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Design and Development of a Web-Based Smart Recycling System based on a Survey on Recycling Awareness

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ABSTRACT

Everyone is aware that recycling reduces the amount of waste that ends up in landfills, but the biggest environmental advantage of recycling is the preservation of energy and natural resources, as well as the reduction of pollution that results from the use of raw materials to create new products. The energy wasted in the disposal of products like aluminium cans and newspapers that can be recycled is equal to the annual output of fifteen power plants. The goal of this study is to determine how much faculty and students at UTHM are aware of recycling. Out of the roughly 18,000 pupils enrolled at the institution, 450 locals were chosen as the study's sample. According to Mitchell and Jolly, the populations require a minimum sample size of 374 samples, a 95% confidence level, and a 5% margin of error. There were tick boxes, a Likert scale, and slots for other suggestions to indicate responses. Residents are eager to engage in recycling activities, according to poll results, if more recycling facilities and technologies, such reward and redemption systems, are made available to them. Therefore, a strong program like the Web Automated Bin Recycle (WARB) System is necessary to address these problems. The carbon emission avoidance (tCO2e) calculator, which is part of WARB's core module, is used to calculate the total amount of CO2e generated by the weight of each material since each material has a unique CO2e reading. User acceptance testing (UAT) and functionality testing are the two types of evaluation tests used to assess WARB. The software system's compliance with their functional requirements or specifications has been successfully validated. The UAT results show that most users are content with the functionality and aesthetics of the system interface.

1. Introduction

Due to their large populations, universities like Universiti Tun Hussein Onn Malaysia (UTHM) can be considered mini cities. Waste management is a recurring issue for the institutional sustainability of this tiny city, which has a population of just under 20,000. The amount of waste created increases in tandem with global population growth. Recycling is becoming a vital practice as a result. Reusing

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materials for their original use or for another is the process of recycling, which removes waste from the original use of the material.

There are many different viewpoints and studies on recycling practices that strive to explain why people should recycle certain things [1]. The public debate over how to reduce waste to conserve natural resources is increasingly heated. There is a general awareness of the environmental consequences of waste, which is reflected in the legislative environment. Recycling is widely regarded as the preferred method of waste reduction [2].

However, very little is understood by staff and students about recycling to cut waste. For instance, using plastic straws with cold beverages has nearly become the norm. Contrarily, plastic straws are not biodegradable and can only break down into tiny pieces of plastic [3]. Garbage segregation bins were accessible in some places. But all these efforts were in vain. Some of them might think it's simpler to toss all the trash in one bin rather than separate it.

The best recycling management system for UTHM is being attempted, and this study evaluates such attempts with a focus on the behavioral problems that contribute to low recycling participation. To determine what was required and where it could be found, a survey of the campus community's recycling practices was conducted. The responses are essential for fostering pro-recycling attitudes and behaviors among communities as well as for strengthening recycling management systems.

1.1 Recycling Management in UTHM

A task team was established by the vice chancellor of UTHM to develop a comprehensive vision for the university's environmental sustainability initiatives. The first step taken by UTHM in tackling campus sustainability issues in a sensible, logical, structured, and effective manner was the founding of the Sustainable Campus Office (SCO), which provides administrative leadership and coordination for the construction of green campus efforts generally. SCO oversees organizing, creating, and putting into action clever and avant-garde sustainable solutions in order to create an environmentally sustainable campus at UTHM.

As illustrated in Figure 1(a), SCO developed a recycling collection center that was open daily from 9 a.m. to 4 p.m. to better serve its customers. Figure 1 shows the procedure for the existing recycling management (b). Customers are currently compensated in cash according to the weight of the recycled garbage. In addition, each faculty on campus has a little recycle bin to encourage students and staff to recycle.

Fig. 1. (a) Recycling collection center in UTHM; (b) Current recycling management process

1.2 Recyclable Materials Management

Recycling is now a big deal in almost every developed country. Many people are beginning to realize that protecting the environment also entails making wise use of available resources. While this is admirable, there are some questions about how to perceive certain things. One of those grey areas is determining what recyclable materials are. There are numerous materials available on Earth; however, does this mean that all materials are recyclable? No. When it comes to recycling, not all materials are recyclable.

This is because they are unfit for human consumption and are not recyclable. The recyclable materials are those that are placed in the recycling bin [4]. Material separation is frequently required prior to recycling a multi-material product. This category contains many manufactured goods. Plastic, basic metals, and precious metals, for example, can be used to manufacture a mobile phone or television board. Material separation becomes more difficult as the number of material types used in a product grows [5].

As shown in Eq. (1), each recyclable material has a different reading of carbon emission (CO2e) [6]. In assisting the United Nations' 12th Sustainable Development Goal, which focuses on ensuring sustainable consumption, carbon emission avoidance reading for each material is highlighted. Table 1 shows the recyclable material list while Table 2 explains the formula for calculating each CO2e avoidance based on the weight of each respective material.

Total waste (kg) * Emission Factor (kg CO2e/ton)]/1000 (conversion unit kg to ton) (1)

Table 1
Recyclable material list

Waste Material	Category Classification
Organic Food & Drink	General
Glass	General
Clothing	General
Landscape	General
Electronic	WEEE - fridges and freezers
Waste from Electrical and Electronic Equipment (WEEE)	WEEE - large
	WEEE - mixed
	WEEE - small
	Batteries
Metal	Mixed cans
	Scrap metal
	Steel cans
Aluminum	Cans
	Foils
Plastic	Average plastic
	Plastic Film
	Plastic Rigid
	High Density Polyethylene (HDPE)
	Low Density Polyethylene (LDPE) and
	Linear Low-Density Polyethylene (LLDPE)
	Polyethylene Terephthalate (PET)
	Polypropylene (PP)
	Polystyrene (PS)
	Polyvinyl Chloride (PVC)
Paper	Cardboard
	Paper
	Mixed paper and cardboard

Table 2
Carbon emission avoidance calculation formula [7]

Waste Material	Emission Factor	Calculation Example (for 20kg of waste)
Organic Food & Drink	8.951	0.179 tCO2e/kg
Glass	8.902	0.178 tCO2e/kg
Clothing	444.943	8.899 tCO2e/kg
Landscape	578.959	11.579 tCO2e/kg
Electronic	8.902	0.178 tCO2e/kg
Metal	8.902	0.178 tCO2e/kg
Aluminum	8.902	0.178 tCO2e/kg
Plastic	8.902	0.178 tCO2e/kg
Paper	1,041.804	20.836 tCO2e/kg

2. Methods

Figure 2 depicts the percentage of recycling activity at UTHM over a five-year period. Because of the Covid-19 virus outbreak, there will be a significant drop in 2020 and 2021 [8]. Because employees and students are required to stay at home during those times, only a few stayed on campus alternately.

A survey of thirty-one questions was developed, with four sections: (A) general information; (B) current recycling management behavioral pattern; (C) recycling activity awareness; and (D) recycling facility and technology provided. Tick boxes and a Likert scale were used to indicate responses, with spaces provided for additional suggestions. A sample of four hundred fifty residents was drawn from a total campus population of approximately eighteen thousand students. A minimum sample size of three hundred seventy-four samples is required for the populations with a confidence level of 95% and a margin of error of 5% [9].

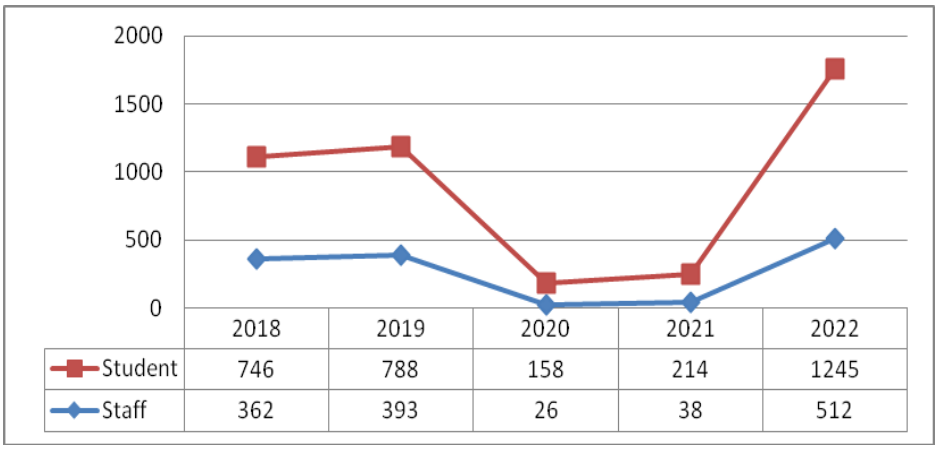


Fig. 2. Recycling trend in UTHM from year 2018 until 2022

3. Results and Discussions

The total number of respondents was four hundred fifty respondents, consisting of one hundred forty-two staff and three hundred thirteen students from over 45 faculties and departments within UTHM. The total percentage of each category are shown in Figure 3 and they were randomly selected for the survey.

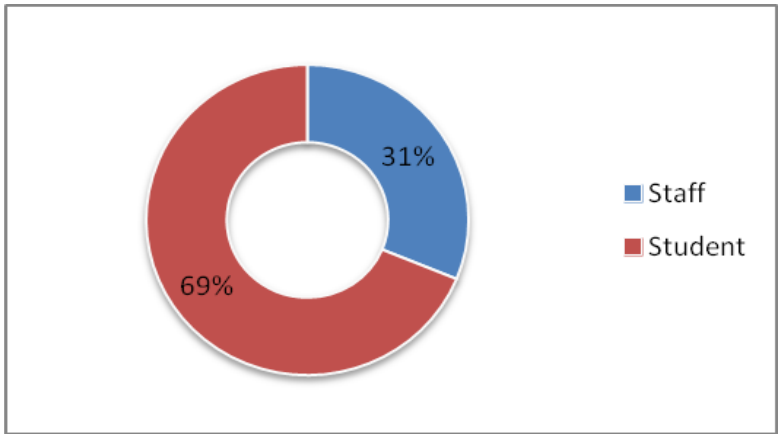


Fig. 3. Level of residency in Universiti Tun Hussein Onn Malaysia

3.1 Behavioural Pattern of Current Recycle Management

Initially, the questionnaire was used to determine how many people were aware of the existing recycling programmes and facilities on campus. The survey is then expanded to investigate the current recycle management behavioural pattern. Questions in Section B that were designed to investigate the pattern and suitable medium for informing residents about recycling programmes and facilities. More than half of the population is unaware of the recycling programme announcement due to a lack of publicity and awareness among them.

According to the result of the survey, Figure 4(a) depicts the frequency of recycling in four-time sequence- daily, weekly, monthly or never recycle. It is comforting to know that there are only a few people on campus who never recycle. The results are quite convincing that the majority of them recycle in their daily lives, even on a monthly basis.

Figure 4(b) listed the methods that are commonly employ when recycling. The survey specifies four main recycling methods, allowing respondents to select the most convenient: (a) Collect all waste material into the same container; (b) Separate waste into its categories; (c) Make the material into smaller pieces before separating according to its categories and (d) Send to recycle centre in bulk amount. As expected, method B is the most selected as a convenient way to recycle.

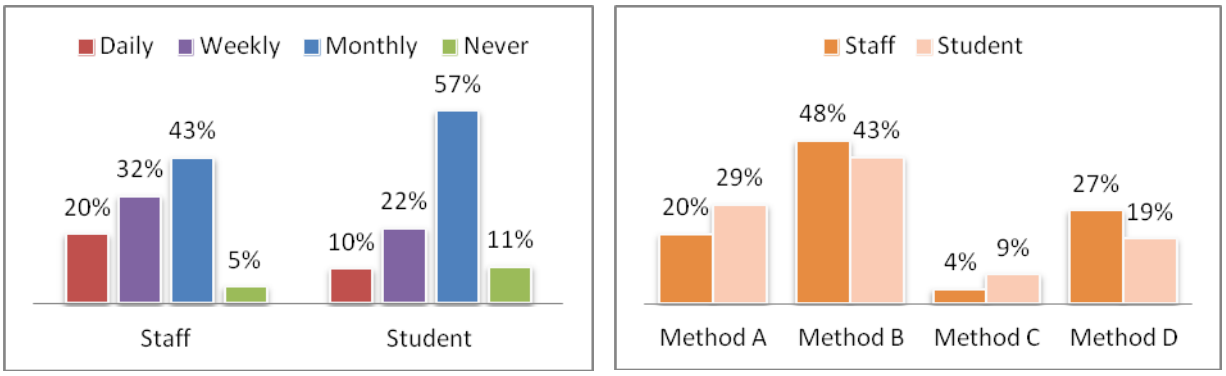


Fig. 4. (a) Recycling frequency by residents; (b) Method preferred by residents

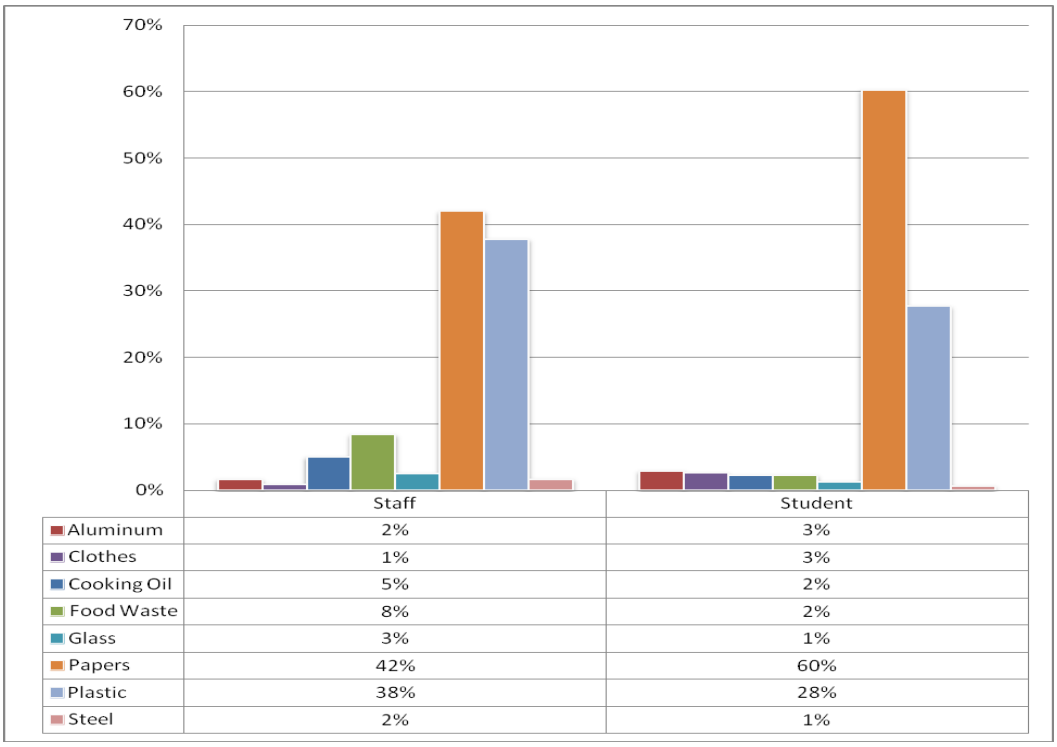
Aside from studying the behavioural pattern and preferred method, one of the main issues in this survey is the type of recyclable materials. This is to see which materials occupy the most space in the centre. As a result, SCO can provide storage space based on the weight of its collection as displayed in Figure 5. It has been identified that most of the waste collected on campus is paper and plastic waste, which may be the result of examination papers, official documents, and mineral water bottles.

It is commonly recognised that producing paper has a significant negative impact on the environment. The use of raw materials and their processing has several detrimental effects on the environment [10].

There are technological advancements that can reduce adverse environmental effects while also having a beneficial economic impact. The recycling is just one of many procedures. Inadequate and ineffective trash collection, recycling, or treatment, as well as the unrestricted disposal of organic waste in dump sites, could have serious consequences, including health risks to people and pollution to the environment. Waste management can be handled effectively in most cases if the policy, actions, and guidelines are widely implemented into the level of action [11].

Figure 6 explains on the recycling notification that are send over multiple platforms such as official website, e-mail, and social media. Data collection indicates that both staff and students are aware of the university's recycling activities. The question is then expanded to know which platform they prefer the most for the announcement notification.

Based on Figure 7, the most preferred platform is via e-mail on staff's side and official website on the students' side. It is more likely because staff check emails in their daily tasks, making it easier for them to stay up to date on the latest activities organised by SCO UTHM through this medium meanwhile students are often check for news and updates regarding university's activities and announcement on the official website.



	Staff	Student
Aluminum	2%	3%
Clothes	1%	3%
Cooking Oil	5%	2%
Food Waste	8%	2%
Glass	3%	1%
Papers	42%	60%
Plastic	38%	28%
Steel	2%	1%

Fig. 5. Recycled material statistics

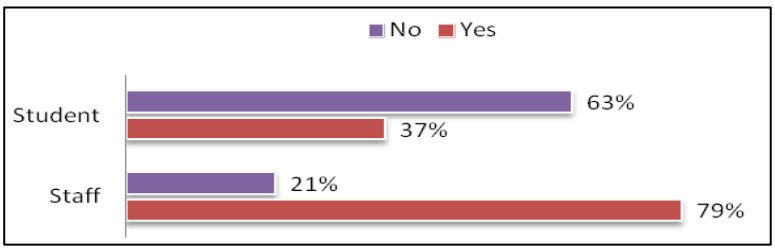


Fig. 6. Percentage of notification on recycling activity received

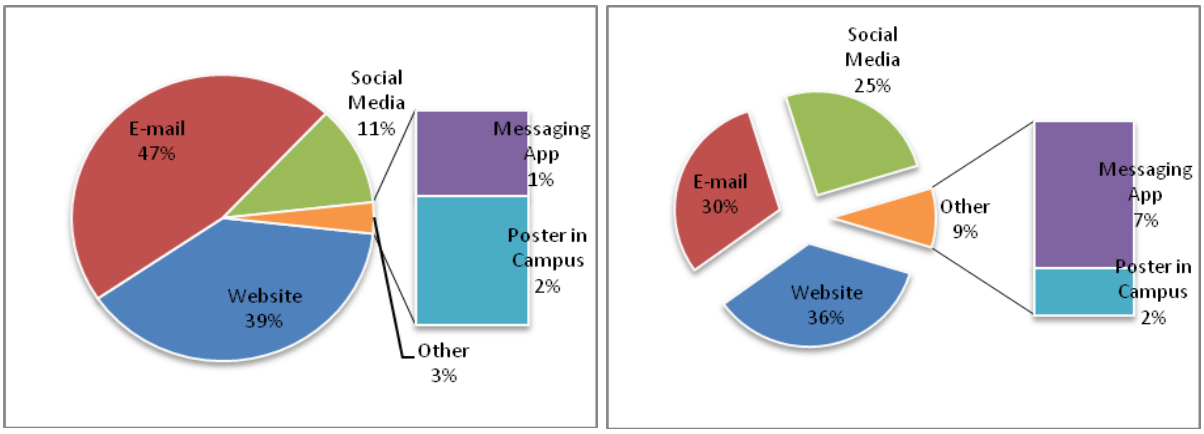


Fig. 7. (a) Notification platform staff's preference; (b) Notification platform students' preference

3.2 Awareness on Recycling Activity

Table 3 displays the results of the recycling awareness activity at UTHM (Section C). Question C1 was a continuation from the previous section, and it was designed to determine whether respondents were familiar with the recycling methods depicted in Figure 6. According to the findings, 59 percent of staff and 50 percent of students are familiar with the methods, while the rest are either unfamiliar or unsure of them.

Table 3
Section C questionnaire results

	Likert Scale	Category	Highly Agree	Agree	Neutral	Disagree	Highly Disagree
C1	You are familiar with recycling methods	Staff	52	31	22	16	21
		Student	77	78	72	56	30
C2	You have fun while recycling	Staff	50	31	23	21	17
		Student	82	80	72	41	38
C3	Recycling takes a lot of time, space and effort	Staff	25	32	30	32	23
		Student	56	67	88	61	41
C4	Recycling is not worthy unless there is a lot of waste	Staff	18	10	28	38	48
		Student	31	43	80	84	75
C5	You are aware of the term 4R: Reduce, Reuse, Recycle, Recovery	Staff	52	34	23	19	14
		Student	100	77	43	50	43
C6	You will recycle often if there is reward/redemption system	Staff	52	22	33	12	23
		Student	106	68	55	43	41

Based on the questions in Section C, it can be translated that most of the respondents prefer not to take part in recycling as it takes a lot of time and worthless to do it in a small amount. However, recycling, in a broad sense, is part of an ethic of resource efficiency - of using products to their full potential. Natural resources and energy are conserved when recycled materials are used to make new products rather than raw materials.

Recycled materials have already been refined and processed once, the second manufacturing process is much cleaner and less energy-intensive than the first. Manufacturing with recycled aluminium cans, for example, uses 95 percent less energy than producing the same amount of aluminium with bauxite [12-13]. Nevertheless, according to the results of this section, 55.7 percent of the residents agreed that if there was a reward system and redemption of the results of recycling activities, they would be more enthusiastic to participate in recycling.

3.3 Facility and Technology Provided

The questionnaire was initially administered to determine how many were aware of the existing recycling programmes and facilities. Section D's goal was to research people's knowledge of the facilities and technology available. In recent years, environmental risk has emerged as one of the primary consequences of population growth [14-15]. The most serious of these issues is the increasing volume of garbage. As the world's population continues to grow at an unprecedented rate, waste management technology and facilities are viewed as an efficient approach to reducing the problem [16-17].

The questionnaire results are shown in Table 4. Based on the data collected for this section, it is estimated that 74 percent of respondents are unaware of the university's recycling facilities and technologies. Some of them stated that there are not enough recycling facilities available. As a result, as stated in question D2, 76.4 percent are pleased if more recycling centres or bins are added within UTHM.

Table 4
Section D questionnaire results

	Likert Scale	Category	Highly Agree	Agree	Neutral	Disagree	Highly Disagree
D1	You are aware with recycling center at UTHM	Staff	35	30	34	25	18
		Student	34	51	92	69	67
D2	You are happy if more recycling center/bin is available	Staff	57	31	18	19	17
		Student	96	71	71	41	34
D3	You prefer having an automatic recycling system to manage your recycling activity	Staff	56	35	20	12	19
		Student	111	72	52	37	41
D4	You prefer to store recycling receipts online compare to conventional receipts	Staff	57	20	31	13	21
		Student	102	54	74	42	41
D5	You prefer recycling if there is a web-based system that display all recyclers' activities status and reward	Staff	53	31	23	15	20
		Student	107	82	44	44	36

In response to question D4, only 28.3 percent of the total number of respondents prefer to store conventional receipts, while in response to question D5, 65.6 percent of the respondents, mostly from the Faculty of Computer Science and Information Technology (FSKTM), show positive feedback on having a web-based system that displays the recyclers' activity, while 31.2 percent do not like the idea of wasting another space in the web server for the sake of a simple recycling system. This is most likely because they found it difficult to log in before recycling. Nonetheless, there are plans in the future to develop the campus's own recycling application to make record storage easier for everyone.

4. Design and Development of the System

Web Automated Recycle Bin is a web-based application that is designed to manage recycling activities in recycle centres. The development of WARB adopts the Evolutionary Prototyping Methodology [18]. Table 5 shows the methodological phases and activities involved in the development methodology.

Table 5
Methodological phases and activities involved

Phase	Activity	Tools & Techniques	Result
Planning	• Proposal writing	• Microsoft Project • Microsoft Office	• Gantt chart • Proposal • Flowchart
Analysis	• Web Project Manager elaborate requirements • Organize and divide team task	• Microsoft Office • Draw.io	• Use case diagram • Class diagram • Activity diagram • Requirement • Traceability matrix
Design	• Design the interface • Design a database structure	• Photoshop CS6 • Sublime Text 3 • MySQL	• User interface • System database
Implement	• Creating encoding • Build a database • Connecting a database with the web	• Sublime Text 3 • MySQL	• Web based system • Report draft
Testing	• Alpha testing • Beta testing		• Web application testing • Test case
Completion	• Report completion	• Microsoft Office	• Final report

4.1. System Design

WARB is developed to cater both public users and administrative users of the recycling system. The landing page of the web-based system will navigate users to register, login or interact with the carbon emission avoidance calculator as shown in Figure 8. Personal information such as name, staff, or student ID number, contact number, email address and organization name are required upon registration.

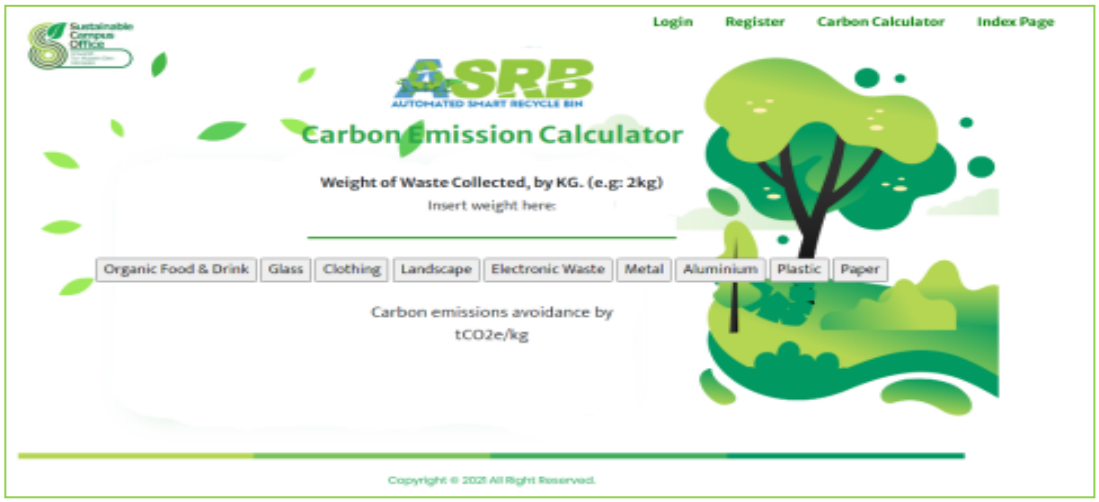


Fig. 8. CO2e avoidance calculator page

Besides the dashboard page, WARB also provides a platform of easy sustainable waste management, whereby admin users can manage the available recycle bins and the recyclable

materials with two modules of viewing list or adding new data into each respective page. These options can be viewed on the side menu navigation as shown in Figure 9.

The main objective of this project is to enable user to record their recycling activities, the recycling record feature is the core functionality in WARB. Admin users will be able to insert all the information needed upon recycling directly to the database as shown in Figure 10 (a). Once the information is recorded, details such as price and points earned, carbon emission avoidance reading, and redemption status are displayed. Users are given option to choose between three redemption method, by cash, vouchers or merchandise as shown in Figure 10 (b).

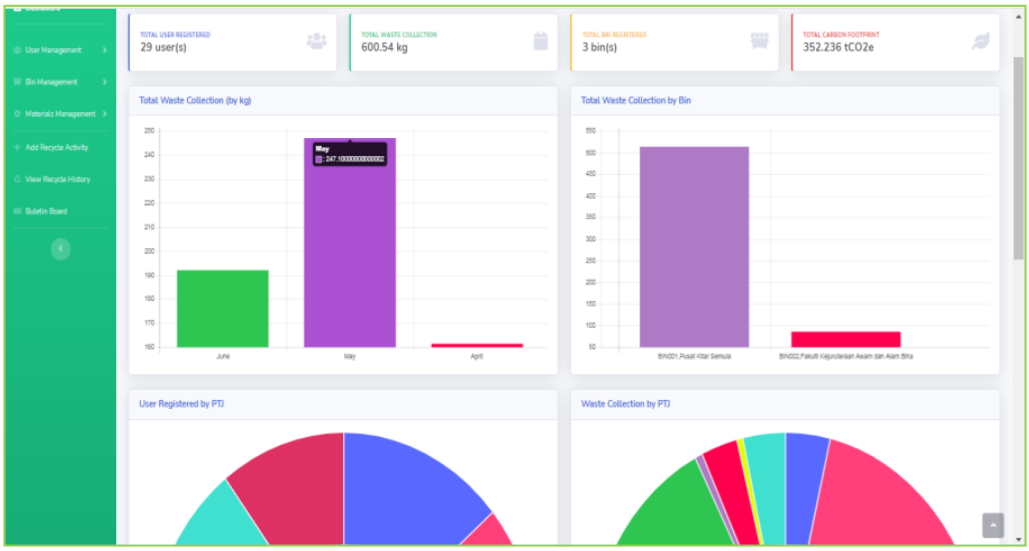


Fig. 9. Dashboard page for admin user

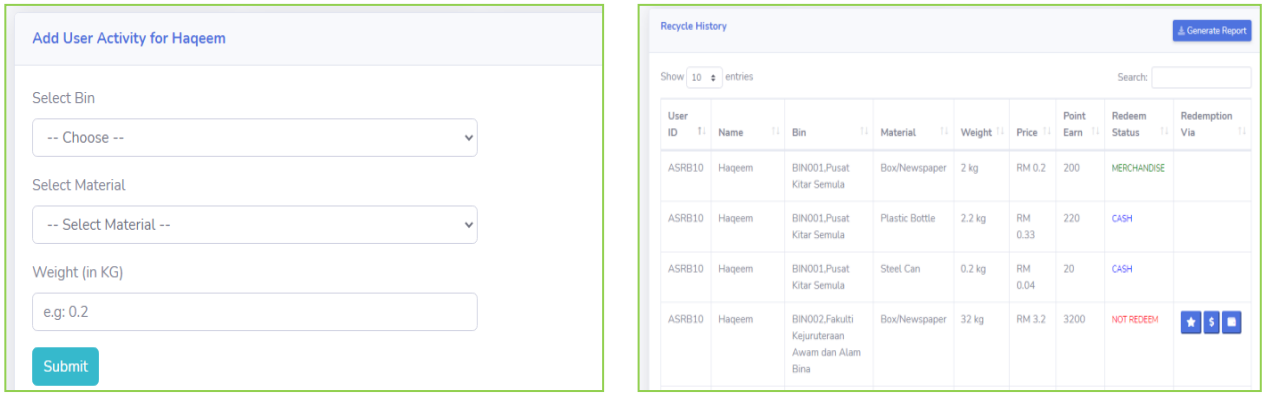


Fig. 10. (a) Add user recycling activity; (b) User recycle activity history

Meanwhile for user side, the main modules include dashboard, user profile, recycle history, voucher redemption list, recyclable materials and available bin list as displayed as shown in Figure 11 and Figure 12. On dashboard page, data and analytics from user's recycling activity are displayed on the top columns. Recyclable materials page displays the details for each material including the rate/kg.

Fig. 11. (a) User dashboard page; (b) Recyclable material list page

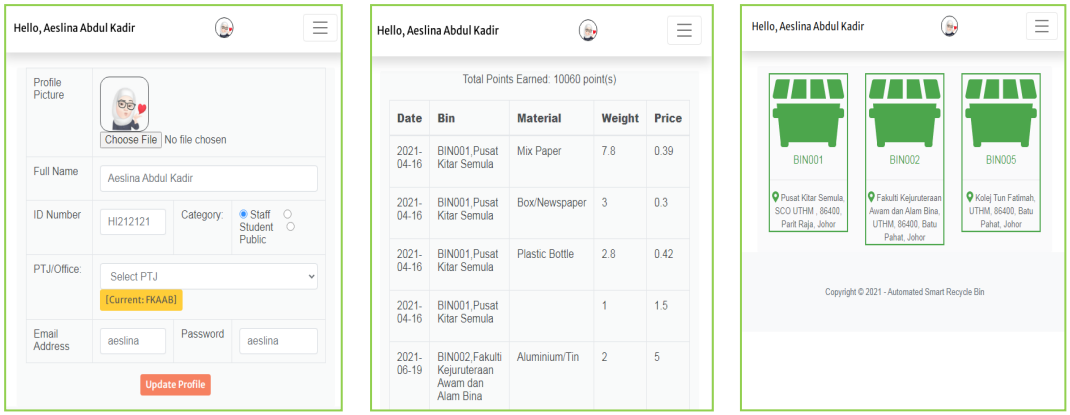


Fig. 12. (a) User profile page; (b) User recycle history page; (c) Available bin list page

4.2. System Evaluation

To validate the performance of the proposed WARB system, two types of testing are carried out, which are functionality testing and user acceptance testing.

4.2.1 Functionality Testing

Functional testing helps validate the software system of their functional requirements or specifications. Table 6 shows partial test case for the modules in Web ASRB for two actors, which are admin and user.

Table 6
Functional test result

Functionality	Expected Result	Test Result
Admin Side		
Views data and analytics on dashboard page	The dashboard displayed data and analytics in graph and chart form for easy view	SUCCEED
Manage ASRB registered users	Provides registration, alteration and deletion of user. *e.g: user ID ASRB0010 change contact number.*	SUCCEED
Manage ASRB available smart bin list	Provides registration, alteration, and deletion of bin. *e.g: BIN001 changes location*	SUCCEED
Manage ASRB recyclable materials	Provides registration, alteration, and deletion of materials. *e.g: rate of materials from 0.20/kg to 0.15/kg*	SUCCEED
Add user recycling activity for record tracking	Manage to store recycling information for each registered user	SUCCEED

System can calculate the price earned for each recycle transactions automatically	Generate price, points and carbon emission avoidance automatically once weight of waste collection inserted	SUCCEED
Manage user activity history	History can be altered if error occurs upon recycling record insertion	SUCCEED
User Side		
View recycling history and news or information on recycling event via bulletin board	Bulletin board is displayed as slideshow, history and analytics from recycling activities are displayed in attractive interface	SUCCEED
Update profile and view recyclable materials and available bin list with the complete details	Profile can be updated upon information change. All modules worked fine. Materials and Bin List page displayed correct information	SUCCEED
General Use		
On index page of the system, Carbon Emissions Avoidance Calculator will calculate the amount of tCO2e based on the total weight recycled.	Manage to calculate and generate the correct total of carbon emission avoidance	SUCCEED

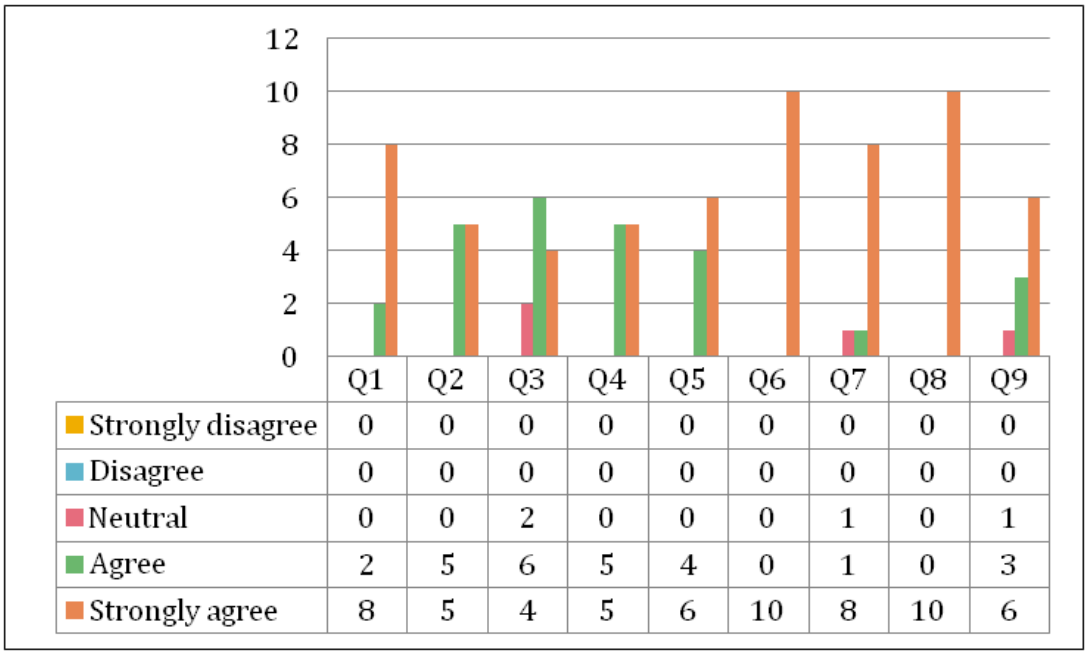
4.2.2 User Acceptance Testing

Figure 13 showed result for seven functionality and design questions answered by 20 users with scale 1 (least agree) to 5 (strongly agree). The questionnaire designed to identify the user interface suitability is listed in Table 7.

Table 7
Section D questionnaire results

Questions
1. WARB is user friendly
2. The layout of content on the web is appropriate
3. The text style and writing type chosen are appropriate and easy to read
4. The interface design (UI) is appropriate for the scope of the user
5. The dashboard page works fine. Analytics displays a summary of recycling information that users have done.
6. User profile display works fine. Users can also update personal information
7. A list of recycling activities is displayed in detail
8. Smart bin information and waste types are well displayed
9. Bulletin pages work well

From Figure 13, it is shown that most users agree and strongly agree with the system design interface and none of the user disagree and strongly disagree with the design interface which validate that the system design are delivered nicely to the audience.



	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Strongly disagree	0	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	0	0	0	0	0
Neutral	0	0	2	0	0	0	1	0	1
Agree	2	5	6	5	4	0	1	0	3
Strongly agree	8	5	4	5	6	10	8	10	6

Fig. 13. User acceptance test result

4. Conclusions

Along with the expansion in world population, trash production also rises. As a result, recycling is becoming an essential habit. Recycling is the process of removing waste from a material's first usage and reusing the material for that use or another.

Positive behaviour includes actions that show consideration for the environment and the needs of the present and future generations. Recycling is one such instance. What makes recycling necessary? What negative effects result from not recycling? To increase knowledge of these practices and secure universal acceptance, the answers to these questions have been published in a variety of print and electronic media.

However, these initiatives have mostly failed to inform and create awareness, and some individuals disregard them because they think recycling is a minor concern compared to other, more urgent problems.

The Web Automated Recycle Bin (WARB) system aims to improve the recycling process. By keeping track of the statistics of recycling activity, the monthly list of top recyclers, the total amount of carbon avoided, registered users and their recycling activities, total waste collection, and the total number of smart bins registered, this system's implementation helps the administrative manage waste more effectively and systematically. On the other hand, users can keep track of the overall amount of carbon emissions avoided by each recycling activity, accumulate points, and receive incentives online.

Consequently, by encouraging individuals to recycle frequently, this strategy may also help to civilize the recycling process. In conclusion, there is great potential for research into the factors influencing recycling intentions and behaviour in higher education institutions. College students, teachers, and staff, as well as the greater community of stakeholders, may be inspired by new methods to consumer involvement and encouraged to adopt more sustainable behaviours by recent technological breakthroughs.

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