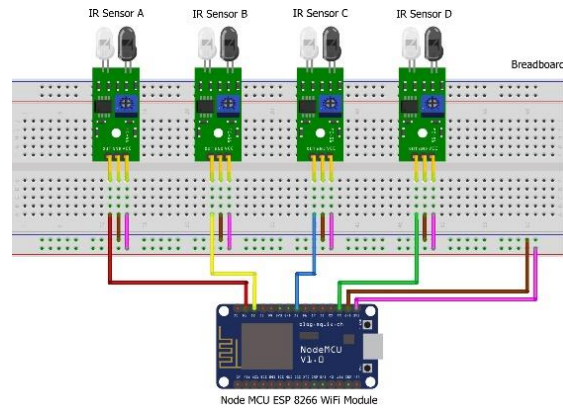
3.5 Circuit Diagram

External components can be interfaced with both Arduino Mega and NodeMCU ESP8266 through the I/O pins either as input or outputs. The circuit connections for both microcontrollers are shown in Figures 3 and 4. Tables 2 and 3 show the pin assignment of I/O ports of Arduino Mega and NodeMCU ESP8266 respectively.

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Fig. 3 - Circuit connection diagram of Arduino Mega

Table 2 - Pin assignment of I/O ports of Arduino Mega

| Peripheral	Peripheral Pin Name	Arduino Pin No.	Function
Servo Motor A	Signal	8	To vend item "Panadol Regular".
Servo Motor B	Signal	9	To vend item "Face Mask".
Servo Motor C	Signal	10	To vend item "COVID-19 Rapid Antigen Test Kit".
Servo Motor D	Signal	11	To vend item "Roller Bandage".
LCD Display	SDA	20	To display text messages.
	SCL	21	
Black Push Button	OUT	22	To proceed to the next function.
Red Push Button	OUT	23	To select item "Panadol Regular".
Yellow Push Button	OUT	24	To select item "Face Mask".
Blue Push Button	OUT	25	To select item "COVID-19 Rapid Antigen Test Kit".
Green Push Button	OUT	26	To select item "Roller Bandage".
Red LED	Anode	30	To indicate whether item "Panadol Regular" is chosen.
Yellow LED	Anode	31	To indicate whether item "Face Mask" is chosen.
Blue LED	Anode	32	To indicate whether item "COVID-19 Rapid Antigen Test Kit" is chosen.
Green LED	Anode	33	To indicate whether item "Roller Bandage" is chosen.
IR Sensor	OUT	36	To detect whether the buyer has retrieved the item.
Buzzer	Anode	37	To alert the buyer to collect the purchased item if they forget.
RFID Module	RST	48	For user identification.
	MISO	50	
	MOSI	51	
	SCK	52	
	SS	53	

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Fig. 4 - Circuit connection diagram of NodeMCU ESP8266

Table 3 - Pin assignment of I/O ports of NodeMCU ESP8266 Module

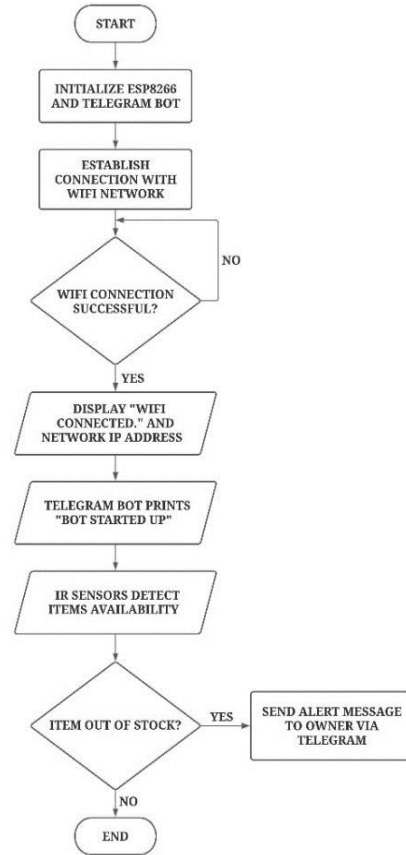| Peripheral	Peripheral Pin Name	Arduino Pin No.	Function
IR Sensor A	OUT	D1	To detect the availability of item "Panadol Regular".
IR Sensor B	OUT	D2	To detect the availability of item "Face Mask".
IR Sensor C	OUT	D5	To detect the availability of item "COVID-19 Rapid Antigen Test Kit".
IR Sensor D	OUT	D6	To detect the availability of item "Roller Bandage".

3.6 Flow Chart

Figures 5 to 8 depict the flowcharts of the system, including main program, stock checking subsystem, security access subsystem and cashless payment subsystem. For the main program of the system, it will be initialized first and the LCD display prints "Welcome to the vending machine". Then, the user activates the system by pressing the "Next" button to proceed to the security access subsystem. Once the card has been verified, customer can select the required item(s). After the item(s) is(are) selected, the system will proceed to the cashless payment subsystem. The requested items are vended carefully after payment is successful. Lastly, in case the customer forgets to retrieve their items, the buzzer will ring to remind them.

For the stock checking subsystem, the ESP8266 Wi-Fi module and Telegram Bot are initialized. Then, the Wi-Fi connection is established. The system will continue to attempt to connect to the network until it succeeds. After Wi-Fi connection is accomplished, serial monitor prints "Wi-Fi connected.", followed by the network IP address. On the other hand, Telegram Bot displays "Bot started up" to indicate the connection is successful. Four IR sensors are tasked with detecting whether the items are available or out of stock. If the items are out of stock, an alert message will be sent to the owner over the network via Telegram to restock the respective item immediately.
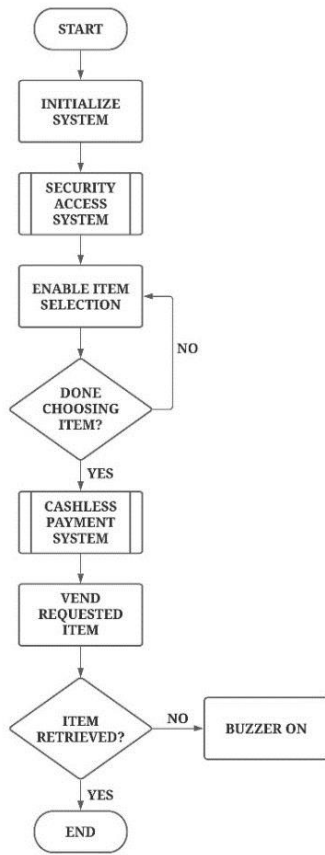
Fig. 5 - Flowchart of system main program **Fig. 6 - Flowchart of stock checking subsystem**

The security access subsystem is important to prevent children from purchasing medicines without adult consent. First, the user is required to scan their ID card before choosing the item for authorization. The RFID reader reads the user ID card and send the data to the microcontroller. The system then determines whether the ID card is valid or invalid. If the card is valid, the access is authorized, and LCD displays his ID name and his card balance. Subsequently, user is directed to items selection. On the other hand, if the card is invalid, the access is denied. LCD display prints "Sorry! Your card is not valid", and the process is terminated.

Lastly, for the cashless payment subsystem, the data is sent to the microcontroller to perform the arithmetic operations, where the price of the selected item(s) is subtracted from the initial balance after the required item are confirmed. If the card balance is sufficient, payment process is successful and LCD display prints "Payment is done" followed by the remaining card balance. Therefore, system will proceed to vend the requested items. However, if the card balance is insufficient, the LCD display will print "Sorry! Balance is not enough", indicating unsuccessful payment. Hence, the process of payment is terminated.
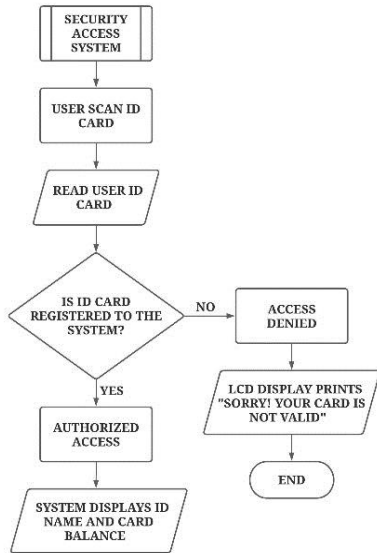
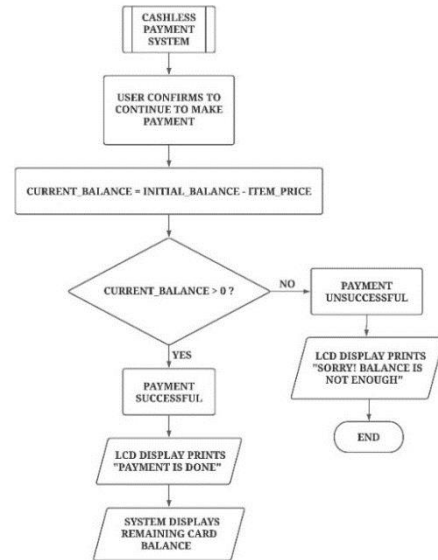**Fig. 7 - Flowchart of security access subsystem**   **Fig. 8 - Flowchart of cashless payment subsystem**

4. Results and Discussions

In this section, the functionalities of the medical supplies vending machine is tested and validated. The limitations and future development of the system is also discussed.

4.1 Prototype

Figure 9 shows the physical appearance of the prototype of Medical Supplies Vending Machine while Fig. 10 shows the product packaging of the selling items in the vending machine.

Fig. 10 - Product packaging of the selling item

Fig. 9 - Prototype of medical supplies vending machine

4.2 Validation of Work

The functionalities of the vending machine were tested and will be discussed in this subsection. Before the user activate the system, "Welcome to the vending machine" will be displayed to the user as shown in Fig. 11(a). After the user press "Next" button, the user is requested to scan their card using LCD display as shown in Fig. 11(b). After the user scan the card using RFID card or RFID tag, LCD Display will display the user ID and card balance as shown in Fig. 11(c) if the user has registered the card. On the other hand, if the user has not registered, an error message "Sorry, your card is not valid" will be displayed as shown in Fig. 11(d) and then followed by initializing the system.

There are four items for the user to choose. If the card is valid, the user can proceed to select the desired item(s) by pushing the button of the respective item. The LEDs of the respective item will be lighted up if the item is chosen. Fig. 12 shows the initial state of LEDs of the respective item, which is LOW that means all the items are not chosen.

The user can select one or more desired items for single payment before next stage. After the user choose the items, the state of LEDs will be changed to HIGH. For example, if the user chooses the items of Face Mask and COVID-19 Rapid Antigen Test Kit, the LEDs of the respective items (Yellow and Blue) is lighted as shown in Figure 13.

LCD display will ask the user whether they have done selecting the items or not as shown in Fig. 11(e). After the user press "Next" button, the user will proceed to the next function. If the user did not choose anything, LCD display will tell the user that they did not choose anything as shown in Fig. 11(f) and followed by initializing the system.

If the user selects one or more than one items, he will be directed to confirm the payment as shown in Fig. 11(g). After paying, the card balance of the user will be displayed. As shown in the Fig. 11(h), the current balance is evaluated by subtracting the initial balance (RM 50) with the price of item(s) purchased. As the item chosen by the user is Face Mask (RM 1) and COVID-19 Rapid Antigen Test Kit (RM 6), a total of RM 7 is deducted from the initial balance hence the current card balance is RM 43. If the user has no enough balance in the card, it will show an error message "Sorry! Balance is not enough." as shown in Fig. 11(i) and then followed by initializing the system.

After payment, the system will vend the requested item to the "item collecting slot" for the buyer as shown in Fig. 14. If the item is not collected, the buzzer will be switched on and the LCD display will show "Please collect your item(s)" as shown in Fig. 11(j). After the item is collected, thank you message will be displayed on the LCD display as shown in Fig. 11(k) and followed by initializing the system for the next user.

(a)	(b)	(c)
(d)	(e)	(f)
(g)	(h)	(i)
(j)	(k)	
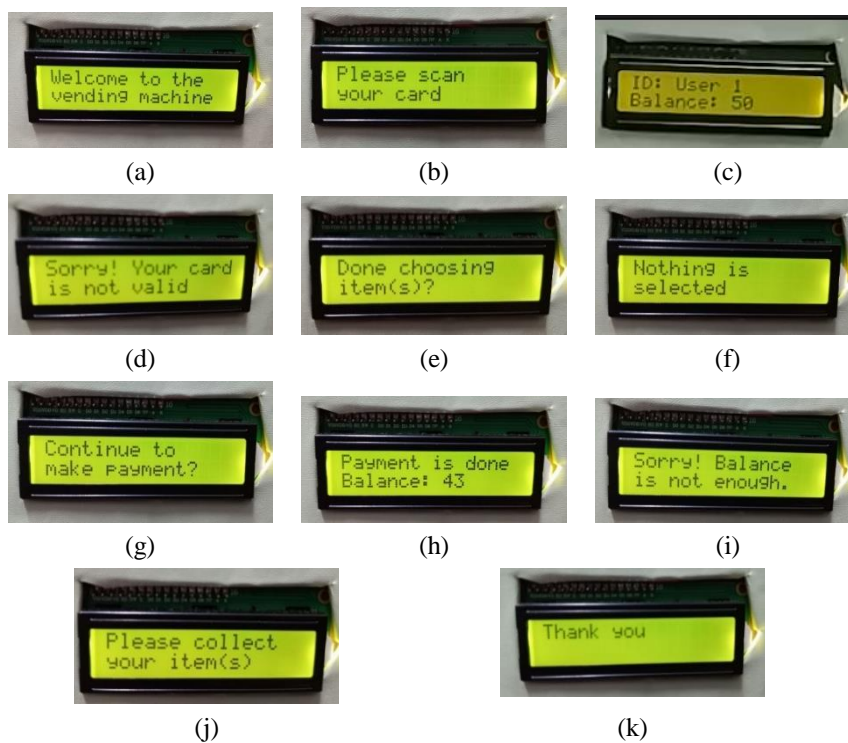
Fig. 11 - LCD Display for user at different stage (a) welcoming message; (b) scan card; (c) user id and initial card balance; (d) error of invalid card; (e) confirm selected item; (f) error for nothing is selected; (g) confirm payment; (h) current balance after payment; (i) error for insufficient balance; (j) collect requested item; (k) thank you

**Fig. 12 - Initial state of LEDs of the respective item**

Fig. 13 - Current state of all LEDs when face mask and rapid antigen test kit is chosen

Fig. 14 - The item is vended to the "item collecting slot"

The QR code generated using ME-QR website (see Fig. 15) appears on the design of the packaging of respective selling item. If they wish to know the detailed direction of the relevant medical supplies, the buyer can scan the QR code on it to read the infographic of the item. The infographic of each item is designed for showing detailed direction on how to use or consume the medical supplies sold on the vending machine. The infographics of all the medical supplies sold is attached in Appendix A.


| (a) | (b) | (c) | (d) |
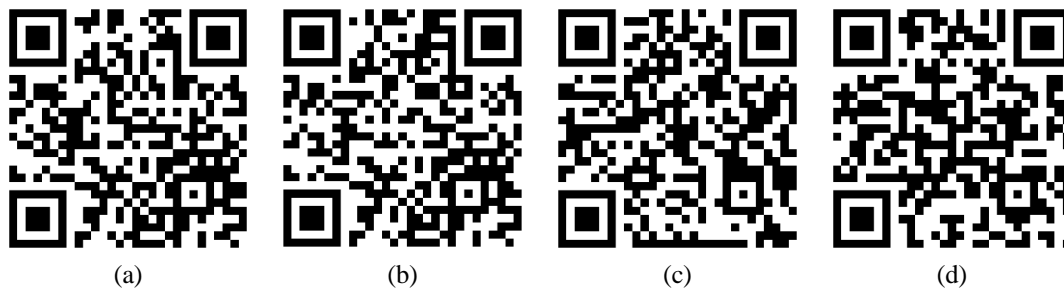
**Fig. 15 - QR code for the medical supplies sold (a) panadol regular; (b) face mask;
(c) COVID-19 rapid antigen test kit; (d) roller bandage**

For stock checking subsystem, the Telegram App is used as the medium to send message automatically if the stock is not available. Therefore, a telegram bot is created for this feature by getting the bot token and telegram user ID. To check the availability of the stock of each selling item, an IR sensor is placed on each slot of the item as shown in Fig. 16. The IR Sensors will keep detecting the availability of the items. If the item is out of stock, alerting message(s) will be sent to the owner to notify him that the respective item is currently out of stock. Fig. 17 depicts that all the item is currently out of stock. Hence, he can restock the item(s) as soon as possible. If the item is still out of stock, like Roller Bandage, it will keep sending the message after every 30 seconds interval repeatedly to remind the owner.

Fig. 16 - IR sensors in each slot of the selling items
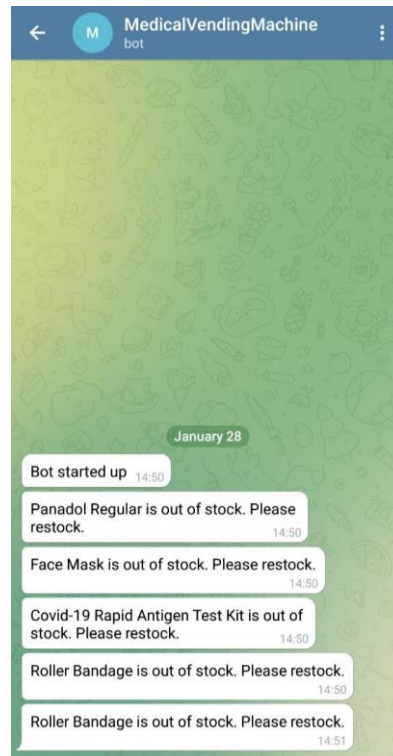
Fig. 17 - Notification messages to the owner

4.3 Discussion

The prototype of Medical Supplies Vending Machine is successfully developed. For the aspect of economic, this system could save buyer time to purchase desired items and also save the cost of manpower of the owner to open 24/7. The owner also does not need to keep checking the availability of the items in the vending machine as he will be notified if there is any item currently out of stock. This can save the fuel cost and travelling time of the owner.

While for the aspect of environmental, the consumer is no longer required to store a lot of medicines at home in case there is an urgent and throw away after few years due to expiry dates. This is because they can purchase the item when they need at anytime and anywhere. Thus, it could reduce the waste produced at home. The system is safe to use as the buyer need to be identified before purchasing an item in the machine. It will also alert the buyer to retrieved the purchased item to avoid the medical supplies to be accessed by others, especially children. In addition, the infographic on the detailed direction of the medical supplies can be accessed by scanning QR code instead of by reading the printed paper attached to the item. As it is paperless, this is more sustainable and the user can read in a more convenient way. As the infographic is displayed using digital devices, they can zoom in to enlarge the wordings in order to see the directions clearly. While designing the infographics, the precaution to use, consume or store the medical supplies is included to avoid the user misusing them. Not only this, the way to dispose the face masks is also included to create awareness of the public to throw it properly.

Next, the limitation of the project is the purchase limit to buy the item(s) cannot be set. This feature is used to avoid drug abuse due to the medical supplies can be accessed easily. The initial idea of the program flow is to set a time interval (for example 60 seconds) as the limit for the user to purchase the item only once. Initially, previous time is set to 0. The system will continuously read the current time. Let x be the time interval of the user purchase currently and previously of the running system. When the user wishes to purchase the item, it will minus the previous time to get the time interval of the user purchased previously. If x is smaller or equal to 60 sec, the purchase process is restricted. If x is greater than 60 sec, the purchase process is allowed. This feature could not be implemented in the program as the Arduino Mega has only one processor. It is impossible to perform multiple tasks concurrently. Hence, it cannot evaluate the time interval x while running the main program simultaneously. To overcome this limitation, Raspberry Pi 4 can replace Arduino Mega as it has four processors thus can perform multiple tasks concurrently.

For future development of the system, more items can be added to the system for the user to purchase. The security system could be improved by implementing Touch ID System or installing face-recognition system. More methods to pay for the requested item(s) could be implemented in the system for the user to choose their preferred method such as cash, e-wallet, Touch 'n Go, debit or credit card, QR pay and so on. Furthermore, if there are more medical supplies vending machines produced, a website to track the location of the vending machines could be implemented to ease the user to find the nearest location of the machines.

5. Conclusions

In conclusion, the prototype of Medical Supplies Vending Machine is developed successfully with the additional features of preventing children from purchasing using card verification, paying for the item with cashless payment method, displaying text messages to communicate with consumer on the purchasing process, showing the detailed direction on how to use or consume the medical supplies by scanning QR code on the product item and also sending an alert message to the owner using Telegram when the item is out of stock. However, there are some limitations for this project such as the feature of limiting the user to buy one unit selling item in certain period could not be implemented as Arduino Mega has only one processor hence it is impossible to perform multiple tasks concurrently. In future, Arduino Mega could be replaced with Raspberry Pi 4 as it has four processor and is able to perform four tasks simultaneously. Hence, it can interact with the user to purchase desired item and evaluate the duration of the user was purchased previously at the same time.

All in all, the Medical Supplies Vending Machine is a great idea to fulfil the needs of the public to buy medical supplies anytime, even at night or during the weekend and also anywhere, such as places where there are limited medical stores around.
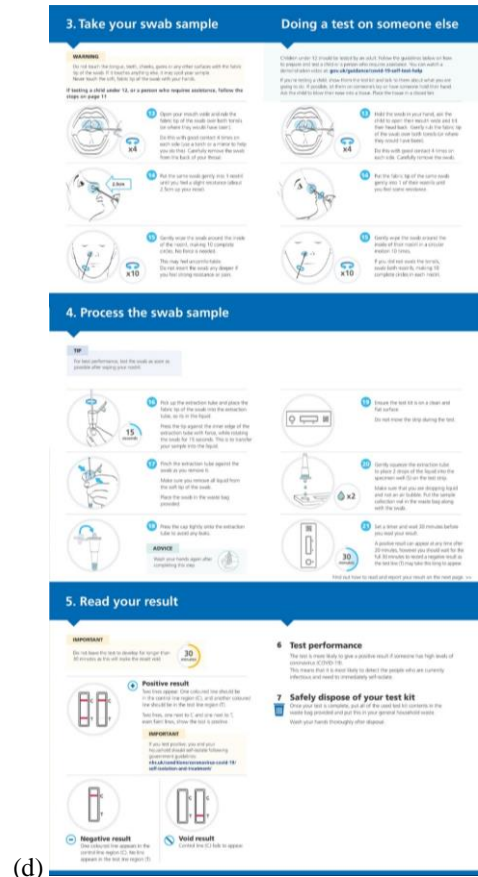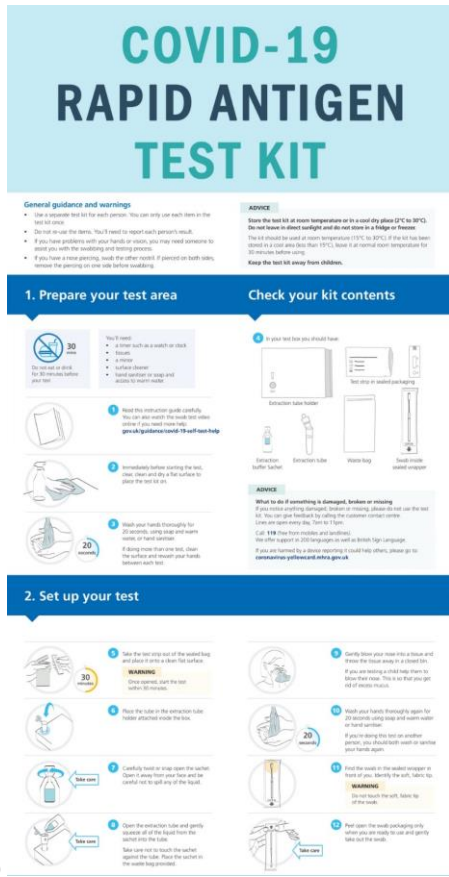
Acknowledgement

Appendix A: Infographic for the Direction of the Medical Supplies Sold

The infographic of each item is designed for showing the detailed direction on how to use or consume the medical supplies sold on the vending machine. The infographics of Panadol Regular, Face Mask, COVID-19 Rapid Antigen Test Kit and Roller Bandage is shown in Figure 18.
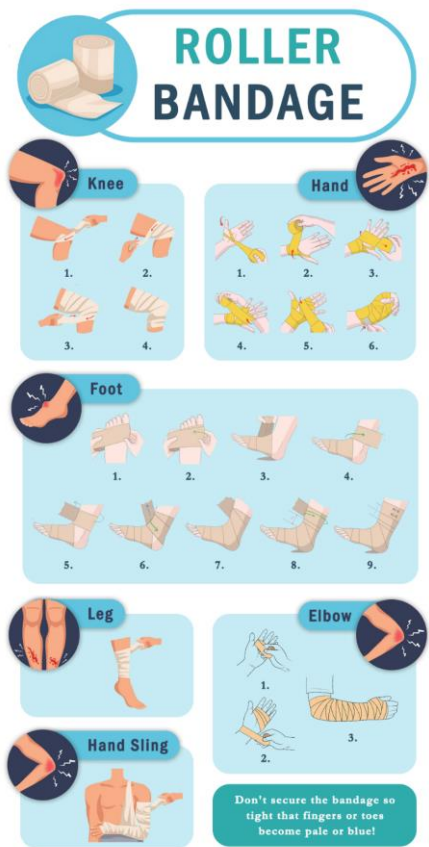

(a)   (b)

(c)

(d)

(e)

Fig. 18 - Infographics (a) panadol regular; (b) face mask; (c) COVID-19 rapid antigen test kit (top); (d) COVID-19 rapid antigen test kit (bottom); (e) roller bandage [10] [11] [12] [13]

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