

Designing a Mobile App for Solid Waste Management: A Case Study from Southern Philippines

Jun Mhark O. Lloren¹, Maria Noelyn S. Dano¹, Elvina B. Mabelin², Demetria May T. Saniel¹

¹University of Science and Technology of Southern Philippines
City Government of Cagayan de Oro, Philippines

²University of Science and Technology of Southern Philippines

³City Government of Cagayan de Oro, Philippines

⁴University of Science and Technology of Southern Philippines

Abstract: *This paper presents a digital solution to improve solid waste collection in Cagayan de Oro City, Philippines. It proposes a mobile application design that integrates sources of waste and employs GPS - directed truck systems for real - time tracking. The study found high community engagement and interest in using the application, indicating its potential effectiveness in addressing solid waste management issues.*

Keywords: Solid Waste Collection, Mobile Application, Local Governance, Philippines

1. Introduction

A few years ago, Municipal Solid Waste Management rose to the top of local governments' lists of most pressing environmental and public health concerns in low - and middle - income countries. Population increase, sustained economic expansion, urbanization, and industrialization contribute to the rising global volume of solid waste due to increased consumption rates (Henry et al., 2006; UNEP, ISWA, 2009; Aleluia et al., 2016). These trends have altered the mix and accelerated the generation rate of municipal solid trash (United Nations Human Settlements Programme, 2010).

Ineffective and inefficient garbage collection and management systems are a significant cause for concern in many cities and areas as waste production rises (Jacobsen et al., 2018). On the other hand, smart cities are increasingly concentrating on finding answers to these issues by employing innovative enabling technologies like the Internet of Things, big data, and Artificial Intelligence (Esmailian et al., 2018). It was predicted that the widespread use of these technologies would alter urban planning and enhance efforts to create a Circular Economy (Ghisellini et al., 2016). The dominant linear (extract - make - dispose) economic paradigm has been discredited, mainly favoring Circular Economy, a more sustainable alternative. The existing supply chain paradigm must be more creative and sustainable for this economy to take hold (Zanella et al., 2014).

With an average daily generation rate of 1.4 kg, Asia and the Pacific's total municipal solid waste (MSW) in 2014 was predicted to be over 870 million tonnes or 43% of the global total. It is anticipated to rise until 2030 and reach 1.6 kg per person per day, or almost 1.4 billion tonnes annually. The organic percentage of municipal solid waste in low - income

countries is between 50 and 70 percent and between 20 and 40 percent in high - income countries.

In the Philippines, there has been a notable increase in the volume and diversity of garbage over the past few decades due to urbanization and changes in lifestyles and consumption habits (Olivia et al., 2013). Daily trash production in 2015 was estimated at 39, 422 kilos (EMB, 2015), projected to double from 2010 by 2025 (World Bank, 2012). A large portion of up to two - thirds of municipal solid wastes (MSW) produced in cities needs to be collected. However, it is dumped carelessly on the ground or into waterways, which can cause flooding and the proliferation of insects. The Philippines contributes between 0.28 and 0.75 million metric tons (Mt) annually—the third - highest rate in the world of plastic trash that ends up in the ocean after China and Indonesia, which are first and second, respectively (Jambeck et al., 2015). In addition, the urban poor, especially those residing in slums or low - income settlements, are particularly vulnerable to the health risks of improper solid waste management. Open dumping, which is more or less uncontrolled, is the most typical waste disposal option (UNEP/IETC, 2009). In Southern Philippines, Cagayan de Oro is the third city with the highest waste generation, next to Davao City and Zamboanga City.

With the pressing issues of solid waste collection impacting the environment and increasing the quantity of solid wastes, the study sought to develop innovative solutions for waste collection. The purpose of this study is to propose a mobile application as a digital solution to enhance solid waste collection and management in Cagayan de Oro City, Philippines.

1.1 Significance

This study is significant as it proposes a digital solution that could potentially improve the efficiency and sustainability of solid waste management in Cagayan de Oro City, contributing to environmental protection and the promotion of a smart city.

2. Literature Review

Garbage management is a pressing problem for society and the planet's future. This is almost inevitable as a result of human actions. Not only has the human population exploded over the past few centuries, but our consumption habits have also shifted, and the composition of our garbage has diversified. Avoiding landfill disposal in favor of more efficient waste management is crucial to the widespread adoption of growth and consumer - oriented economic development that is occurring at present, as reported by UN - HABITAT in 2010.

The main goal was to minimize the adverse effects on the environment and human health from improper solid waste storage, collection, transfer, treatment, and disposal. As a result, waste management systems might be planned and implemented with the help of available information systems and logistical technologies. This shift in focus has increased the need for mobile applications in the waste management industry, as resource management and social behavior are now essential components of every waste management system (Antonis Mavropoulos, 2015). How waste management and recycling firms conduct their operations are beginning to evolve due to mobile technologies. Access to information on services and planning is made more accessible, and business owners and the general consumer of waste and recycling, thanks to new tools, may make better decisions.

3. Research Method

The study employs a mixed - methods approach, combining a survey questionnaire to gather data on the community's willingness to use the proposed mobile application and stakeholder consultation to finalize the applications design and features.

4. Results and Discussions

4.1. Preliminary Users' Survey Results

The researcher surveyed for the study on developing mobile applications for solid waste management. A total of 400 participants answered the survey questionnaires. The survey questionnaire was used to determine (I) the willingness of the community to access the proposed features of the Solid Waste Management Information System and (II) its willingness to download the mobile application.

4.1.1. Likelihood of accessing the following proposed information and features of the SWM application

In this section, participants were asked how likely they would access the proposed information and features of the

solid waste management application. The participants must choose extremely likely, very likely, a little likely, and not at all likely. The proposed features of the Solid Waste Management Information System are (a) Waste Collection Route, (b) Collection Schedule, (c) Waste Booking Collection for Recyclables, (d) Location of Solid Waste Management Facilities, (e) Waste Segregation Guide (f) Environmental Articles (g) data on waste generation, composition, and generation, and (h) Reporting of Concerns. The respondents were very likely to access the features such as waste collection routes, collection schedules, and waste booking for recyclables at 74%, application for reporting of concerns at 73%, for Waste Segregation Guide at 69%, Environmental Articles at 67%, Data on waste generation, composition, and waste diversion, and Location of solid waste facilities at 64%. A significantly higher percentage compared to not at all likely, a little likely and extremely likely. Figure 1 below shows the likelihood of the respondents accessing the proposed mobile application features.

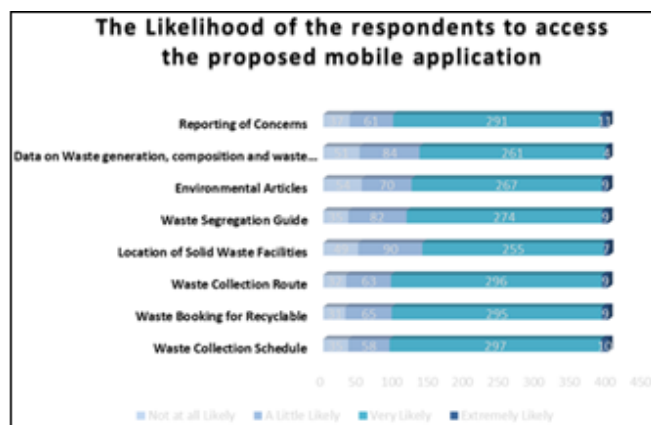


Figure 1: Likelihood of the respondents to access the mobile applications

4.1.2. Willingness to download the SWM Mobile Application

The results indicated that 91% are willing to download the mobile application, while only 9% are unwilling to access the SWM Information System. Willingness to use such an application daily did not differ from across the households who segregated their waste at source. They even agree that the segregation of waste itself is not a barrier to such. Interestingly, households with less access to waste collection trucks reported a strong interest in using smartphones and mobile applications to track the waste collection schedule and collection route. Figure 2 below shows the respondents' willingness to download the mobile application.

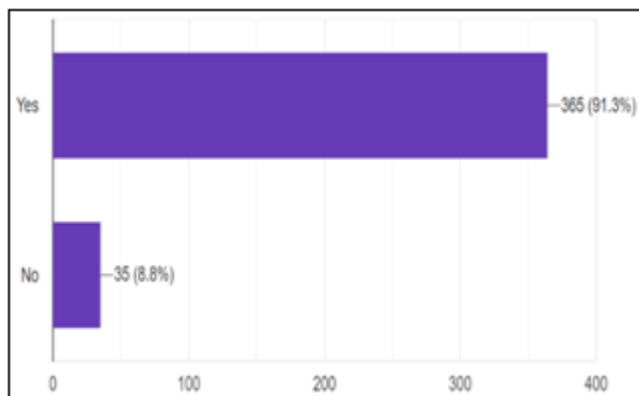


Figure 2: Willingness to download the mobile application

4.2. System Design and Features

A mobile application approach has been chosen to develop a recycling support tool. Bonino et al. stressed that based on several studies, one possible cause of recycling's low uptake is the need for a user - centered design strategy. The community and stakeholders' participation were planned and driven by a clear objective. The researcher considered the data collection phase findings as they finalized the system's features and content to meet the user's needs. The features were identified to be beneficial for the following:

4.2.1. System Users

The user can be the household owner, commercial establishment, institution, and government agency. They can access the key features of the mobile application. Figure 3 below shows the Interface Design for the mobile application.



Figure 3: Interface Design of the Mobile Application

4.2.1.1. Collection Route and Schedule

This system feature allows the community to monitor the waste collection vehicle using a Global Positioning System (GPS) installed in the collection truck, which will help the user view the real - time tracking, Route Coverage, and Stoppage Tracking. Also, the community can monitor the list of scheduled days for every barangay's residual waste collection and pick - up services. It enables the community to monitor waste collection easily. They can regularly update their area's garbage collection route and collection days to prepare and eliminate late throwers.

4.2.1.2. Recyclable Booking

A Recyclable booking application is the best option for waste management. Utilizing mobile applications to let waste producers request waste collection services for their

recyclables and to let the authorized recyclers who registered in the application handle the request. Management of recyclable wastes can be booked by choosing the waste type, location, and estimated weight. This system's feature will aid the waste collector in quickly locating the customer's address. This feature will help the household owner to book their recyclable wastes and put them up for sale. In addition, the user can monitor the impact of their waste management, such as the amount of waste they recycle and sell according to their classifications. The user who booked their recyclable wastes will receive a payment equivalent to the price of the recyclables turned over by the collector.

4.2.1.3. Complaint/Feedback System

These features will help the Barangays and CLENR Office easily connect to the community and vice - versa. Households can report uncollected wastes, illegal dumping, open burning, and other solid waste management concerns. The Barangays and CLENR Office can respond and investigate the reports and provide appropriate actions.

4.2.1.4. Waste Segregation Guide

Waste Segregation Guide is a feature that will help users segregate their wastes properly. It will show the users the segregation process and the step on how to perform it in households and other sources. Waste segregation can be done by sorting out different types of wastes, such as but not limited to Recyclables, Biodegradables, Residuals, and Special Wastes as mandated in RA 9003, the Ecological Solid Waste Management Act, and the City Ordinance 13378 - 2018 Integrated Ecological Solid Waste Management in Cagayan de Oro City. Mobile applications will also help in the Information, Education, and Campaigns on waste management.

4.2.1.5. Incentives

This feature will allow users to gain an incentive scheme and reward program. It is expected to reduce waste generation significantly. It can be accomplished using these features that will provide precise information on daily waste pick - up (recycled) using the booking system at home or work. Each member will receive points on the system based on her/his efforts to reduce the quantity of wastes s/he generates. The points can be converted into grocery items and other basic needs in the partner establishments.

4.2.1.6. Information Center

These features will help the researcher and the community to access the policy easily, and ordinances enacted by the city, as well as data on waste generation, waste reduction, and other reports concerning solid waste management and environmental management by the city.

4.2.2. Recyclable Collector

The Dashboard of the Recyclable Collector has four (4) features. First is the list of users booked for collection. The features of the recyclable collectors allow one to access the list of users booked to collect their recyclable waste according to barangays. The collector must confirm that they will collect the recyclable wastes and provide the details on the collection day so they can make the itinerary before the collection schedule. It helps the recyclable collector to have a cost - efficient strategy. The location of the user who

booked them for collection and the contact number will also be accessed to locate them quickly.

Second, the Order Data Base features will reflect all the users from whom the waste recycler will be collecting. It provides the location of the booker, the contact number, the collection schedule, and a consolidated location map. A record of the classified recyclable wastes (e. g., plastics, pet, glass, metals) collected and the weight of every recyclable waste of the user who booked them must be inputted to reflect the waste turnover by the booker.

The third feature is expense recording which will help the collector monitor all the expenses of their operations. Lastly is the Sales and Inventory Management feature, which will help the collector understand the business. They can record sales, make inventory, and understand their business management performance. One of the challenges in entrepreneurship is recording sales, making inventory, and even compiling reports.

4.2.3. Barangay and City

The barangay is one of the administrators of this application, but its accessibility is limited to its area of jurisdiction. According to the DILG Memorandum Circular 2018 - 112 Organization or Reorganization of the Barangay Ecological Solid Waste Management Committee, the barangay is still required to send Solid Waste Management Report to the city. It mandates all barangays to submit Monthly Reports on Solid Waste Management stated in the Function and Responsibility of the Committee. Paperless submission will be implemented with this application, significantly reducing waste generation. In addition, all complaints relevant to Solid Waste Management will be received and responded to by the barangay.

The city has full access to the application through the dashboard and will approve the recyclable collector application and give them access to the waste booking system based on the guidelines and qualifications for the Recyclable Collector. The city will also have the right to terminate or cut off the recyclable waste collector if they fail to uphold its engagement or commitment. The city will receive all statistics on solid waste collection activities through the system. These statistics will aid decision - makers and impact the projection for solid waste management collection in the future. They can also respond to all complaints and reports according to the Magna Carta Law and check the responses of the barangay.

5. Conclusion

The study proposes a mobile application as a solution to solid waste management issues in Cagayan de Oro City, Philippines. The initial findings indicate high community engagement and willingness to use the application, suggesting its potential effectiveness.

6. Future Research

An empirical study that focuses on performance monitoring and evaluation in terms of the solid waste diversion, community participation, the efficiency of waste collection,

and barriers in the implementation of the mobile application for solid waste management is highly recommended.

References

- [1] Aleluia, J.; Ferrão, P. Characterization of urban waste management practices in developing Asian countries: A new analytical framework based on waste characteristics and urban dimension. *Waste Manag.* 2016, 58, 415–429
- [2] Esmailian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C., Behdad, S., 2018. The future of waste management in smart and sustainable cities: A review and concept paper. *Waste Management*, 81 (November), 177 - 195
- [3] Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular Economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11 - 32. <https://doi.org/10.1016/j.jclepro.2015.09.007>
- [4] Henry, R. K.; Yongsheng, Z.; Jun, D. Municipal solid waste management challenges in developing countries—Kenyan case study. *Waste Manag.* 2006, 26, 92–100.
- [5] Jacobsen, R., Willeghems, G., Gellynck, X., & Buysse, J. (2018). Increasing the quantity of separated postconsumer plastics for reducing combustible household waste: The case of rigid plastics in Flanders: *Waste Management*, 78, 708 - 716
- [6] Jambeck, J. R.; Geyer, R.; Wilcox, C.; Siegler, T. R.; Perryman, M.; Andrady, A.; Narayan, R.; Law, K. L. Plastic waste inputs from land into the ocean. *Science* 2015, 347, 768–771.
- [7] Mavropoulos, A. A. (2013). *Mobile Applications & Waste Management. D - Waste.*
- [8] NSWMC (2015): *National Solid Waste Management Status Report*, Philippines.
- [9] Oliveira, J. P., Doll, C., Kurniawan, T. A., Yong, G., Kapshe, M., Huisingsh, D (2013). Promoting win - win situations in climate change mitigation, local environmental quality and development in Asian cities through co - benefits, *Journal of Cleaner Production* 58, 1–6.
- [10] UNEP - IETC (2009): *Technology for Waste Management/Infrastructure - Cebu, Philippines*, UNEP/IETC, Osaka.
- [11] UN - Habitat (2010) *Solid Waste Management in World Cities*
- [12] United Nations Environment Programme (UNEP). *Developing Integrated Solid Waste Management Plan, Training Manual, Volume 3: Targets and Issues of Concern for ISWM*; United Nations Environment Programme: Osaka, Japan, 2009; p.48.
- [13] United Nations Human Settlements Programme. *Solid Waste Management in the World's Cities: Water and Sanitation in the World's Cities 2010*; 9781849711692; United Nations Human Settlements Programme: London, UK; Washington, DC, USA, 2010; p.228.
- [14] World Bank (2012): *What a Waste: A Global Review of Solid Waste Management*, World Bank, Washington DC, USA.
- [15] Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M., 2014. Internet of things for smart cities. *IEEE Internet of Things Journal*, 1 (1), 22 - 32

Author Profile



Jun Mhark O. Llorenis is a graduating student of Master in Public Sector Innovations at the Institute of Governance, Innovation, and Sustainability, University of Science and Technology of Southern Philippines, where he also obtained his BS in Environmental Science and Technology. He is currently working in the City Government of Cagayan de Oro, Philippines under the City Local Environment and Natural Resources Office.

Dr. Maria Noelyn S. Dano is an Associate Professor with the Master in Public Sector Innovations, and Master in Sustainable Development programs of the University of Science and Technology of Southern Philippines. She obtained both her Master's Degree and PhD in Environmental Studies at the Australian National University in Canberra.

Elvisa B. Mabelin is the Assistant Department Head for Operation at the City Local Environment and Natural Resources Office, Cagayan de Oro. She obtained her Master's Degree in Applied Anthropology and Participatory Development at The Australian National University, and her BS - Chemistry at Xavier University, Philippines.

Dr. Demetria May T. Saniel is an Associate Professor of the University of Science and Technology of Southern Philippines, and the Director of the Institute of Governance, Innovation, and Sustainability.