Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 17 No. 23 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijim.v17i23.44417

PAPER

Improving Environmental Sustainability: A Geolocation-Based Mobile Application to Optimize the Recycling Process

Orlando Iparraguirre-Villanueva[1], Luis Tuesta-Pereda[1], Elvis Tapia-Chavez[1], Michael Cabanillas-Carbonell[2](✉)

[1]Facultad de Ingeniería y Arquitectura, Universidad Autónoma del Perú, Lima, Perú

[2]Facultad de Ingeniería, Universidad Privada del Norte, Lima, Perú

mcabanillas@ieee.org

ABSTRACT

Environmental pollution caused by human activities is a global concern, and recycling is an effective strategy to reduce waste and minimize its negative impact on the environment, as these pollutants can have detrimental impact on ecosystems, human health, and the quality of life in general. Recycling avoids the accumulation of waste in landfills, which can contaminate soil, water, and air as well as reducing the production of new products. The objective of this work is to implement a mobile application to improve waste management by recycling companies. The Mobile-D methodology was used for the development of the project because it focuses on optimizing the efficiency and performance of mobile applications since it allows working in 5 phases which are: Exploration, Initialization, Production, Stabilization and Testing. In the first indicator (KPI-1), an improvement in customer retention was observed, with an increase of 114.29% in positive responses in the post-test. In the second indicator (KPI-2), there was a 39.92% decrease in response time, indicating a faster response in the collection service. In the third indicator (KPI-3), a significant increase of 86.86% in the volume of waste for recycling was observed. The results showed improvements in all indicators, indicating a positive impact of the implementation of the mobile application on waste management by the companies in the sector.

KEYWORDS

Mobile-D, geolocation, mobile application, recycling

1 INTRODUCTION

According to reports from the World Health Organization and the World Meteorological Organization [1] [2], environmental pollution caused by human activities has become one of the major concerns worldwide, and one of the main causes

Iparraguirre-Villanueva, O., Tuesta-Pereda, L., Tapia-Chavez, E., Cabanillas-Carbonell, M. (2023). Improving Environmental Sustainability: A Geolocation-Based Mobile Application to Optimize the Recycling Process. *International Journal of Interactive Mobile Technologies (iJIM)*, 17(23), pp. 32–48. https://doi.org/10.3991/ijim.v17i23.44417

Article submitted 2023-08-26. Revision uploaded 2023-09-25. Final acceptance 2023-09-25.

© 2023 by the authors of this article. Published under CC-BY.

of this problem is poor waste management [3]. Waste recycling is one of the most effective strategies to reduce the amount of waste generated and its negative impact on the environment [4]. Recycling is one of the basic methods to achieve a responsible production and consumption system [5]. To achieve Sustainable Development Goal (SDG) no. 12: Responsible production and consumption, it is necessary first and foremost to reduce the amount of waste generated and avoid its accumulation in landfills or environmental pollution [6]. Effective waste management has been difficult due to inadequate recycling infrastructure and lack of awareness [7]. There is no doubt that inefficient waste management can harm the environment and human health. In addition to accumulating waste, wastes can also be a breeding ground for pests and diseases, as well as a source of pollution of water and air [8], [9]. As a result, respiratory diseases, gastrointestinal diseases, etc., can spread among the population. There is a necessity to promote environmental education and awareness about the importance of waste recycling and proper waste management to solve this problem [10].

In addition to supporting and creating policies and programs that promote waste reduction, reuse, and recycling, as well as the implementation of integrated waste management systems, public authorities are responsible for promoting and creating policies and programs that promote these practices [11], [12]. Information technology can play an important role in effective waste management and recycling [13]. Mobile applications for waste management, as suggested, can facilitate communication between businesses and customers [14], enabling better planning of waste collection and disposal. In addition, this technology can be used to monitor the progress of waste management and recycling in real time, allowing more informed and effective decisions to be made [15]. GIS can also identify areas of high waste generation and establish strategic collection points [16]. It has been shown that integrating information technology in the waste management process can make it easier and more efficient to recycle waste [17] and can reduce the negative impacts of poor waste management on the environment and public health [18]. Furthermore, these technologies should be designed for easy use. It is because they are intuitive and easy to use, they become an attractive option for users. The objective of this work is to implement a mobile application based on geolocation to optimize the recycling process.

A brief description of the organization of this paper can be found as follows: Section 2 presents work related to the process and optimization of recycling using technological tools. In section 3, we will describe the main phases of the mobile-D methodology used for developing our case study. As a result, Section 4 explains how each indicator's results were obtained and analyzed statistically. Section 5; focuses on interpreting and discussing the results and their relationship with previous literature results, and finally, section 6 synthesizes the main findings and implications.

2 RELATED WORK

Researchers and academics have written different papers related to the study topic. For example, in [19] they addressed two questions: how to improve the quality-of-life cycle analysis work and how to select municipal solid waste management strategies. For this they carried out a review of 79 scientific studies in 36 countries. As a result, they highlighted that raising public awareness is fundamental to obtaining reliable results, but approximately 38% of the studies did not do so. They also concluded that the integration of recycling, treatment and disposal technologies is the most appropriate strategy for proper solid waste management. Similarly, in [20], they conducted an analysis of best practices for construction and demolition solid waste management throughout the construction chain. As results, they conclude that the European Commission has proposed new objectives and targets for the management of these wastes in the context of the circular economy. Also, they emphasize the need for new approaches due to the heterogeneity of waste management practices; they suggest the systematic implementation of best practices to improve resource efficiency and reduce their environmental impact. Also, in [21], they analyzed municipal solid waste in Latin America and concluded that the large volume of waste generated in urban centers can become a constant resource if recovery options are prioritized. In addition, they identified that good management could help address the challenges in waste management. Also, they stated that financial issues are a major problem in bureaucratic governance. On the other hand, in terms of technology, the authors of [22] developed a mobile application to improve solid waste management methods focused on PET beverage bottles. As a result, they optimized 80% of the tasks. They used the data mining methodology [23] to classify waste using models such as MobileNetV2, VGG16, SVM, and Convolutional Neural Networks (CNN). Finally, they concluded that the SVM model achieved the highest performance with 97% accuracy. Also, in [24] they designed a mobile application to improve waste recycling practices. Co-design and a hybrid architectural framework were employed. According to the results, technology can address climate change positively. In [25], we developed a mobile application to connect the local population with waste collectors. Through the analysis of the use of technology and the perceptions of participants, the results indicate that, although the mobile application facilitates the connection, it does not generate significant changes along the same lines, [26]. They proposed a model with four metrics: energy, economy, performance, and energy/performance for mobile applications design that address environmental concerns. They sought to demonstrate that applications according to these metrics preserve the environment and have better performance. In [27], we developed a mobile application for plastic waste recycling in Indonesia, to promote a recycling culture in the Indonesian population. The results showed a significant increase in citizen participation and increased awareness about the plastic recycling culture. In [28], we proposed an e-commerce-based reverse supply chain mode based on an e-commerce platform, to create strategies to recycle discarded cell phones through an e-commerce platform. [29] investigated the effect of a playful application called DoItRight to raise awareness among children; the application was evaluated using the standardized System Usability Scale (SUS) instrument. DoItRight scored 93.25% acceptance. The results indicate that the application has high potential. Also, [30] developed an application for waste management using the QR code system. For this application, they involved 388 people to evaluate. They concluded that app-enabled community members simplified the waste management process and generated a positive attitude towards waste use. Similarly, in [31], they developed a gamified mobile application to manage food waste collection and decomposition, for which they applied an agile approach, involving experts. The results showed that experts rated the mobile application design positively.

3 METHODOLOGY

This section presents the research method and the development of the mobile application.

This is an applied study, with a quantitative approach and a pre-experimental design in which the experiment was carried out according to the research plan. The pretest and posttest design are represented in equation (1):

$$GE{:}O_1 \times O_2 \tag{1}$$

Where:

- GE: Experimental group
- O_1: Pre-Test
- O_2: Post Test
- X: Variable manipulation

For this study, a convenience sample of 60 households from the Palmas de Pachacamac urbanization was selected based on their willingness to participate in the project. To collect and validate information from these households, the following objectives were used: (1) customer retention, (2) response time, and (3) volume of waste recycled. Questionnaires were used to collect information on types of waste, participation in the recycling process, time spent recycling, and volume of waste recycled per week, both in the pretest and posttest phases.

All data were then subjected to statistical analysis to validate the hypothesis and draw conclusions from the results. In addition, experts in the field verified the reliability (KR-20) and validity of the instruments used.

Henceforth, the study aimed to determine the effectiveness of the recycling program in the Palmas de Pachacamac urbanization. It focused primarily on identifying the factors that promoted customer retention, response time to the recycling process, and the volume of waste recycled. This study also focused on exploring the types of waste most frequently recycled and the level of participation in the recycling program.

The study is designed to provide valuable information on the effectiveness of the recycling program in the Palmas de Pachacamac urbanization, with the goal of promoting sustainable waste management practices and reducing environmental impact.

3.1 Development of the case study

The Mobile-D methodology is a mobile application development approach that focuses on the creation of highly effective and optimized applications for mobile devices [32], covering from the definition of objectives and the design of the user interface to the development of prototypes, the implementation of the application and exhaustive testing to ensure its correct operation and its adaptation to the needs and characteristics of mobile users [33]. The five phases or stages of the Mobile-D methodology are presented below.

3.2 Exploration

In this phase, the stakeholders involved in the project were identified, covering different roles, responsibilities, and technologies used, as shown in Table 1. Clients represent the people who wish to request a waste collection service for further recycling. Likewise, administrators and managers were identified, who play a fundamental role in the direct management of the process, maintaining close interaction with clients. Finally, collectors who collect waste or establish links with customers were mentioned. Subsequently, the project scope was defined. It focuses on the development and implementation of mobile applications designed to optimize the recycling process.

Table 1. Technologies used in the project

Technologies Used in the Project	
IDE:	Visual Studio 2022
Programming language:	C#
Framework:	.NET
Information storage system:	Firebase
Study Methodology:	Mobile-D
Physical equipment for development:	Laptops, Cell Phones

Table 2 shows the system modules, which are the functional and autonomous components that make up the application. Each module is assigned a unique code and a descriptive name for easy identification and reference in the development and use of the system. These modules represent different functions and features of the system. These range from authentication of different types of users, such as customers, collectors, and administrators, to the management of different activities and resources.

Table 2. System modules

Code	Module Name
M001	Authentication Module for the Client
M002	Authentication module for the Collector
M003	Authentication module for the Administrator
……	………
M014	Customer Management Module

Each module is categorized where the functional requirements associated with each module are identified and detailed. These functional requirements (shown in Table 3) provide precise information about the specific characteristics and operations to be performed by the system and its expected behavior in various situations. These details allow you to define the standards and capabilities necessary for proper system operation and performance. In this way, you ensure that it meets the established expectations and requirements.

Table 3. Functional requirements

Code	Description
RF001	The application must allow the user to enter his/her ID to identify him/herself.
RF002	The mobile application must verify the authenticity of the ID entered by the user.
RF003	The geolocation-enabled mobile application must allow access to the application once user authentication is complete.
RF004	The mobile application with geolocation must allow the user to enter his e-mail address and password to identify himself
RF005	The mobile application must verify the authenticity of the login credentials entered by the collecting user.
RF006	The mobile application with geolocation must allow access to the application once authentication of the collecting user is completed.
RF007	The geolocation-enabled mobile application will allow users to enter their e-mail addresses and passwords to identify themselves as administrators.
RF008	The mobile application must verify the authenticity of the login credentials entered by the administrator.
RF009	Once the administrator authentication has been completed, the mobile application with geolocation must allow validation.
RF010	The mobile application with geolocation allows the user to visualize the waste available for recycling
RF011	The mobile application with geolocation will allow the user to select the waste to be recycled.
RF012	The mobile application with geolocation will allow the user to accumulate points when using the recycling service.
RF013	The mobile application with geolocation will allow users to request waste collection.
RF014	Administrators can visualize how much waste is recycled each day with the mobile application.
RF015	The mobile application will allow managing waste collection requests by the administrator.
RF016	The mobile application allows managers to view reports.
RF017	The mobile application allows administrators to manage the configuration.
RF018	The mobile application with geolocation must allow administrators to manage customers.

3.3 Initialization

A visual representation of the overall architecture of the application is shown in Figure 1. The architecture describes how the different modules, components and services are connected to form a system. The architecture used focuses on the creation of three applications: one for the client, one for the collector, and one for the administrator. This architecture is based on cloud services, specifically geolocation, and a Firebase database.

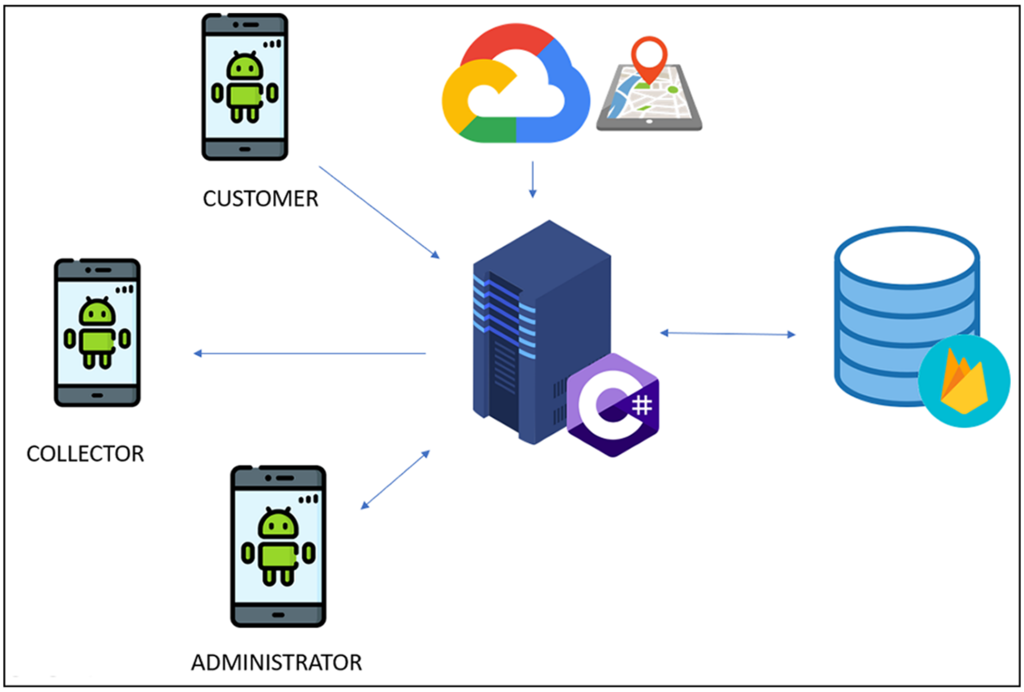

Fig. 1. Project architecture

A communications plan and activity schedule were drawn up to plan and control the development project. At this stage, prototypes, and navigability between them were established. This was because they would be the basis to start with the mobile application coding. Using models from the implementation of this methodology, the user stories consist of id, user, history, priority, difficulty, effort, description, and observations based on the functional requirements.

3.4 Production

At this stage, we worked on the design and visual appearance of the mobile application user interface. Graphic elements are created, styles are defined, and an intuitive and attractive user experience is ensured. There are three types of applications for each actor mentioned above. Each access interface has its own characteristics.

In Figure 2, you can see an application for the administrator that deals with keeping the residual products active. This involves ensuring that they are available and updated in the system. In addition, the administrator can change settings related to residual products. This includes modifying details such as description, category, or price. Also, the administrator is responsible for the efficient and effective allocation of incoming requests for residual products. This ensures that requests are fulfilled in a timely and appropriate manner. This involves assigning requests to the appropriate collectors according to their availability, location, and capacity to handle specific waste products.

Figure 3 shows the customer's application that allows him to request recycling collection according to previously established schedules. The customer can choose the most convenient date and time for the collection of his reusable materials. The customer can access the details of what is charged for the service or the dollar total, which provides a clear view of the costs associated with the process. He is also allowed to view detailed information on the different types of waste and the number of kilograms he has recycled. Customers can join the collector through the mobile app.

In Figure 4, the collector will be able to record the customer's location accurately and efficiently. By pressing the geolocation button, the user will be redirected to Google Maps, where he/she can select a location and save it precisely where the customer is located. This functionality allows the user to find and store information related to the exact location of the address or location where the service will be performed, to facilitate the task of finding and storing such information. The search and geolocation option ensures that the location information is captured correctly, improving the efficiency and accuracy of waste collection.

Fig. 2. Administrator application

Fig. 3. Customer and collector application

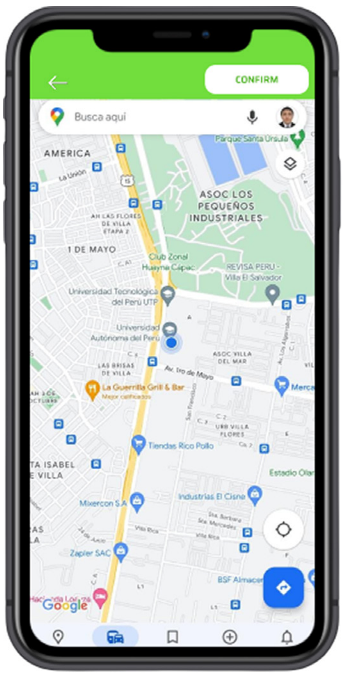

Fig. 4. Geolocation

3.5 Stabilization

In agile software development, a technique known as Story Cards is used to describe requirements or functionalities from the perspective of the user [28]. As shown in Table 4, each of these cards contains information about the story as well as the identifier, name, priority, difficulty, and estimated effort of the story. In addition, they contain a detailed description of the required functionality.

Table 4. Geolocation history card

ID	H009	User	Administrator
Story name	Geolocation	Priority	High
Difficulty	High	Effort	8 hours
Description	As a collector, I want to be able to see the location of customers who have requested waste collection service so that I can plan the most efficient route to collect waste and provide quality service.		
Remarks	The application must have access to the customer's location data. On the application map, customers who have requested the waste collection service should be marked with an icon representing the location of the house.		

3.6 System testing

A series of test cases were run in this phase of the project to verify whether the functional requirements of the project had been met. The test cases are created to verify if the system behaves as expected, identifying possible errors or failures, and ensuring that the system meets the requirements and user expectations [34]. Two test cases related to the geolocation requirement are shown in Table 5. The structure is composed of the identifier, description, inputs, outputs, and the section where successful or unsuccessful fulfillment is confirmed for each test case.

Table 5. Geolocation test cases

ID	CP041	CP042
Description	The application must have access to the customer's location data.	On the application's map, customers who have requested the waste collection service should be marked with an icon representing the location of the house.
Tickets	Customer location data.	Customer location data.
Expected outflows	Access to customer location data by the application.	Customers who have requested the waste collection service are marked with an icon representing their location on the application map.
Result	Successful	Successful

4 RESULTS

The purpose of this section is to provide a detailed description of the results obtained during the development of the research. In addition, this study is based on a rigorous analysis of the data collected, as shown in Table 6.

Table 6. Results of the 3 KPIs

#	Customer Retention (KP1)		Response Time (KP2)		Recycled Waste (KP3)	
	Pre	Post	Pre	Post	Pre	Post
1	4	2	2	1	3.5	6.52
2	4	2	1.5	0.5	3.2	6.28
3	5	4	3	2	4.2	7.1
4	2	1	2.5	1.5	1.9	4.93
5	4	1	1	0.5	2.8	5.79
6	4	2	4	3	5.1	8.09
7	5	3	3.5	2.5	4.5	7.45
8	3	2	2	1	2.7	5.67
9	2	1	1.5	0.5	3.4	6.38
10	5	1	3	2	4.8	7.82
11	4	5	2.5	1.5	4	7.03
12	2	2	1.5	1	3.1	6.14
13	1	2	2	0.5	1.6	4.59
14	4	2	4.5	3.5	5.4	8.43
15	3	1	3	2	3.9	6.87
…	…	…	…	…	…	…
60	5	3	1	0.5	2.7	5.75

Table 7 shows the averages for each KPI indicator, which are derived from the data presented in Table 6. To measure the indicators, we have used the quantity, time, and volume scales.

Table 7. Summary of results

Indicators		Pre-Test	Post-Test
KPI-1	Customer retention	7	15
KPI-2	Response time	2.38	1.43
KPI-3	Recycled waste	3.5	6.54

Figure 5 shows that in KPI1, the number of people who have responded positively and wish to continue using the services of the mobile application with geolocation has increased. In KPI2, it is observed that the response time in the collection service has been contracted in a faster and more efficient way. KPI3 shows a significant increase in waste volume.

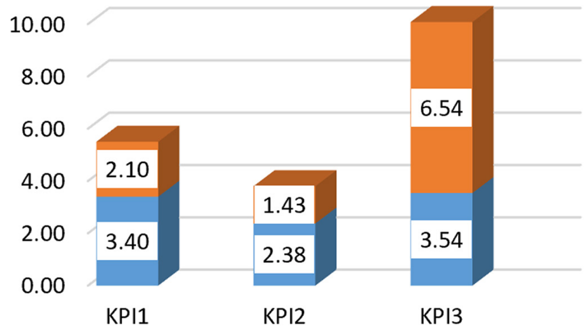

Fig. 5. Pre and post comparison of the three PKIs

Results of the first indicator (KPI-1). In Table 8, for the client retention indicator, a mean of 3.40 leaning toward negative responses was obtained for the pre-test. For the post-test, the mean value was 2.10 leaning toward positive responses. Figure 6 shows a positive response from clients and that they are willing to continue using the services in the future.

Table 8. Summary report

		Pre_Test_I1	Post_Test_I1
N	Valid	60	60
Mean		3.40	2.10
Std. Error of Mean		.294	.261
Median		3.60[a]	1.87[a]

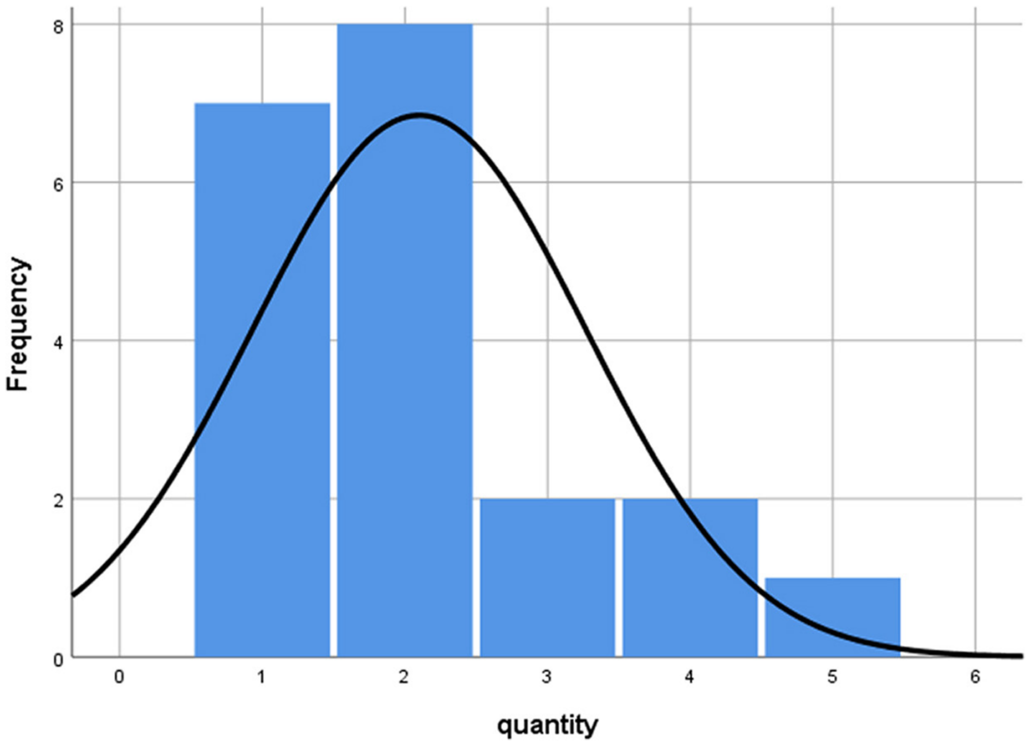

Fig. 6. Histogram of KPI-1 – post-test

Results of the second indicator (KPI-2). Table 9 shows the response time indicator results. For the pre-test, an average of 2.3750 hours was obtained, and for the post-test, 1.4250 hours, which means that it has improved significantly, leaning towards positive responses. In the same line, Figure 7 shows a higher proportion in a shorter time than the pre-test.

Table 9. Summary report

		Pre_Test_I2	Post_Test_I2
N	Valid	60	60
Mean		2.3750	1.4250
Std. Error of Mean		.21422	19959
Median		2.2857[a]	1.2857[a]

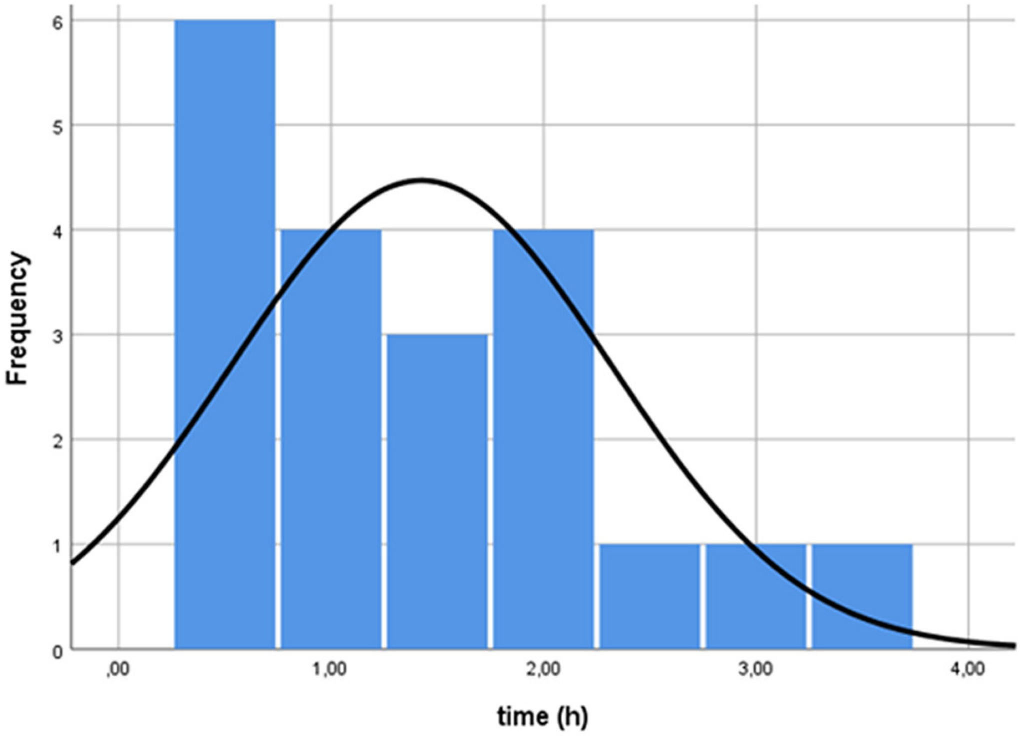

Fig. 7. Histogram of KPI-2 – post-test

Results of the third indicator (KPI-3). Table 10 shows the volume of waste. In the pre-test, a mean of 3.5400 kilograms was obtained and for the post-test, 6.5380. Figure 8 shows an increase in the volume range as opposed to the pre-test, which shows a significant increase.

Table 10. Summary report

		Pre_Test_I3	Post_Test_I3
N	Valid	60	60
Mean		3.5400	6.5380
Std. Error of Mean		.24186	.24078
Median		3.4500[a]	6.4500[a]

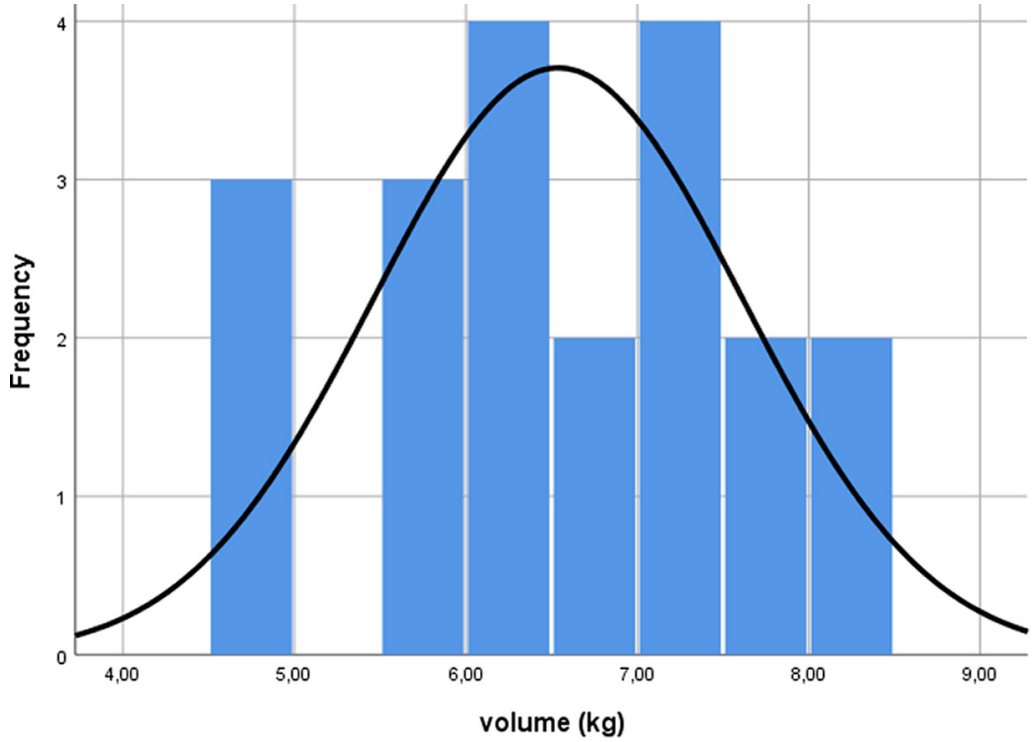

Fig. 8. Histogram of KPI-3 – post-test

5 DISCUSSION

In terms of related work, there have been several research studies on waste management and mobile applications.

The results of KPI-1 are related to [27], where a mobile application was developed for plastic waste recycling in Indonesia. The results showed that the use of factors such as personal attitude, perceived behavioral control, and perceived moral obligation helped to efficiently increase the participation and use of the application, as well as to create greater awareness about the culture of plastic recycling. Similarly, in the project conducted, customers have approved the use of mobile applications to request the services of the organization leading to positive results.

It is significant to note that [23] focuses on waste sorting, while our study focuses on waste management response time optimization. However, both works share the objective of improving waste management processes and achieving increased efficiency. These results demonstrate that the implementation of mobile technology and appropriate methodologies can have a positive impact on waste management response time reduction.

These results are consistent with the findings presented in [26], where it is highlighted that the design of mobile applications considering environmental metrics can have a significant impact on the preservation of the environment. Also, the results of this research are in line with the recommendations and conclusions of studies [20], [21]. Citizen awareness, effective management and waste valorization stand out as crucial elements for effective solid waste management, and these results support these ideas. Furthermore, the results of the work [22] provide concrete evidence that the strategies implemented are having a positive impact on solid waste management.

In essence, this study confirms that we must raise public awareness of the importance of waste management and the benefits of waste recovery. Entities and the population must manage waste effectively in order to reduce its environmental impact and optimize the use of resources. By implementing effective strategies, it is possible to achieve these objectives and promote a more sustainable future.

6 CONCLUSIONS

The results obtained in this study show that the implementation of mobile applications with geolocation functions has a positive effect on user retention in organizations. The number of users who want to continue using the service has increased significantly. This shows that the application improves the user experience and their satisfaction with the recycling process. The response time of the service also improves with the implementation of the mobile application. The results showed a significant decrease in the average response time, indicating an increase in the effectiveness of the organization's management. This finding is crucial, as a faster response time improves the user experience and reinforces the company's image. The volume of waste recycled increased significantly after the implementation of the geo-localized mobile application. This suggests that mobile technology has facilitated customer participation in recycling and encouraged greater commitment to environmental responsibility. These results are encouraging, as they reflect a positive impact on the organization's environmental responsibility management.

As future work, we propose to incorporate new features into the mobile application that enhance the user experience and promote sustainability.

- Incorporate social features that encourage interaction between users, creating a community focused on sustainability.
- Integrate machine learning algorithms that provide personalized recommendations based on user history.
- Collaborate with local waste management systems to improve their efficiency and effectiveness.
- Incorporate features that allow users to track and measure their environmental impact.
- Integrate with businesses and local governments to offer incentives to users.

7 REFERENCES

[1] World Health Organization, "A rapidly escalating problem," https://www.who.int/news/item/15-06-2021-soaring-e-waste-affects-the-health-of-millions-of-children-who-warns
[2] World meteorological organization, "Economic costs of weather-related disasters soars but early warnings save lives," https://public.wmo.int/en/media/press-release/economic-costs-of-weather-related-disasters-soars-early-warnings-save-lives
[3] L. W. Qin *et al.*, "Precision measurement for industry 4.0 Standards towards solid waste classification through enhanced imaging sensors and deep learning model," *Wirel Commun Mob Comput*, vol. 2021, 2021. https://doi.org/10.1155/2021/9963999
[4] D. Gibovic and A. Bikfalvi, "Incentives for plastic recycling: How to engage citizens in active collection. Empirical Evidence from Spain," *Recycling*, vol. 6, no. 2, p. 29, 2021. https://doi.org/10.3390/recycling6020029

[5] United Nations, "Objetivo 12: Garantizar modalidades de consumo y producción sostenibles," https://www.un.org/sustainabledevelopment/es/sustainable-consumption-production/
[6] United nations foundations, "Sustainable development goals," https://unfoundation.org/what-we-do/issues/sustainable-development-goals/, 2021.
[7] O. T. Sanchez *et al.*, "Green Bear – A LoRaWAN-based Human-in-the-Loop case-study for sustainable cities," *Pervasive Mob Comput*, vol. 87, p. 101701, 2022. https://doi.org/10.1016/j.pmcj.2022.101701
[8] N. Farronato, V. Scuotto, M. Pironti, and M. Del Giudice, "The green frontier of mobile applications in improving recycling consumers' behavior," *IEEE Trans Eng Manag*, pp. 1–10, 2022. https://doi.org/10.1109/TEM.2022.3200945
[9] A. C. Lidia, R. T. Julio, D. S. P. Petra, and P. J. Rafael, "How to encourage recycling behaviour? The case of WasteApp: A gamified mobile application," *Sustainability (Switzerland)*, vol. 10, no. 5, p. 1544, 2018. https://doi.org/10.3390/su10051544
[10] M. Gamboa-Ramos, R. Gómez-Noa, O. Iparraguirre-Villanueva, M. Cabanillas-Carbonell, J. Luis Herrera Salazar, and del Perú, "Mobile application with augmented reality to improve learning in science and technology," [Online]. Available: www.ijacsa.thesai.org.
[11] M. J. Welfens, J. Nordmann, A. Seibt, and M. Schmitt, "Acceptance of mobile phone return programmes for increased resource efficiency by young people-experiences from a German research project," *Resources*, vol. 2, no. 3, pp. 385–405, 2013. https://doi.org/10.3390/resources2030385
[12] "Recycling e-waste: The sky is the limit," 2008. [Online]. Available: https://www.sciencedaily.com/news/.
[13] M. Stutz, V. M. Thomas, and S. Saar, "Linking bar codes to recycling information for mobile phones," in *IEEE International Symposium on Electronics and the Environment, 2004. Conference Record. 2004*, Scottsdale, AZ, USA, 2004, pp. 313–316.
[14] S. Beltozar-Clemente, F. Sierra-Liñan, J. Zapata-Paulini, and M. Cabanillas-Carbonell, "Augmented reality mobile application to improve the astronomy teaching-learning process," *Advances in Mobile Learning Educational Research*, vol. 2, no. 2, pp. 464–474, 2022. https://doi.org/10.25082/AMLER.2022.02.015
[15] M. Sozoniuk, J. Park, and N. Lumby, "Investigating residents' acceptance of mobile apps for household recycling: A case study of New Jersey," *Sustainability (Switzerland)*, vol. 14, no. 17, p. 10874, 2022. https://doi.org/10.3390/su141710874
[16] K. K. de Wildt and M. H. C. Meijers, "Time spent on separating waste is never wasted: Fostering people's recycling behavior through the use of a mobile application," *Comput Human Behav*, vol. 139, 2023. https://doi.org/10.1016/j.chb.2022.107541
[17] O. Iparraguirre-Villanueva, F. Sierra-Liñan, and M. Cabanillas-Carbonell, "Location-based mobile application for blood donor search." [Online]. Available: www.ijacsa.thesai.org.
[18] K. Thibuy, S. Thokrairak, and P. Jitngernmadan, "Holistic solution design and implementation for smart city recycle waste management case study: Saensuk city," in *InCIT 2020—5th International Conference on Information Technology*, Institute of Electrical and Electronics Engineers Inc., Oct. 2020, pp. 233–237. https://doi.org/10.1109/InCIT50588.2020.9310948
[19] A. Iqbal, X. Liu, and G. H. Chen, "Municipal solid waste: Review of best practices in application of life cycle assessment and sustainable management techniques," *Science of the Total Environment*, vol. 729, 2020. https://doi.org/10.1016/j.scitotenv.2020.138622
[20] J. L. Gálvez-Martos, D. Styles, H. Schoenberger, and B. Zeschmar-Lahl, "Construction and demolition waste best management practice in Europe," *Resour Conserv Recycl*, vol. 136, pp. 166–178, 2018. https://doi.org/10.1016/j.resconrec.2018.04.016

[21] H. Hettiarachchi, S. Ryu, S. Caucci, and R. Silva, "Municipal solid waste management in Latin America and the Caribbean: Issues and potential solutions from the governance perspective," *Recycling*, vol. 3, no. 2, p. 19, 2018. https://doi.org/10.3390/recycling3020019

[22] K. Jankee, "Enhancement of polyethylene terephthalate bottles recycling in mauritius through the creation of a mobile application," *European Journal of Sustainable Development*, vol. 10, no. 3, p. 27, 2021. https://doi.org/10.14207/ejsd.2021.v10n3p27

[23] M. M. Ablaza-Cruz, "Designing a mobile application framework as an innovative IT solution for waste recycling," in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, 2020. https://doi.org/10.1088/1757-899X/803/1/012046

[24] T. R. Coelho, M. R. M. C. Hino, and S. M. O. Vahldick, "The use of ICT in the informal recycling sector: The Brazilian case of Relix," *Electronic Journal of Information Systems in Developing Countries*, vol. 85, no. 3, 2019. https://doi.org/10.1002/isd2.12078

[25] K. Macháčková, "The nature of project management found in nature," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 6, pp. 108–122, 2023. https://doi.org/10.3991/ijep.v13i6.39199

[26] J. Selamet and T. Simpson, "A design for recycling: Developing a mobile application to improve recycling behavior," *International Journal of Visual Design*, vol. 13, no. 4, pp. 45–61, 2019. https://doi.org/10.18848/2325-1581/CGP/v13i04/45-61

[27] M. Lindholm *et al.*, "Substance flow analysis on diffused toxics contained in end-of-life cellular phone," 2003.

[28] I. A. Abu-AlSondos, A. A. Salameh, A. F. Alkhwaldi, A. S. Mushtaha, M. Shehadeh, and A. Al-Junaidi, "Evaluating mobile e-learning systems acceptance: An integrated model," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 17, no. 16, pp. 30–47, 2023. https://doi.org/10.3991/ijim.v17i16.42679

[29] A. Alfahid, M. Alrige, H. Abeeri, and E. Sulami, "DoItRight: An arabic gamified mobile application to raise awareness about the effect of littering among children." [Online]. Available: www.ijacsa.thesai.org.

[30] P. Wandee, Z. Bussabong, and S. Duangkum, "Application for a waste management via the QR-code system." [Online]. Available: www.ijacsa.thesai.org.

[31] E. Campos-Pajuelo, L. Vargas-Hernandez, F. Sierra-Liñan, L. Liñan, J. Zapata-Paulini, and M. Cabanillas-Carbonell, "Learning the chemical elements through an augmented reality application for elementary school children," *Advances in Mobile Learning Educational Research*, vol. 2, no. 2, pp. 493–501, 2022. https://doi.org/10.25082/AMLER.2022.02.018

[32] Y. Daniel and A. Balaguera, "Metodologías ágiles en el desarrollo de aplicaciones para dispositivos móviles. Estado actual Agile methodologies in the development of applications for mobile devices. present state," *Revista de tecnologia – Journal of Technology*, vol. 12, no. 2, pp. 111–124, 2013.

[33] SYNTONIZE, "mobile application development methodologies," https://www.syntonize.com/en/agile-development/.

[34] kissflow, "3 main types of application development methodologies [Updated]."

8 AUTHORS

Orlando Iparraguirre-Villanueva, Systems engineer with a master's degree in information technology management, PhD in Systems Engineering from the Universidad Nacional Federico Villarreal – Peru. Extensive experience in undergraduate and postgraduate teaching in different universities in the country. Thesis advisor and jury in different universities. Professional experience in management positions in the field of Information Technology. Research professor with publications in Scopus and WoS indexed journals. Topics of interest: Open-Source Software,

IoT, Augmented Reality, Machine Learning, AI, CNN. You can contact us by email: oiparraguirre@ieee.org

Luis Tuesta-Pereda, Systems engineer, with solid knowledge in the C# programming language. I have worked on academic and business projects. I have experience in database design and development using SQL EXPRESS as database manager, I am familiar with Telerik UI for WinForms, a tool that offers a variety of controls, themes, and functionalities to create modern and attractive applications. Currently, I work as a freelancer developing web applications.

Elvis Tapia-Chavez, Systems engineer passionate about innovation and the creation of cutting-edge technological solutions. My focus is on developing projects that drive progress and improve people's quality of life. Through my work experience, I have acquired a solid knowledge in software design and development, as well as in the implementation of efficient IT systems.

Michael Cabanillas-Carbonell, Systems engineer. A qualified researcher by the National Council of Science, Technology, and Innovation – Peru. Research professor at different universities in Peru. President of the IEEE-Peru Education Society Chapter. President of the EIRCON Conference (Engineering International Research Conference) (E-mail: mcabanillas@ieee.org).