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Reverse Vending Machine Using TCRT5000 and Inductive Proximity Sensors for Bottles and Cans Sorting

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***Abstract*—Garbage has always been a problem in Indonesia. One root is the lack interest in throwing them in their proper place. Additionally, the waste that has been disposed is not managed properly. In response to it, the authors designed a trash bin as a Reverse Vending Machine (RVM) with the ability to detect bottles and cans and provide rewards for the person. The machine was able to detect bottles by using the TCRT5000 sensor and cans by using an inductive proximity sensor. Both trashes were also sorted to a specific trash bin directly, and the reward was calculated directly based on the total of bottles and cans put into it. A push button can be pressed to print out the ticket, but it would decline the request when there is no bottles or cans input. In addition, ultrasonic sensors were installed to automatically check the trash bins of the RVM, and LEDs were used to notify the user whether the trash bin of the bottles or cans were already full or not. After 24 attempts of testing, the successful rate was found to be 100%.**

Keywords—Arduino UNO, Bottles, Cans, Reverse Vending Machine, TCRT5000, Thermal Printer

I. INTRODUCTION

Garbage has always been a problem in Indonesia. If they are managed improperly, piles of them can fill the final disposal area, and pollute the environment. In the research from Sustainable Waste Indonesia (SWI), LITBANG agency from the Ministry of Home Affairs revealed that waste with the total of 24% is still unmanaged. To be more specific, the number corresponds to approximately 15 million tons out of 65 million tons of waste each year [1].

Even though trash bins availability is relatively high in a lot of places –some of them even have notes or colors to let people know how to sort the wastes– the problem still exists. In this case, the trash bins' performance is less than optimal. In fact, the lack of interest from the people in sorting the garbage properly is one of the key problems.

To solve it, a trash bin as the modification a vending machine can be implemented. It is also known as a Reverse Vending Machine (RVM). In its essence, a vending machine provides a product when the user puts a certain amount of money. Thus, the RVM rewards the user by a certain amount of money in accordance to the product put into it. It is also possible to put multiple items, and the machine will accumulate all of them before giving the rewards. By this feature, hopefully people will be attracted and gain interest in putting garbage into the trash bin [2]–[7].

In this work, the authors focus in designing and implement the RVM. It is designed to be able to detect plastic bottles and cans, and rewards the user based on the total number of both objects. For convenience, the word bottle which refers to the plastic bottle will be used throughout this paper. In addition, each type of trash has one specific trash bin in the RVM, thus the machine is able to do sortation automatically. All trash bins are also automatically checked whether they are already fully filled or not.

The rest of this paper is designed as follow. Section 2 elaborates several related works in this topic, as well as the difference with this work. Section 3 focuses in the discussion on software and hardware implementation of the machine. Section 4 explains the result. Finally, Section 5 concludes this paper.

II. RELATED WORKS

This section focuses on the discussion of comparison between this work and three previous works. There are several points that differentiate several researches on this topic. One is the type of garbage along with the sensor installed to detect it, as well as the microcontroller. Besides, it is also possible to see if the system has any display on it. Finally, what the reward will be, as well as how it will be given.

Authors in [2] designed a RVM to handle bottle-type garbage with infrared sensor. Even so, the bottles were limited to three sizes, i.e., 300 ml, 600 ml, and 1500 ml. The machine had an LCD to display the information to the user, and LEDs to indicate the size of the bottles. The reward was a ticket and was calculated based on the number and the size of bottles. The machine designed by authors in [3] were able to take bottles and cans, with LDR sensor and inductive proximity sensor for respective objects. A loadcell was installed to measure the weight of the objects, especially make sure that they are empty. The reward was given via a website. Authors in [4] designed a machine with infrared sensors to detect bottles with multiple sizes. In this case, the machine gave rewards in a form of stationary tools. In contrast, this work implemented TCRT5000 as the sensor which detected bottles, and inductive proximity sensor to detect cans. An LCD was installed to display the information. In addition, a buzzer and LED were installed to inform the user when an object was put it. Finally, the reward was calculated based on the number of bottles and cans, and a thermal printer printed out a ticket that could be exchanged with rewards such as voucher. The comparison is shown in Table I.

III. System Design

In this section, the discussion mainly covers the software and hardware design of the system. The discussion starts with the block diagram of the system. After that, the flowchart of the system is explained. Then the pin configuration, as well as the hardware implementation is discussed. Finally, the section discusses the methodology used to evaluate the RVM.

A. Block Diagram

The RVM used an Arduino UNO as the microcontroller. As mentioned previously, the system had TCRT 5000 sensor to detect bottles, and inductive proximity sensor for cans. Practically, the TCRT 5000 sensor was used to detect whether the inserted object was a plastic bottle or not, while the inductive proximity sensor was used to detect if it was a can. After that, servo motors would separate the object to a different trash bin. At the same time, the system counted the total of each object, and an LCD displayed the result. A push button was installed to let the user print out their reward via a thermal printer. In addition, ultrasonic sensors were installed to detect whether the trash bins were already full or not, and three LEDs were installed to notify different information about the machine. The block diagram of the system is shown in Fig. 1.

B. Flowchart

The systems started by initiating the hardware components. After everything had been powered on, the LCD displayed first text of “Welcome to RVM Put Your Trash”. For the rest of this paper, this text is referred as text0. At the same time, first LED (i.e., LED1) is lighted on, indicating the push button for the thermal printer was not pressed yet. Then, the user can put the garbage in. One ultrasonic sensor was installed to detect trash bin of cans (i.e., U1), and another one for trash bin of bottles (i.e., U2). In this case, since the distance between ultrasonic sensor and the trash bin mouth was approximately 40 cm, then the threshold was set to 41 cm. If the distance read by the sensor was less than the set value, then the trash bin would be considered as full. As the notification, a LED was installed for each sensor (i.e., LED2 for trash bin of cans, and LED3 for trash bin of bottles). Thus, if U1 detected the trash bin as full, then LED2 would be turned on. If U2 detected the trash bin as full, then LED3 would be turned on. It was also possible for both LED2 and LED3 turned on at the same time.

In this case, there were four possible conditions based on the status of LED2 and LED3. The first one was when both of them were turned off. The LCD was set to display the text1, which showed the total of bottles and cans put in. The machine kept counting both objects until the push button was pressed. As soon as the push button was pressed, the system calculated the final amount of reward based on the number of both objects, and printed the result as a ticket. Another case was when it was only the trash bin of bottle was full, which was indicated by LED3. In this case, the system would only count the number of cans. The LCD kept updating the display, showing the total of cans put in, and zero amount for the bottles. For the rest of this paper, this text is referred as text2. Similarly, as soon as the push button was pressed, the system stopped counting and printed the amount of reward in a ticket for the user. The third case was when only the trash bin of cans was full, which was indicated by LED2. The system would only count the number of bottles until the push button for the thermal printer was pressed. The LCD kept updating the display, showing the total of bottles put in, and zero amount for the cans. For the rest of this paper, this text is referred as text3. Last, when both trash bins were full, both LED2 and LED3 were turned on and the LCD displayed a text of “The RVM's Full Try Next Time”. For the rest of this paper, this text is referred as text4. Additionally, every time the ticket was printed, the LCD displayed a text of “Thank you for saving the Earth”, which will be referred as text5 for the rest of this paper. The main flowchart of this system is shown in Fig. 2.

For the detection of the bottles, the system started by taking the digital input from the TCRT5000 sensor. If the input voltage was high, then the system chose to set the object as a bottle. In turn, the servo opened the way for the bottle to get into the trash bin. If the voltage was low, then the system determined that it was not a bottle.

For the detection of the cans, the flow was similar to bottle detection. The difference was only in the sensor, where an inductive proximity sensor was used in this case. Another servo would be opened to let the cans get into the correct trash bin.

For the thermal printer, a template text had been assigned. Here, it printed out the total amount of bottles, cans, and the total reward obtained. The flowcharts for the detection of bottles, cans, as well as the thermal printer’s push button are shown in Fig. 3.

Table I. Related Works

Parameter	**References**			**This work**
	[2]	[3]	[4]	
Bottle Detector	IR sensor	LDR sensor	IR sensor	TCRT-5000
Cans Detector	N/A	Yes	N/A	Yes
Notification	N/A	N/A	N/A	Yes
Display	LCD 20x4	N/A	LCD 16x2	LCD 16x2
Micro-controller	Arduino UNO	Arduino Mega 2560	Arduino Mega 2560	Arduino UNO
Rewards	Yes	Yes	Yes	Yes
Size-Weight Indicator	Only for size	Both	Only for size	N/A

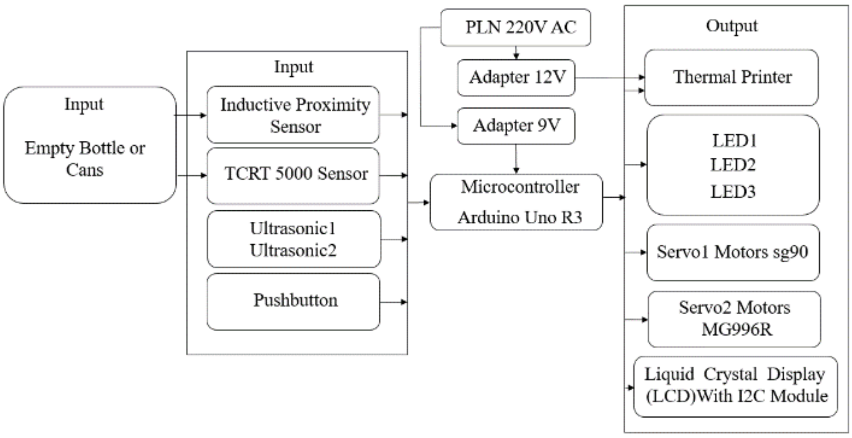


Fig. 1. Block diagram of the proposed RVM

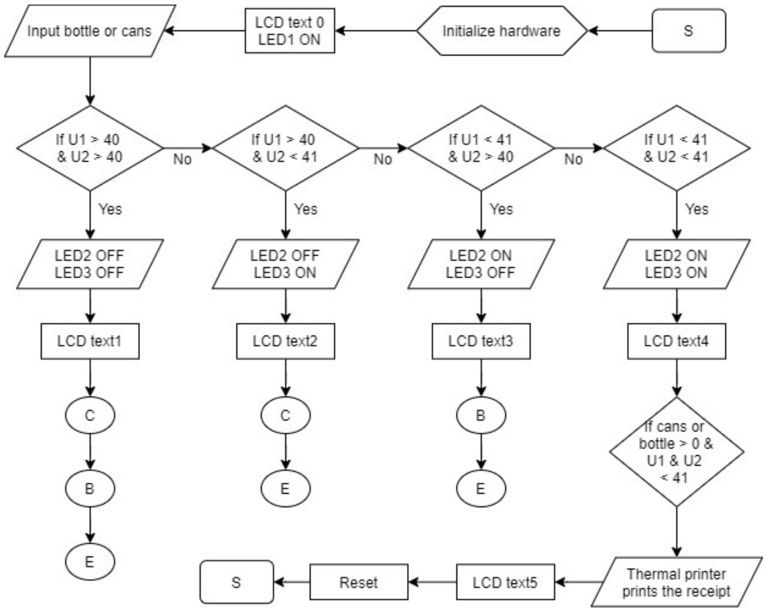


Fig. 2. Main flowchart of the system

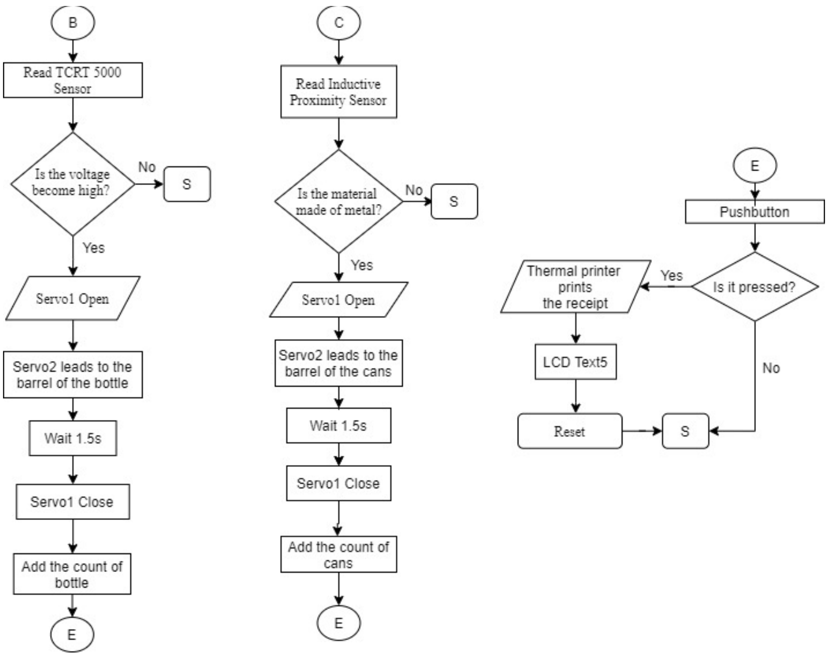
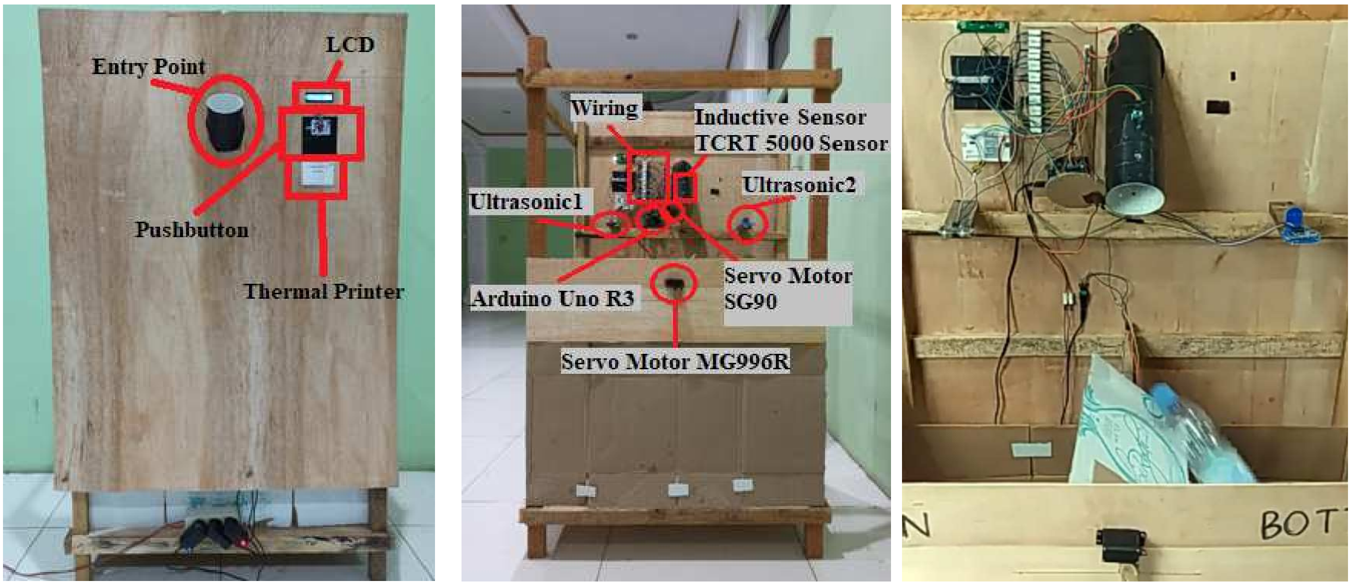


Fig. 3. Flowchart for object detection and the printer



(a) (b) (c)

Fig. 4. Hardware implementation from the (a) front view, (b) back view, (c) close-up view of the back

C. Hardware Implementation

The physical implementation of the RVM is shown in Fig. 4. The body was built by using plywood, which was common as hardware component. The overall size of the machine was 150 cm in height, 90 cm in length, and 70 cm for its width.

Based on the block diagram presented in Fig. 1, the pin configurations of the Arduino UNO can be seen in Table II. For simplicity, the pins are only for the data, not the power. All units were powered on by the 5V pin in Arduino UNO, while the thermal printer had its own 12V adapter for its power. In this case, the sensor output from the inductive proximity sensor was connected to digital pin 2 in the Arduino. The TCRT5000's analogue output was connected to the A0 pin, while its digital output was connected to pin 7. LED1, LED2, and LED3 were connected to pins 3, 9, and 13, respectively. The push button was connected to pin 12. The first servo motor (i.e., SG90) was controlled via pin 8, while the second servo motor (i.e., MG996R) was connected to pin 4. The first ultrasonic sensor was connected to pin 5, while the second was connected to pin 6. The LCD had the I2C module to simplify the connection to the Arduino, where its SDA and SCL pins were connected to pins A4 and A5, respectively. Finally, the thermal printer had its pins connected to pins 10 and 11 of the Arduino UNO.

D. RVM Testing

To evaluate the performance of the RVM, several bottles and cans were used. Table III shows several brands along with their physical properties. There were four kinds of bottles and three kinds of cans. As for the physical properties, there are height in centimeter (denoted as H), diameter in centimeter (denoted as D), and weight in gram (denoted ad W).

TABLE II. PIN CONFIGURATIONS

Unit	Pin Name	Arduino
Inductive Proximity Sensor	Out	2
TCRT5000 Sensor	A0	A0
	D0	7
LED1	Pin	3
LED2	Pin	9
LED3	Pin	13
Push Button	Pin	12
Servo 1 (SG90)	Pin	8
Servo 2 (MG996R)	Pin	4
Ultrasonic 1	Pin	5
Ultrasonic 2	Pin	6
LCD (I2C Module)	SDA	A4
	SCL	A5
Thermal Printer	Tx	10
	Rx	11

TABLE III. DATA OF SEVERAL BOTTLES AND CANS

Unit	Brand	H (cm)	D (cm)	W (g)
Bottles	Aqua (600 mL)	22.5	6.5	14
	Le Minerale (600 mL)	24	6.5	16
	Pocari Sweat (500 mL)	21	6.5	15.4
	Mizone (500 mL)	21.5	6.4	16.3
Cans	Milo (240 mL)	13.2	5.2	12
	Bear Brand (189 mL)	10	5	10
	Lasegar (320 mL)	11	6	13

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TABLE IV. PRICES FOR BOTTLES AND CANS

Type	Cost/kg (Rp)	Cost/g (Rp)
Plastic Bottles	2,500	2.5
Cans	8,000	8.0

Since there was no sensor to measure the object's weight, this RVM did not consider the weight for the reward. In this case, the reward was calculated only by the number of bottles and cans put in. Based on the Garbage Bank article in Bangarna 2020 [8], the prices of a clean plastic bottles can be set to Rp 2,500 per kg, while the dirty one can be set to Rp 1,500 per kg. As for the cans, the price was higher at Rp 8,000 per kg. Table IV shows the prices per kg, as well as per gram. In this work, the RVM was set to give a reward of Rp 25 per bottle, and Rp 80 per can, where both objects were assumed to have the weight of 10 grams.

IV. RESULT AND DISCUSSION

The result is shown in the form of a table. In the column header, S1 stands for the inductive proximity sensor, while S2 stands for the TCRT5000. U1 and U2 stand for the ultrasonic sensor at the cans and bottles trash bin, respectively. B1 and B2 are the counting of the system for cans and bottles, respectively. PB stands for the push button that controls the thermal printer, which is shown in the last column with the header of TP. Since there are three LEDs, the performance from each of them is shown separately.

The result shown in S1 and S2 is in binary condition, with only yes or no. In this case, the table uses a checklist for a yes or detected or equivalent meaning, while a dash represents a no or not detected or equivalent term. Since U1 and U2 are the results for ultrasonic sensors, the result is basically in the form of a distance. To be specific, it is in the unit of cm. however, for simplicity, the system was set to have a binary classification for both sensors, where the result can only be either greater than 40 cm, or less than 41 cm. the result in B1 and B2 also come in binary state, where the result can only be either "+1", meaningly that the counter for the respective object was increased, or a dash when the respective counter was not increased. The PB's result comes in ternary state. A checklist means it is pressed and working successfully. On the other hand, a dash means that the button was not pressed. A cross sign (X) represents that the button was pressed but there was no response from the thermal printer. For the LCD, the result is shown with six options, which are text0, text1, text2, text3, text4, or text5. Finally, the LEDS and the TP also come with binary state where a check list means that the units were turned on, and a dash represents the opposite.

Table V shows the result for the performance testing. The evaluation was done in four stages. The first one was when both trash bins were empty with nine tests. For the U1 and U2, the sensors did a perfect measurement. When there were no objects put in, both S1 and S2 did not detect any object, which is perfect. The B1 and B2 counter were not changed as well. But when the PB was pressed, there was no response from the thermal printer. In this case, the RVM prevented the user to print a ticket when there was no trash put in. In the second and third instance, the bottles were put in. In this case, S2 detected the objects perfectly, and B2 was increased. the LCD also showed text1, which is correct. Additionally, PB was not pressed, there was also no response coming from the TP. The similar result was also obtained when cans were put it. In this case, the S2 did not make any detection, but the S1 did. At the same time, B1's counter always increased, and the LCD updated the information as text1 at all time. At the ninth instance, when the PB was pressed, the LCD displayed text5, and the TP turned on and printed out the ticket.

The next five tests show the testing result when both trash bins were fully filled. At all instances, U1 and U2 were able to make a perfect measurement. In this case, when a can of bottle were put in randomly five times, both S1 and S2 did not make any detection, thus B1 and B2 were not increased as well. The PB also declined the request to print out the ticket, thus the TP did not make any printing. Additionally, since both trash bins were full, both LED2 and LED3 were turned on, and the LCD displayed text4 at all time.

The next five tests show the testing result when only the trash bins for bottles were fully filled. At all instances, U1 was able to make a detection perfectly, as well as U2. Since bottle's trash bin was full, the LED3 was also turned on at all time. Thus, when a bottle was put in, S2 did not make any reaction, thus no increment in B2. As cans were inserted in, S1 made perfect detection, and B1 was increased perfectly. In this case, the LCD displayed text2 at all instances, except at the fifth attempt where the user pressed the PB. In that case, the LCD displayed text5, and the TP was turned on.

The last five tests showed the testing result when only the trash bins for cans were fully filled. At all instances, U2 was able to make a detection perfectly, as well as U1. Since the can's trash bin was full, the LED2 was also turned on at all time. Thus, when cans were put in, S1 did not react, thus no increment in B1. As bottles were inserted in, S2 made perfect detection, and B2 was increased perfectly. In this case, the LCD displayed text3 at all instances, except at the fifth attempt where the user pressed the PB. In that case, the LCD displayed text5, and the TP was turned on.

After all of the test, the RVM showed perfect responses in all four conditions within several attempts. Overall, after 24 attempts of testing, the successful rate was found to be 100%.

V. CONCLUSION

To sum up, this work focused on designing and implementing an RVM that is able to give a reward to people that throw trashes into it. Specifically, the machine was able to detect bottles by using TCRT5000 sensor and cans by using an inductive proximity sensor. Both trashes were sorted into one trash bin directly, and the reward was calculated directly based on the total of bottles and cans put into it. A push button can be pressed to print out the ticket, but it would decline the request when there were no bottles or cans put in. In addition, ultrasonic sensors were installed to automatically check the trash bins of the RVM, and LEDs were used to notify the user whether the trash bin of bottler or cans was already full or not. After 24 attempts of testing, the successful rate was found to be 100%.

TABLE V. PERFORMANCE TESTING

No	Object	S1	S2	U1	U2	B1	B2	PB	LCD	LED			TP
										1	2	3	
1	-	-	-	>40	>40	-	-	X	Text0	✓	-	-	-
2	Bottles	-	✓	>40	>40	-	+1	-	Text1	✓	-	-	-
3	Bottles	-	✓	>40	>40	-	+1	-	Text1	✓	-	-	-
4	Cans	✓	-	>40	>40	+1	-	-	Text1	✓	-	-	-
5	Bottles	-	✓	>40	>40	-	+1	-	Text1	✓	-	-	-
6	Cans	✓	-	>40	>40	+1	-	-	Text1	✓	-	-	-
7	Cans	✓	-	>40	>40	+1	-	-	Text1	✓	-	-	-
8	Cans	✓	-	>40	>40	+1	-	-	Text1	✓	-	-	-
9	Cans	✓	-	>40	>40	+1	-	✓	Text5	-	-	-	✓
10	Cans	-	-	<41	<41	-	-	X	Text4	✓	✓	✓	-
11	Bottles	-	-	<41	<41	-	-	X	Text4	✓	✓	✓	-
12	Cans	-	-	<41	<41	-	-	X	Text4	✓	✓	✓	-
13	Cans	-	-	<41	<41	-	-	X	Text4	✓	✓	✓	-
14	Bottles	-	-	<41	<41	-	-	X	Text4	✓	✓	✓	-
15	Bottles	-	-	>40	<41	-	-	-	Text2	✓	-	✓	-
16	Bottles	-	-	>40	<41	-	-	-	Text2	✓	-	✓	-
17	Cans	✓	-	>40	<41	+1	-	-	Text2	✓	-	✓	-
18	Cans	✓	-	>40	<41	+1	-	-	Text2	✓	-	✓	-
19	Cans	✓	-	>40	<41	+1	-	✓	Text5	-	-	✓	✓
20	Cans	-	-	<41	>40	-	-	-	Text3	✓	✓	-	-
21	Bottles	-	✓	<41	>40	-	+1	-	Text3	✓	✓	-	-
22	Bottles	-	✓	<41	>40	-	+1	-	Text3	✓	✓	-	-
23	Bottles	-	✓	<41	>40	-	+1	-	Text3	✓	✓	-	-
24	Cans	-	-	<41	>40	-	-	✓	Text5	-	✓	-	✓

For future development, this RVM can be improved by adding a sensor that can measure the weight, thus, the reward can take it as a consideration. Additionally, the RVM can also be improved by replacing thermal printer with RFID, so the machine can be used without using papers. In that case, the reward can be transferred digitally.

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