Implementing a Cutting-Edge Recycling Web Application for Sustainable Progress in Tha Pho Sub-district: Empowering Residents and Recycling Industry Partners

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Abstract

This article explores the integration of circular business practices into sustainable digital entrepreneurship in Tha Pho district, Phitsanulok province, addressing local waste management challenges through a design thinking approach. By considering the local context, cultural nuances, and technological infrastructure, the study aims to create a user-friendly and effective platform. The design process involves prototyping, allowing for iterative feedback and customization through rigorous testing with community members, stakeholders, and waste management entities. This ensures that the platform meets local requirements and motivations, encouraging participation, collaboration, and sustainable digital practices. The goal is to foster engagement, promote sustainable behaviors, and utilize local resources to create an environmentally conscious digital landscape in Tha Pho. The study highlights the significance of user-centered design in developing efficient solutions for sustainable recycling practices. The research findings demonstrate high satisfaction with the NUZeroWaste Web application, with students giving an overall score of 4.00 and university outsiders rating it 4.42. Key benefits reported include improved accessibility to recycling knowledge, streamlined processes, and real-time feedback. The application also significantly reduced errors and negative feedback, showcasing its effectiveness over conventional methods. Overall, the NUZeroWaste Web application successfully enhanced recycling practices and promoted long-term sustainable behavior, underscoring its potential to address community-specific challenges in waste management.

Keywords: Phitsanulok, Recycling Business, Digital Entrepreneurship, Sustainable Development Goals, Web Application, Community Participation

Introduction

While Thailand is celebrated for its iconic tourist destinations, it grapples with substantial sustainability and waste management challenges. In response, the government has enacted a range of strategies, from international to local levels, to tackle these issues. These initiatives encompass Circular Economy endeavors, the Economic and Social Development Plan, and the adoption of the 3Rs (Reduce/Reuse/Recycle) strategy and practices. The present research seeks to elucidate these governmental policies while proposing practical solutions, with a particular focus on innovative tools within the recycling sector. (Office of Nation Resources and Environmental Policy and Planning, 2022)

Circular economy initiatives, spearheaded by the government, aspire to supplant linear economy models with more sustainable practices. These initiatives prioritize environmental conservation, waste reduction, and bolstering public income through recycling practices. Central to this concept is the minimization of waste across all stages of product and service design, manufacturing, and usage. It advocates for practices like reusing, repairing, recycling, and recovering unwanted materials to achieve sustainability. (Singtong, n.d.)

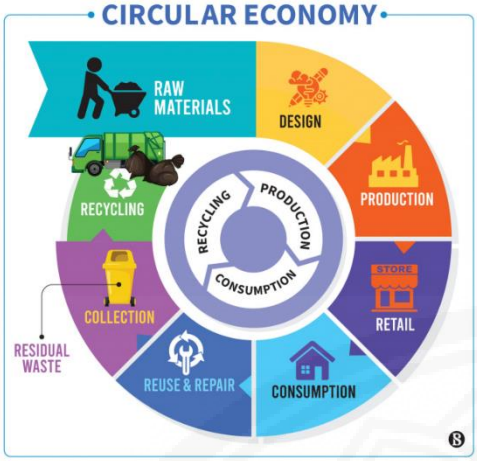

Figure 1 Circular Economy.

Source: Begum (2023).

Figure 2 SDG Goals.

Source: SDG Move (n.d.).

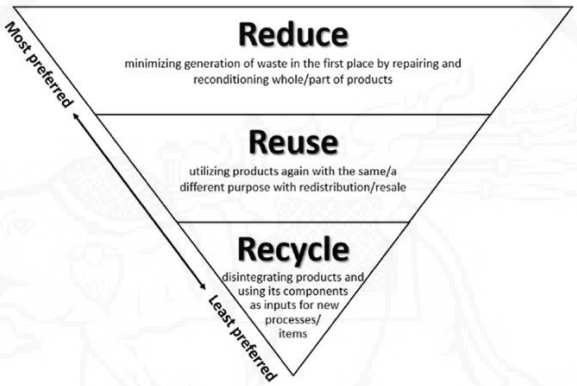

Figure 3 Strategies 3R Concept.

Source: Eser et al. (2016).

The overarching goal is to foster sustainable living through a zero-waste paradigm. Additionally, government support for recycling businesses can enhance economic opportunities, including boosting employment rates within the waste management sector. For example, reusable materials should be returned to factories for repurposing into new products. Implementing a modernized logistic waste management system is vital for standardizing waste collection practices. Furthermore, embracing new technologies to replace conventional tools can reduce costs, streamline processes, and pave the way for expanding into new business ventures. (In-ai, 2019)

Aligned with the national strategy and Sustainable Development Goal (SDG) Plan (Economic and Social Development Plan between 2018 and 2037), Thailand aims to eradicate poverty and reduce inequality within two decades. Consequently, there is a compelling need to prioritize sustainable solutions. These include encouraging recycling behaviors, fostering the growth of new recycling businesses, and expanding recycling education centers. Promoting recycling behaviors is crucial for significantly reducing total waste and mitigating the adverse effects of dumping and landfilling. Additionally, supporting the growth of recycling businesses not only adds value to waste but also creates opportunities for new business owners, thereby contributing to poverty reduction. Enhancing recycling education centers through both online and offline channels is essential for addressing the lack of waste management knowledge and effectively tackling associated challenges.

From the perspective of the 3Rs strategy and practice, recent research published in Science Advances in October 2020 revealed that Thailand ranks third globally in waste generation. Approximately 69.54 kg of waste is

produced per person annually, with household waste production reaching approximately one kilogram per person. Unfortunately, only a fraction of this waste undergoes recycling processes, leaving a significant amount destined for dumping or landfilling. Furthermore, the global waste issue has exacerbated due to the encouragement of single-use products amid the COVID-19 pandemic, leading to accumulation and contributing to a severe environmental crisis worldwide.

The Thai government's adoption of the "3R" strategy aims to effectively reduce total waste by fostering collaboration among households, private companies, and other stakeholders. Recycling businesses are emerging as a prominent solution to these challenges, deemed both easier and more practical compared to the "Recovery" strategy. In the realm of recycling investments, findings indicate a significant increase in revenue and business growth, particularly in the Central region.

The GSB Research findings from 2023 highlight the thriving landscape of recycling investments in Thailand. The data reveals that a majority (80%) of recycling business owners are Thai nationals, underscoring a growing concern for environmental conservation within the country. This trend has led to significant financial gains for recycling businesses, with revenue increasing by 70.4% and net profits soaring to 175.6%. Thailand currently boasts 21,493 recycling shops, primarily categorized as wholesale establishments. Notably, there has been substantial growth in the number of new recycling companies, totaling 20,998 shops. While the Central region dominates the recycling industry, other regions also contribute, albeit to a lesser extent. Despite its popularity and low entry barriers, the growth of the recycling sector was modest at 1.7% in 2022.

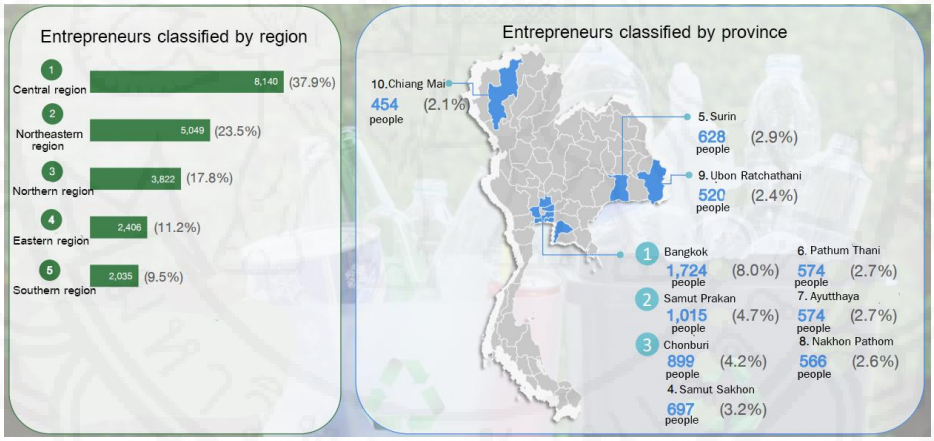

Figure 4 Recycling Business Operators Classified by Province and Region.

Source: GSB Research (2023).

At the local level, authorities have actively encouraged residents to enhance their recycling efforts through various initiatives. However, existing policies and strategies have not fully achieved the desired success due to factors such as a lack of robust networking among stakeholders. The integration of new tools and technologies is essential to accelerate progress in this area. Hence, the research proposes the development of a novel Recycling Web Application, "www.nuzerowaste.com", to raise awareness and promote recycling practices among residents.

Waste management challenges, particularly in Phitsanulok, pose significant environmental concerns. To address these challenges, comprehensive waste management plans and improved communication among stakeholders are necessary. The implementation of a new web application is recommended as a practical tool aligned with government policies to effectively promote recycling practices among residents. Through enhanced engagement and participation, the goal is to reduce residential waste and foster a sustainable environment.

In the Phitsanulok area, waste management poses a significant challenge, akin to other provinces. In 2022, the total daily waste generation reached 152.5 tons. Notably, the Tha Pho subdistrict accounted for the majority, with 81% of the waste, totaling 123 tons daily (equivalent to 45,000 tons annually). Waste originates from various stakeholders, including public sectors such as schools and universities, private sectors like department stores, and others (Pollution Control Department, n.d.). In previous research findings, research conducted by Phetumpai and Sitthisak (2020) on waste management in Phitsanulok revealed that both municipal waste management plans and sub-municipal waste management units adhere to the same policies and employ similar key index factors to enhance their processes. However, it was observed that communication gaps existed, and there was a dearth of standard templates for recommendations or constructive feedback, leading to limited participant involvement. Furthermore, discrepancies in project timelines were noted, with some plans concluding prematurely. Additionally, the study identified instances of income disparity and inequality among residents in smaller communities. These performance shortcomings have resulted in societal discontent and hindered educational opportunities in the region.

Proposed solutions, to effectively promote recycling practices among residents of Tha Pho, the implementation of a new web application is recommended as a practical tool aligned with government policies. This initiative aims to benefit residents, private sectors, government agencies, and other stakeholders. The following solutions outline key strategies for enhancing recycling behaviors:

1. Enhance accessibility to recycling education through diverse channels, including online platforms and offline marketing tools, to increase public engagement.

2. Improve participation by providing accurate feedback mechanisms to foster long-term recycling behaviors.

3. Streamline the recycling process and introduce easier trading methods to make recycling more convenient for residents.

4. Establish new recycling educational centers to further educate and empower the community.

5. Reduce waste sent to landfills by promoting recycling initiatives and waste reduction efforts.

6. Facilitate the return of recyclable items to industries through recycling shops and other recycling businesses.

7. Support new recycling entrepreneurs by providing resources and assistance to help them establish and grow their businesses.

8. Assist authorities and social marketers in collecting and analyzing data to develop effective strategies for improving recycling performance.

9. Foster the development of a sustainable green community by building a strong network of stakeholders committed to environmental conservation and recycling initiatives. As the following table.

Table 1 The Benefits of the Web App

Topic of the Benefits of the Web App	**Conventional Methods and Present Activities**	**The Use of "NU Zero Waste Web Application"**
Individual Perspectives (1-2) 1. Accessibility of recycling knowledge channels	● Activities in classes ● Recycling posters at the student club ● Google form (the link was provided via Facebook Page)	● Updated recycling news from First page of "NU Zero Waste Web Application"

Table 1 (Cont.)

Topic of the Benefits of the Web App	Conventional Methods and Present Activities	The Use of "NU Zero Waste Web Application"
2. Accessibility of participants with high accuracy feedback and proper official records for the student affair department in order to add the numbers of hours of social activity participation	● A wait for Facebook announcement managed by student club members containing mild human errors	● Real-time records of number of items, amount of student funds or student social participant hours ● Real-time shown service provider names ● 24-hour services for checking of the outcome of activities for the student affair department service providers
Social Perspective (3) 3. To provide more convenient recycling process and easier recycling trading method	● Many steps of recycling donation and recycling business trading	● A succeed of process reduction such as directly showing the up-to-date recycling items and prices via the online system
Community-Educational Perspective (4) 4. To provide a new recycling educational center	● Basic recycling sorting information from each university events or booths	● 24-hour service source
Public Health and Environmental Perspective (5) 5. To reduce total waste to landfills	● Total waste reduction report	● Total waste reduction report ● An increase of recycling rate report ● Amount of carbon credit emission reduction report
Business Perspective (6-7) 6. To increase recycle items back to the industry via recycling shops and other recycling business	● Co-working with recycling private sectors/ 2 recycling business owners	● Building a strong recycling business network with 3 recycling business shops
7. To help new recycling entrepreneurs to run their business and gain more income		● Attending the comprehensive new recycling business owners' course for 5 days and gain more social impact and attention under the leaders of university student club ● Creating a new recycling network by sharing the recycling prices from the headquarter of recycling business company to the new recycling entrepreneurs
Local and International Perspective (8) 8. To help authorities or social marketers to collect and analyze data for creating the new strategy to gain better performance and improvement	● Using social medias to gain more performance	● Using a new platform to save and analyze important data and information
9. To build a sustainable green community with a strong network	● Building trust and reputation for a green university and community	● Expanding the reputation via the fund provider (NIA)

From the perspective of the private sector in Phitsanulok, there has been a notable increase in the number of recycling shops, rising from 85 shops in 2021 to 417 new shops (SDG Move, n.d.). This growth presents a significant opportunity to stimulate both recycling behaviors and recycling businesses, ultimately improving quality of life. Consequently, researchers are inclined to conclude that this innovative tool will not only enhance the economy but also foster social growth, aligning with various Sustainable Development Goals (SDGs).

For example, SDG Plan No. 1 aims to end poverty, and the proliferation of recycling businesses can contribute to this goal by creating employment opportunities and generating income. Plan No. 4 advocates for equity in society and promoting recycling behaviors can help address social disparities by involving diverse community members in sustainable practices. Plan No. 11 focuses on building safe, resilient, and sustainable communities, aligning with the objectives of the proposed recycling initiative. Additionally, Plan No. 13 addresses climate change, and promoting recycling can mitigate environmental degradation and contribute to climate resilience.

In recent years, Thailand has seen the development of more recycling business applications (Paaopanchon, 2018). For example, Recycoex is a Thai platform for buying and selling recyclable waste, accepting nine types of recyclables: PET bottles, cans, stretch/soft plastics, drink cartons/paper cups, snack bags/coffee sachets, glass bottles, HDPE plastics, paper, and various items like clothing, shoes, and toys. Users can specify the amount of recyclable waste they want to sell, and buyers will pick it up directly, eliminating the need for users to worry about sorting waste. However, Recycoex is accessible only via mobile phones and not through web browsers (Urban Creature, 2023). Another example is Green2Get, a web application that manages waste by addressing three main questions: What material is our waste made of, how can it be managed, and who wants this material and where. Users can add information to the app at any time and it is very easy to use, simply by viewing information or scanning a barcode from the waste. However, these examples are not yet available in provinces like Phitsanulok (Sukkong, 2021). Therefore, the researchers have developed a prototype into the web application NUZeroWaste.com to facilitate recycling businesses in Phitsanulok province (Manrique et al., 2021).

In conclusion, by understanding governmental policies and leveraging innovative tools in the recycling sector, Thailand can address its sustainability and waste management challenges effectively. The proposed solutions aim to foster collaboration, raise awareness, and promote sustainable practices among stakeholders, ultimately leading towards a greener and more sustainable future for the nation. Therefore, this article introduced the innovative solution and elucidated the reasons for its implementation, highlighting its potential to positively impact various aspects of sustainable development.

Here are three research objectives for the article:

1. To develop a user-friendly and effective digital platform that integrates circular business practices into sustainable digital entrepreneurship, tailored to the local context and technological infrastructure of the Tha Pho district, Phitsanulok province.

2. To enhance recycling behaviors and waste management practices by leveraging design thinking and prototyping, allowing for iterative feedback and customization from community members, stakeholders, and waste management entities.

3. To evaluate the impact and usability of the NUZeroWaste Web application through rigorous testing and satisfaction surveys, aiming to foster engagement, reduce errors, and promote long-term sustainable behaviors within the local community.

Research Scope

This research focuses on the development and implementation of a user-friendly and effective digital platform to promote sustainable recycling practices within the Tha Pho sub-district, Phitsanulok province. By leveraging design thinking and integrating creative solutions that consider the local context, cultural nuances, and technological infrastructure, the study aims to address the community's waste management challenges. The primary objective is to foster engagement, encourage sustainable behaviors, and harness local resources to create an environmentally conscious digital landscape in Tha Pho.

Populations and Samples

Population

The population for this study includes all residents of the Tha Pho sub-district, Phitsanulok province, as well as key stakeholders involved in waste management, such as local authorities, recycling businesses, and educational institutions.

Sample

The sample consists of 724 participants, including students, housewives, food shop owners, and non-university students. This diverse group was selected to provide a comprehensive understanding of the community's recycling behaviors and to gather feedback on the usability and impact of the NUZeroWaste Web application.

Sample Size Calculation

To determine the sample size, the researchers employed a combination of surveys and informal conversations. The total number of participants (724) was derived based on the following considerations:

1. **Population Size:** Estimation of the total number of residents and relevant stakeholders in the Tha Pho sub-district.

2. **Confidence Level and Margin of Error:** A standard confidence level of 95% and a margin of error of 5% were used to ensure the reliability of the results.

3. **Response Rate:** An expected response rate was factored in to account for non-responses and incomplete surveys.

The calculated sample size ensures that the study results are statistically significant and representative of the population, providing valuable insights into the effectiveness of the NUZeroWaste Web application and its impact on sustainable recycling practices in the community.

Methods and Materials

In recent years, the significance of effective waste management in serving sustainable environmental solutions has become increasingly evident. However, a significant disparity exists between the national roadmap for waste management and actual residential practices. Therefore, researchers are committed to delving into the design considerations necessary for creating an effective recycling web application. The aim is to streamline the recycling process for waste generators, making it more accessible and user-friendly. Additionally, this research will involve the utilization of this innovative invention. The results will include user feedback, which will be instrumental in refining and improving the application's functionality and user experience.

In this study, the reliability of the satisfaction survey used to evaluate the NUZeroWaste Web application was assessed using Cronbach's Alpha, a measure of internal consistency. Here are the detailed steps and results:

1. Data Collection Tool

The survey instrument included several items designed to measure user satisfaction across different dimensions such as the modern appearance of the web application, essential menus or main functions, speed of data accessibility, and overall satisfaction.

2. Reliability Testing

To ensure the reliability of the survey, Cronbach's Alpha was calculated for the collected data. This statistical measure assesses how closely related a set of items are as a group, providing an estimate of the consistency of the responses.

3. Cronbach's Alpha Calculation

For Students:

- The survey administered to 265 student participants showed a high level of internal consistency.
- Cronbach's Alpha: 0.88, indicating good reliability.

For University Outsiders:

- The survey conducted among 105 university outsiders (housewives, food shop owners, and non-university students) also demonstrated high reliability.
- Cronbach's Alpha: 0.91, indicating excellent reliability.

4. Interpretation

Cronbach's Alpha values above 0.70 are generally considered acceptable, above 0.80 are good, and above 0.90 are excellent. The high values obtained in this study suggest that the survey items are consistently measuring the intended satisfaction dimensions across different user groups.

The high Cronbach's Alpha values confirm that the data collection tool used in this study is reliable. This reliability ensures that the survey results accurately reflect user satisfaction with the NUZeroWaste Web application, providing a robust basis for evaluating and improving the platform. However, this research faced limitations including a small and geographically limited sample size, a short evaluation period, potential technological barriers for users, and language usability issues that may hinder understanding among certain groups.

To design a cutting-edge recycling business web application, begin with a user-centered design approach by conducting surveys and testing prototypes with community members to gather feedback and make iterative improvements. Integrate the application with existing waste management systems and ensure it has a user-friendly interface with visual aids for easy navigation. Implement real-time feedback and tracking of recycling activities to keep users informed and engaged. Introduce a rewards system where users can earn points for recycling, redeemable for various products, and integrate social media platforms to enhance user engagement and share updates. Provide comprehensive educational resources within the app, accessible 24/7, and establish recycling education centers to promote community involvement. Ensure the app is compatible with multiple platforms, including iOS, Android, and desktop, and implement stringent data security measures. Continuously collect and analyze data on user behavior to refine strategies and maintain a feedback loop for ongoing improvements.

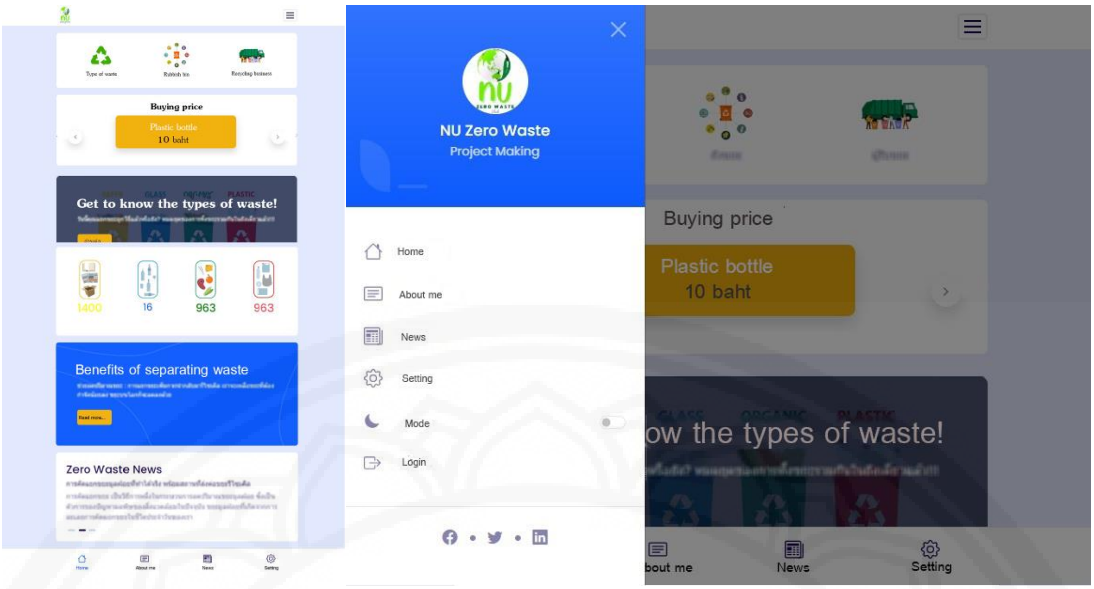

Figure 5 NU Zero Waste Web Application.

Source: http://www.nuzerowaste.com/dist/page-home.php

In conclusion, the development of a cutting-edge recycling business web application offers a comprehensive solution to enhance sustainable waste management practices. By adopting a user-centered design approach, integrating with existing systems, and providing a user-friendly interface, the application effectively meets the needs of the community. Real-time feedback, rewards systems, and social media integration promote active user engagement and long-term recycling behaviors. Comprehensive educational resources and community involvement initiatives further empower users with the knowledge and motivation to participate in sustainable practices. Ensuring multi-platform compatibility and robust data security measures enhances accessibility and trust. Continuous data collection and analysis enable ongoing improvements, ensuring the application remains effective and relevant. Ultimately, this innovative tool has the potential to significantly contribute to environmental conservation and foster a sustainable, eco-conscious community.

Results

The data collected from The Web App between 26 July 2023 and 16 February 2024. The participants logged in the system at 587 users. The results show crucial information with high accuracy and rapid process. The users provide high customer satisfaction scores on the surveys. The results can be described the benefits as below.

The researchers administered a satisfaction survey to 265 student participants, who rated their satisfaction on a scale of one to five. The results indicate that users gave the highest satisfaction rating of 4.01 for the modern appearance of the Web Application layout. Additionally, essential menus or main functions achieved an average satisfaction score of 3.92, while the speed of data accessibility met participant expectations with an average score of 3.83. Overall, survey respondents indicated that the Web Application met their expectations with an average total satisfaction score of 4.00.

Furthermore, feedback from 105 university outsiders, including housewives, food shop owners, and non-university students in the Tha Pho area, also demonstrated positive performance. They expressed satisfaction with every aspect of the WebApp usage, with an average score of 4.38. The rich menus met their expectations at 4.37,

while accessibility scored 4.35. Additionally, participants noted that the platform increased their familiarity with the new system, rating it at 4.33. Overall, the average score across all aspects was 4.42.

Comparing the current outcomes of the new WebApp tool with conventional platforms, the results reveal a significant reduction in errors of nearly 90%. Negative feedback has notably decreased over time, indicating a preference for new technology among recycling participants. However, some minor issues have been identified, particularly related to the use of modern language on the screen, which may hinder understanding among university outsiders. To address this, student volunteers were assigned to assist with the WebApp registration process, providing information and guidance. Overall, it can be concluded that the modern WebApp tool significantly enhances recycling practices and fosters long-term recycling behavior. Additionally, the Web Application serves as a key tool in guiding residents to become environmentally friendly community members committed to sustainability.

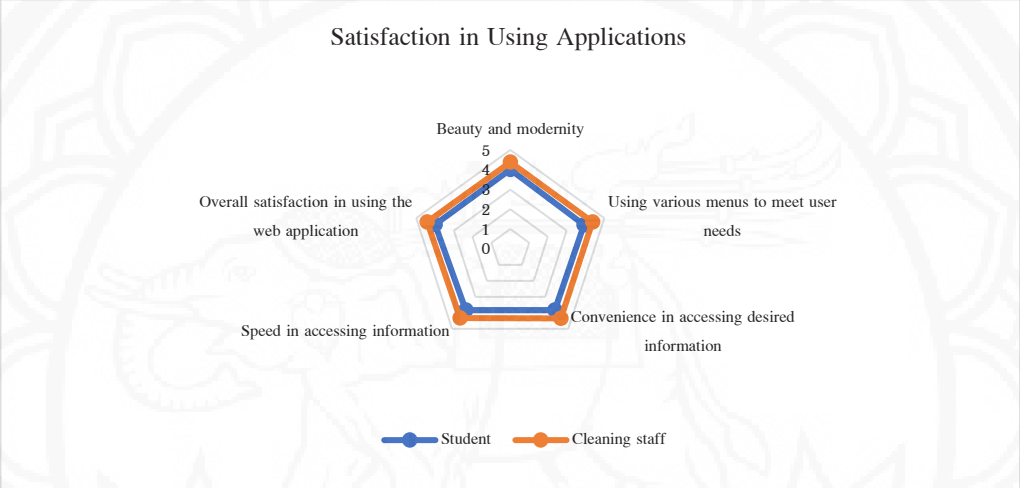

Figure 6 Conclusion of the Users Satisfaction.

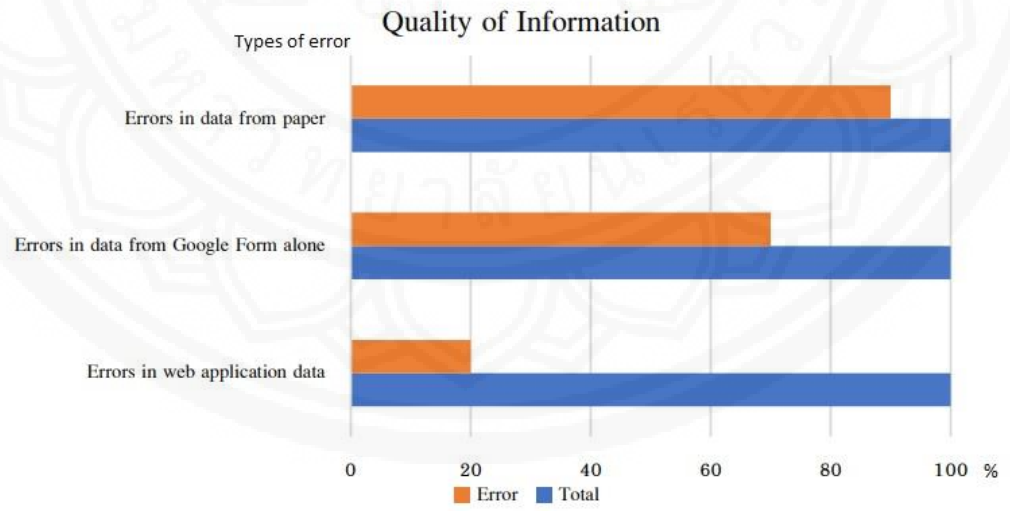

Figure 7 Displays Data Comparing the Quality of Tool Usage Data.

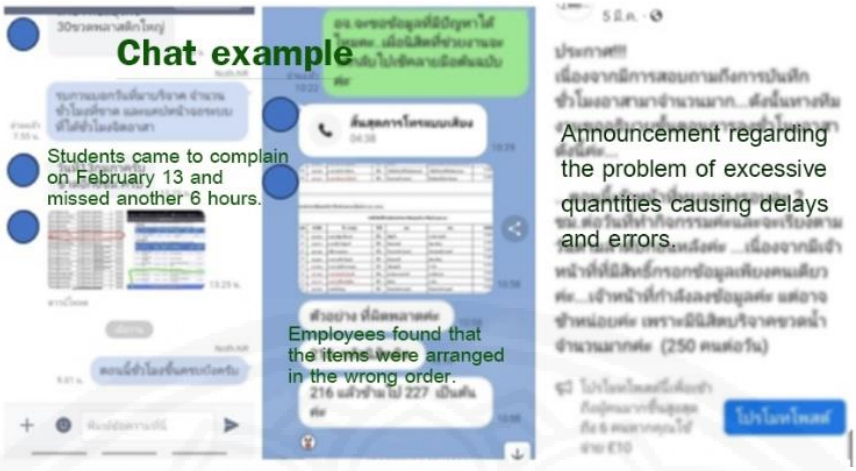

Figure 8 Examples of Data Errors and User Complaints.

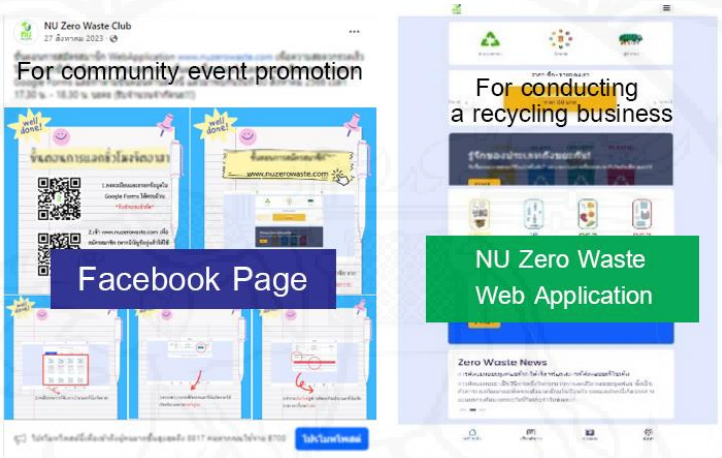

Figure 9 Co-operating between Facebook Page and "NU Zero Waste Web Application" Implementation.

Figure 10 Atmosphere of Expanding Recycling Business with Housewives and Outsiders by Using Web Application as a Crucial Tool.

The NUZeroWaste web application has significantly improved recycling practices and promoted sustainable behaviors in the Tha Pho sub-district, Phitsanulok province, with high satisfaction rates and reduced errors. Future enhancements include integrating AI for personalized feedback and mobile app development for increased accessibility. Gamification through reward systems and community competitions can further boost participation. Educational initiatives, such as online courses and collaborations with schools, will help instill sustainable habits. To extend NUZeroWaste to other communities, it's essential to conduct needs assessments and customize the application based on local requirements. Engaging stakeholders, including government and private sector partners, will provide necessary resources and support. A modular, cloud-based infrastructure will ensure scalability, and continuous feedback and impact assessment will guide improvements and measure effectiveness.

Recommendations

1. **Integration of Advanced Technologies:** Incorporate AI and machine learning for personalized user feedback and optimization of waste collection routes.
2. **Expand Accessibility:** Develop mobile applications to complement the web platform, increasing accessibility and convenience for users.
3. **Enhanced Incentives:** Implement gamification strategies, such as point-based reward systems and community recycling competitions, to encourage participation.
4. **Educational Initiatives:** Offer online courses, workshops, and collaborate with schools and universities to educate the community on sustainable practices.
5. **Stakeholder Engagement:** Secure partnerships with local governments, private sectors, and community organizations to provide resources and support.
6. **Scalable Infrastructure:** Design the application with a modular, cloud-based infrastructure to ensure it can be easily adapted and scaled to other communities.
7. **Continuous Improvement:** Establish robust feedback mechanisms and conduct regular impact assessments to refine and improve the application continuously.

Future Research

1. **User Behavior Analysis:** Conduct in-depth studies on user behavior to understand the factors that drive long-term recycling habits and how digital tools can influence these behaviors.
2. **Technology Efficacy:** Investigate the effectiveness of AI and machine learning in optimizing recycling processes and providing personalized user experiences.
3. **Gamification Impact:** Explore the impact of gamification and incentive-based strategies on increasing user engagement and participation in recycling activities.
4. **Community-Specific Customization:** Study the specific needs and cultural nuances of different communities to tailor the NUZeroWaste platform for broader adoption.
5. **Economic Impact:** Assess the economic benefits of the recycling platform on local communities, including job creation, business growth, and poverty reduction.
6. **Environmental Outcomes:** Measure the environmental impact of the NUZeroWaste platform in terms of waste reduction, recycling rates, and carbon footprint reduction.

7. Scalability and Replication: Evaluate the scalability of the NUZeroWaste model and its replication in diverse geographic and socio-economic contexts to ensure widespread adoption and sustainability.

Discussion

The NUZeroWaste web application has demonstrated significant effectiveness in improving recycling practices and promoting sustainable behaviors within the Tha Pho sub-district. The high satisfaction rates and substantial reduction in errors underscore the platform's potential as a valuable tool for waste management. The results align with the findings of Zhou et al. (2022), who stated that assessing customer satisfaction facilitates the easy identification of existing and emerging operational challenges as well as efficient aspects. This, in turn, aids in planning and implementing proactive managerial and operational measures to enhance customer satisfaction, reduce costs, maximize profit, and improve the overall customer experience. (Hariyono, 2017). The implementation of user-centered design principles, including iterative feedback and customization, has ensured that the platform meets the specific needs and motivations of the local community. (Chatterjee et al., 2022; van Velsen, 2011)

Despite its successes, several challenges remain. The integration of modern language on the platform presented comprehension issues for some users, particularly university outsiders. This highlights the necessity for continuous user education and support, which was addressed by deploying student volunteers to assist with the registration process and provide guidance on using the web application. (Kesici, 2008)

A notable observation from the research is the critical role of business opportunities in sustaining recycling behavior. The introduction of an upcycling strategy to create new products from recycled materials can help maintain engagement and stimulate economic growth. By leveraging social media platforms and influential marketing content, student clubs and community leaders can expand the reach of environmental sustainability initiatives (Hamid et al., 2017). The results are like the findings of Menikpura et al. (2013), who stated that recycling significantly enhances the social, economic, and environmental sustainability of the waste management system. Specifically, recycling 24% of Municipal Solid Waste (MSW) was found to counterbalance the negative impacts of landfilling the remaining 76% of MSW. Additionally, the quantified sustainability results of recycling indicate progress in meeting policy targets and effectiveness in Nonthaburi. Therefore, this study's results could be used to persuade stakeholders in waste management of the comprehensive benefits of recycling and its positive influence on sustainability, thereby promoting and strengthening recycling activities in Thailand.

Furthermore, the positive impact of the NUZeroWaste platform extends beyond environmental benefits. The growth of recycling businesses and the enhancement of recycling education have broader social and economic implications. By creating employment opportunities and fostering entrepreneurial ventures, the platform contributes to poverty reduction and social equity, aligning with multiple Sustainable Development Goals (Morell et al., 2020; Hackl, 2018).

Looking ahead, future enhancements of the platform should focus on integrating advanced technologies such as AI and machine learning to provide personalized feedback and optimize recycling processes (Chen, 2022). Developing mobile applications to complement the web platform will enhance accessibility and convenience for users. Additionally, implementing gamification strategies, such as point-based reward systems and community recycling competitions, can further boost participation and engagement (Chans & Castro, 2021).

To extend the benefits of NUZeroWaste to other communities, it is essential to conduct thorough needs assessments and customize the application based on local requirements. Engaging stakeholders, including government

and private sector partners, will provide the necessary resources and support for broader adoption. Ensuring the platform is designed with a modular, cloud-based infrastructure will facilitate scalability, and continuous feedback and impact assessment will guide ongoing improvements (Jeong et al., 2019; Fylaktopoulos et al., 2018).

In conclusion, the NUZeroWaste web application has successfully fostered a culture of environmental sustainability in Tha Pho. By addressing current challenges and leveraging new opportunities, the platform can continue to enhance recycling behaviors and contribute to a greener and more sustainable future for Thailand and beyond (Akkalatham & Taghipour, 2021) and based on the theory of consumption values (TCV; Tanrikulu, 2021) that lead to using a sharing economy platform. Our study draws on the theory of consumption values and altruistic-egoistic values, as well as spillover effect psychology, to examine associations between context-specific values, green consumption values, and sustainable resale behavior.

Conclusion and Suggestions

In alignment with the research objectives, the development and implementation of the NUZeroWaste web application has demonstrated significant progress in promoting sustainable recycling practices and enhancing waste management in the Tha Pho sub-district. The research aimed to:

1. Develop a user-friendly and effective digital platform: The NUZeroWaste application was designed with a focus on user-centered principles, incorporating iterative feedback and customization to meet the specific needs of the local community. The high satisfaction scores from both students and university outsiders affirm the platform's usability and effectiveness in providing accessible recycling knowledge and real-time feedback.

2. Enhance recycling behaviors and waste management practices: By leveraging design thinking and prototyping, the NUZeroWaste application has successfully streamlined the recycling process, making it more convenient for residents. The introduction of features such as real-time records, up-to-date recycling information, and user feedback mechanisms has significantly reduced errors and negative feedback, thus fostering long-term sustainable behaviors.

3. Evaluate the impact and usability of the NUZeroWaste web application: Rigorous testing and satisfaction surveys revealed high user satisfaction, with overall scores of 4.00 and 4.42 from students and university outsiders, respectively. The substantial reduction in errors and positive feedback highlights the platform's potential to address community-specific challenges in waste management effectively.

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