DIGITAL TRANSFORMATION IN CIRCULAR ECONOMY: ENHANCING PLASTIC WASTE COLLECTION EFFICIENCY AND EFFECTIVENESS

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ABSTRACT

Efficient plastic waste collection on data management and reward calculation are essential for effective downstream recycling. An efficient system is needed to manage plastic waste collection data and calculate commissions or rewards based on the amount of waste collected by waste managers. BijakBerplastik, a web and mobile device-based application, aims to simplify storing plastic waste collection data and help calculate commissions or prizes for waste managers. This application was developed through context analysis, application use case design, application development, and feedback evaluation. Currently, it serves 345 users, including scavengers, waste banks, small stalls, kiosks, large stalls, and waste presses. BijakBerplastik is proven to improve data accuracy, streamline commission calculations, and enhance user experience. Users recommend adding transaction recording features and integrating the customer loyalty system. On the other hand, digitalization also improves productivity by 20% in the decision-making process and saves buying price by about 1.5% by the loyalty program.

Keywords: digitalization, data management, plastic recycling, decision-making, waste management

1. INTRODUCTION

Recycling is the most widely used circular approach and is highly relevant to plastic materials, up or downcycling (Sitadewi et al., 2021). Plastic waste recycling is a vital component of sustainable waste management, playing a crucial role in addressing environmental concerns associated with plastic materials (Tejaswini et al., 2022). However, the global recycling rates for plastic still need to improve, particularly in developing nations where challenges related to infrastructure, governance, and economic disparities pose significant obstacles to effective waste management. Global plastic recycling rates are currently estimated at approximately 9%, with developed countries exhibiting higher rates of around 30% due to stringent regulations, while developing countries often lag at close to 0% (Singh & Walker, 2024). Notable progress has been observed in the European Union, India, and China, with recycling rates reaching 12-13% by 2019, whereas the United States reports a significantly lower rate of approximately 4.5%. The surge in plastic production from 2 million tons annually in 1950 to over 500 million tons in 2020, with projections to reach 1 billion tons by 2050, underscores the urgent need for global efforts to curtail this trend and address the resultant waste management challenges (Woldemar D'ambrières, 2019). Nonetheless, international efforts are underway to combat the plastic waste crisis through initiatives to bolster recycling infrastructure and reduce plastic production. These efforts serve to provide assurance and instill confidence in the global community.

Moreover, managing plastic waste in developing nations presents various challenges, including inadequate infrastructure, improper waste disposal, and environmental pollution (Kibria et al., 2023; Mihai et al., 2022; Yang et al., 2018). However, there are opportunities for improvement, mainly through integrating the informal sector, particularly waste pickers, which plays a pivotal role in managing plastic waste and presents an opportunity for enhancing efficiency and yielding economic benefits. Integrating these workers into formal waste management systems can improve efficiency and yield significant economic benefits (Buch et al., 2021). Essential to this effort are effective policies, including bans on single-use plastics and incentives for recycling (Cowan et al., 2021). However, enforcement can be hindered by limited resources and governance issues. Raising awareness about the importance of recycling and proper waste disposal is crucial. Educational campaigns can be instrumental in reshaping public behavior and reducing plastic waste (Torres-Pereda et al., 2020).

Furthermore, implementing advanced recycling technologies and digital management systems can streamline plastic waste management by tracking waste, optimizing collection routes, and improving recycling processes (Kannan et al., 2024). Providing financial incentives for recycling can also spur greater participation in waste management programs, such as offering subsidies for recycling businesses or rewards for individuals who recycle (Kibria et al., 2023). By addressing these key areas, developing countries can enhance their plastic waste management systems and mitigate environmental pollution.

Plastic waste management and reuse have become very popular among recycling communities due to their high selling value and the availability of clear trade regulations. The plastic waste recycling supply chain stretches from scavengers, collectors, shredders, and plastic factories to the bottled drinking water industry that utilizes it as part of its supply chain. However, managing plastic waste, which is very scattered and sporadic, has resulted in the need for more transparent economic distribution information between stages of the recycled plastic production process (Bhubalan et al., 2022). Although the amount of public plastic consumption continues to increase, there is a gap in the middle chain where the plastic recycling processing factory is always undersupplied and underutilized. Meanwhile, the profession of scavengers, which has always been considered unprofitable, is one of the biggest beneficiaries, so it is possible to earn an income that exceeds the income of ordinary office workers. A consistent supply of recycled plastic has always been a problem for recycling plants due to its uncertainty (Hahladakis & Iacovidou, 2019).

This study proposed a digital-based management system to simplify storing plastic waste collection data and commission a system for waste collectors to optimize the plastic recycling process. By focusing on these critical areas, the paper seeks to provide a thorough understanding of the challenges and opportunities in digitizing plastic waste recycling in developing nations, particularly Indonesia. Ultimately, the goal is to enhance waste management systems and mitigate environmental pollution.

2. LITERATURE REVIEW

Several concepts are involved in the CE definition, and there needs to be more clarity regarding how they relate. Some are basic, classic, and fundamental principles, and others are complex, built on the basic ones. Circular economy (CE) is a new economic model that focuses on maximizing the reuse and recycling of materials to minimize waste generation. It aims to revolutionize the production, consumption, distribution, and recovery process based on a cradle-to-cradle vision (Ghisellini et al., 2018). The Circular Economy is an economic system aiming for zero waste and pollution by reusing materials and using clean, renewable energy sources (Nobre & Tavares, 2021). As definitions evolve, they encompass various aspects of the Circular Economy, including the design of new products, the emergence of new legislation, and adoption by industry (Arruda et al., 2021). Expanding on the criticisms discussed earlier, achieving genuine circularity would require a practical circular economy that should address specific issues, be specific about its goals, consider trade-offs, encompass energy, individuals, and waste globally, and be open and accountable for its economic, social, and environmental impacts (Corvellec et al., 2022).

Digital technology in waste recycling is a significant advancement that complements traditional mechanical recycling methods. This technology, which is continuously evolving, plays a crucial role in managing waste by providing real-time information on the location, status, and quantity of non-biodegradable trash. It enhances traceability and makes products and services more accessible, keeping our audience informed about the latest advancements in the field (Kurniawan et al., 2023; Mangold & von Vacano, 2022). Digital tools enable individuals to make environmentally conscious choices and assist organizations in offering the best sustainable solutions. The leading technologies of Industry 4.0 included sensors, IoT, blockchain, big data analytics, and AI.

Furthermore, much of the research concentrated on municipal waste management, waste collection procedures, and recycling methods (Kannan et al., 2024). Internet of Things devices can efficiently simulate, monitor, and verify products within the supply chain (Sarkis et al., 2021). Dealing with environmental effects and methods for using data, improving energy usage, and reducing digital waste and carbon footprint.

The best way to deal with plastic is by transforming plastic waste into valuable products like tiles, paver blocks, concrete, sanitizers, perfumes, graphene, electrode materials, carbon nanotubes, etc. This addresses the environmental issue and presents a significant economic opportunity. Responsible waste management is a crucial step towards a sustainable future, underscoring the importance of our work and inspiring our audience to continue their efforts (Maitlo et al., 2022). It offers an opportunity to generate economic value. Establishing responsible supplier-buyer relationships requires economic incentives, trust-building efforts, and a willingness to learn and adapt. By having waste pickers sort materials and then using industrial-scale sorting and washing, the resulting recyclables were similar in quality to recyclables from advanced formal recycling systems in high-income countries (Gall et al., 2020)

3. METHOD

The study employed a thorough qualitative approach to obtain contextual findings, utilising a comprehensive mixed method. The research designed a systematic application named BijakBerplastik to record the collection and processing of plastic bottle waste from bottled drinking water used by the Recycling Business Unit (RBU). Komodo Water develops the application in collaboration with Danone Indonesia.

Waterfall software development methodology

The application development is based on the standard software development cycle, while each phase will be executed in a single cycle known as The Waterfall Model (Aroral, 2021; Pargaonkar, 2023). The Waterfall Model is known as a linear sequential life cycle model. The earliest process model is straightforward to comprehend and apply. Each phase must be finished before the next one can commence, and there is no overlap between phases. The model depicts the software development process in a linear sequential flow. As a result, it is also called a linear-sequential life cycle model, which implies that any phase in the development process begins only when the preceding phase is finished. In the waterfall model, the five phases do not overlap. This model is widely utilized in software engineering to ensure project success. In "The Waterfall" approach, the entire software development process is divided into distinct phases, and typically, the output of one phase serves as the input for the subsequent phase sequentially. Each cycle consists of 5 stages: planning and requirements, design, implementation, verification, and maintenance. The application was developed for six months, followed by training for three months.

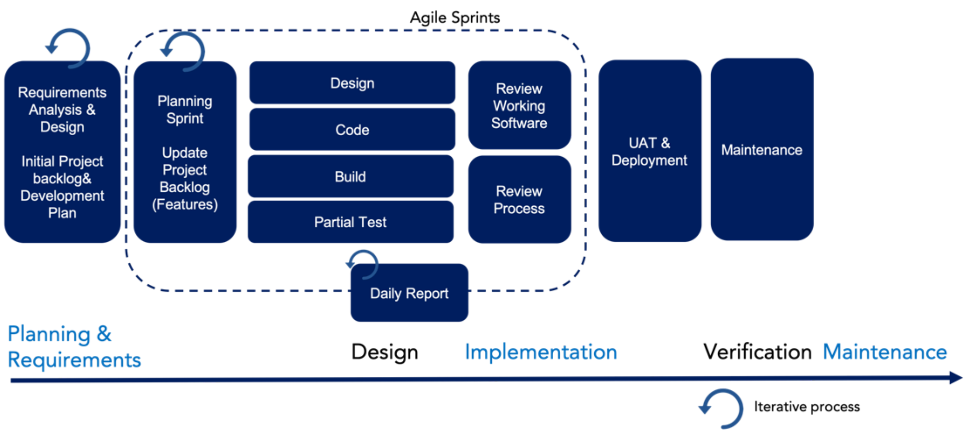

Figure 1. The waterfall model for BijakBerplastik application development

Planning and requirements

In the initial phase of the Design Sprint, a series of crucial activities are undertaken in close collaboration with the client. This ensures that the project meets the client's requirements and expectations. High-level requirements are identified based on the initial client needs, and any further data or information necessary to ensure clarity and accuracy is gathered. Subsequently, a prototype is developed based on the client's input, which is then presented for approval, ensuring that the layout and navigation flow meet their expectations.

Feedback from the client is also solicited, and an 'Unclear Issues' document is provided to address any questions or areas requiring further clarification. This document ensures that all client concerns are addressed and resolved. The feedback is meticulously documented and is a reference for subsequent project stages. Once the client validates the requirements, a flow diagram and high-fidelity designs are created, and each item in the backlog is defined with scenarios and behaviour-driven development specifications. Additionally, a simple Functional Specification Document (FSD) is produced as the final deliverable of the Design Sprint process, accompanied by comprehensive project documentation.

Following the insights gained from the Design Sprint, the Project Manager devises the plan for the subsequent Development Sprint stage. The Design Sprint process is iterative, each lasting five working days and limited to two revisions per iteration to maintain project momentum. Preparedness for any requirements or application flow changes during development is emphasized, and these changes are re-analyzed and may necessitate timeline adjustments. Requests outside the initial scope may result in a Change Request (CR), but the process is adaptable to accommodate such changes.

Design and implementation

The Design and the Implementation phase ensures the system is developed and refined through an iterative approach. The process begins with the continuation of the Design Sprint, which is carried out in tandem with development activities. If the remaining requirements are to be addressed, these are further analyzed during this stage. The design sprint outcomes are then applied in the development sprint scheduled for the following week. Notably, the first sprint of application development cannot commence until at least one design sprint has been completed to ensure a clear and well-validated starting point.

During the Development Sprint, the system is built incrementally, with each cycle focusing on smaller, manageable portions of the application. New features and functionalities are added progressively, allowing the system to evolve with each iteration. The development team remains flexible, accommodating feature adjustments during the development process as long as they stay within the original scope. However, any significant changes to the flow or requirements may affect the project timeline and, if beyond the initial agreement, could result in additional costs.

Verification and maintenance

The Testing phase is essential for ensuring that the system functions as intended. Several types of testing are conducted during this phase. Unit Testing verifies the functionality of individual components, ensuring they meet the specified requirements. Following this, System Integration Testing (SIT) is carried out jointly by Komodo Water and Danone to ensure the smooth integration of the new system with existing ones. Positive and negative test scenarios are explored during SIT to ensure robust system performance. Once integration testing is complete, the end users conduct User Acceptance Testing (UAT) to validate that the solution meets their needs. Any errors or defects identified during testing are addressed through bug fixes. The final deliverables from this phase include the UAT document and deployment approval. The Deployment stage marks the system’s transition to live operation. Once deployed, a 6-month warranty period help to fix any necessary bug.

Training

To ensure a smooth rollout of the system, comprehensive training and mentoring will be provided to all on-the-ground staff, including both application users and administrators. This training will cover all necessary aspects of the system's operation, enabling staff to utilize and manage the application effectively. The mentoring component aims to provide ongoing support to address any challenges during the initial implementation phase, ensuring that staff are fully equipped to operate the system efficiently.

Loyalty program

To increase participation in waste collection, RBU has introduced a loyalty program. Participants will earn points by collecting a certain amount of waste. These points can then be exchanged for rice or cooking oil. Participants will earn 1 point for every 100 kg of plastic waste collected. Five points can be exchanged for 2 liters of cooking oil, and 10 points for 5 kg of rice. The program runs throughout the year, allowing waste collectors to accumulate points as long as they meet the required volume.

Evaluation

Following the maintenance phase, the research also included evaluating the pilot implementation in the field. Data was collected through the distribution of questionnaires, structured focus group discussions (FGDs), and in-depth interviews. The evaluation study was conducted in August-September 2025, with questionnaires distributed to 100 respondents who used the application out of 345 users from RBU South Tangerang.

4. RESULTS AND DISCUSSION

BijakBerplastik is a pilot digital waste traceability program for rPET supply chains in Indonesia. The system empowers all stakeholders by providing traceability of the plastic recycling process supply chain. It consists of a mobile application for waste-pickers and a web-based back office application for aggregators and bottled water companies, like Danone, enabling them to manage and report data. The primary goals are to increase the scope and granularity of information monitored, establish a transparent and traceable chain of custody, and control pricing and incentives to respond quickly to market changes. One of the key features is real-time reporting, which ensures that all stakeholders can operate efficiently and respond promptly to any market changes.

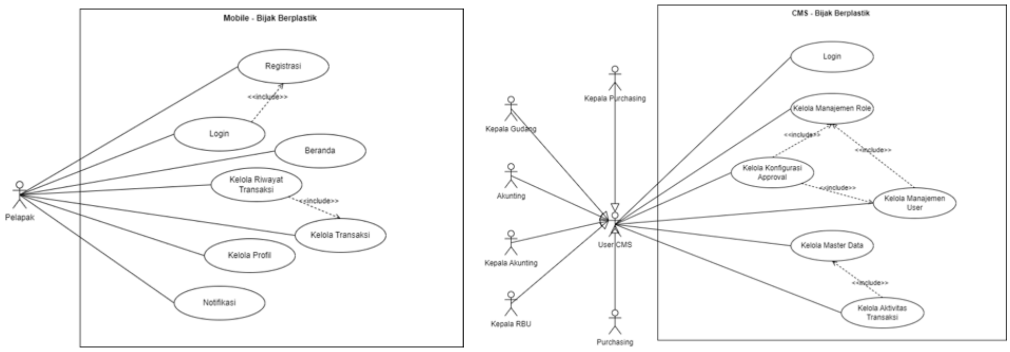

Figure 2. Use case mobile and CMS phase 1

Additionally, it offers cloud-based access to an information dashboard that is not reliant on physical infrastructure, with tiered access depending on the user's role in the supply chain. To operate BijakBerplastik optimally, users must have hardware with specific minimum specifications, including a smartphone, a processor with a minimum capacity of 1.5 GHz, memory/RAM with a minimum capacity of 2 GB, and storage media/hard drive with at least 10 GB of available capacity. The software operating system must be Android with a minimum version of 5.0 or iOS with a minimum version of 12, and the application requires an internet network connection. Users are expected to understand how to use and operate a smartphone device.

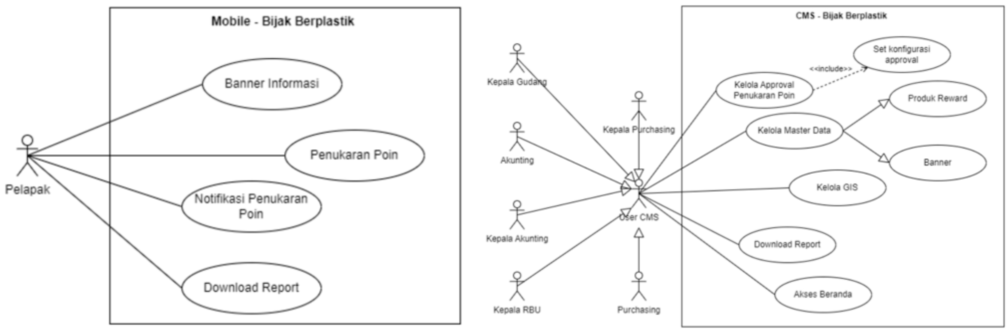

Figure 3. Use case mobile and CMS phase 2

10-month digitalisation journey has yielded promising results, with a 169% increase in users. This surge is attributed to user interest in digitalisation, the practical education provided by the RBU officers, and the incentivisation system in place. The initial three months were the most challenging, with user education being the linchpin. The RBU officers played a pivotal role in enlightening the users about the significance of digitalisation and providing a manual guide to instil confidence in the digital process.

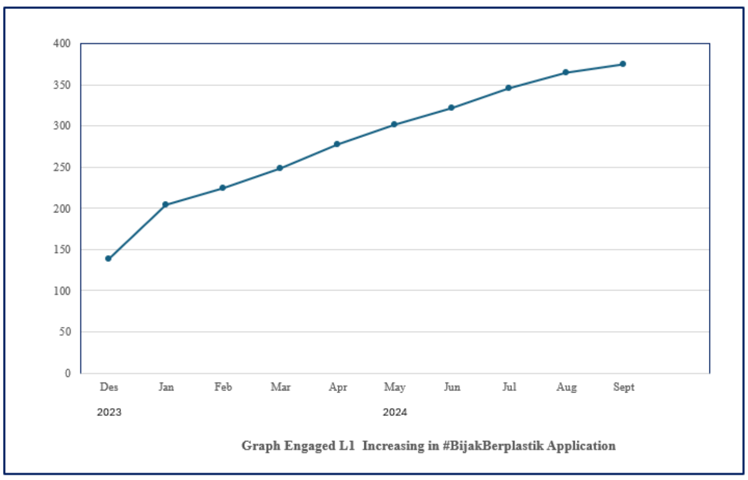

Figure 4. Increasing user number of BijakBerplastik application

The loyalty program trial, conducted in January, has been a resounding success in attracting traders and scavengers to the application system. This is evident from the graph, which shows a consistent increase in participation since January. The point exchange feature has emerged as the most popular among users. However, the quantity of waste collected fluctuates based on its availability in the field, a factor that underscores the program's reliance on external factors and the need for a steady supply of waste. The variation in waste collection is not dependent on the number of users using the application, but rather on the supply of raw materials for plastic bottle waste in the field. This is influenced by the price offered, the number of players, and the competitors in the field who absorb raw materials.

Up to this point, 20 users have availed themselves of the point exchange, a clear indication of the program's popularity. This figure signifies that 20 individuals have collectively redeemed 20 sets of 5 points, totaling 500 kg, or 20 sets of 10 points, equivalent to 1,000 kg, resulting in a total of 10,000 kg and 20,000 kg, respectively. This not only demonstrates the program's success but also the significant economic value it generates. Assuming the selling price of plastic waste is IDR 7,300.00/kg, it is estimated that transactions involving 500-1,000 kg carry an economic value of IDR 36,500,000.00-73,000,000.00. When juxtaposed with the capital costs of purchasing rice or cooking oil, the expenses incurred by RBU for this endeavor amount to only IDR 3,500,000.00 -7,000,000.00, constituting a mere 5% of the total sales value.

The results indicate that digitalization did not increase the volume collected. This can be attributed to various factors, primarily driven by competition. Price competition, buying mechanisms, and social relations all affected this outcome. However, it is essential to note that digitalization has other significant benefits, as discussed in the following paragraphs. We acknowledge the challenges faced in the digitalization process and are committed to addressing them for future improvements.

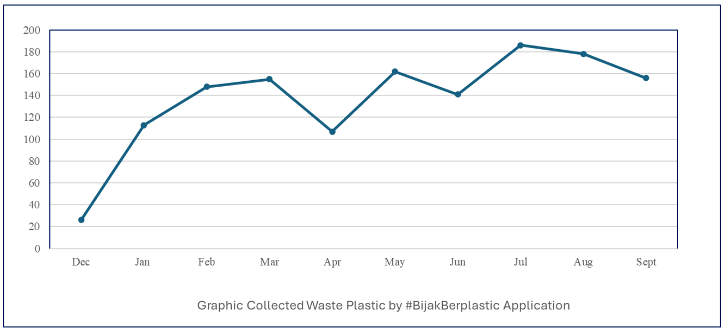

Figure 5. Collected plastic waste by BijakBerplastik application

The digitalization journey has significantly improved RBU's productivity, simplifying supplier data management by 20%. Previously, RBU relied on spreadsheets for data collection and analysis. However, with digitalization, RBU can now make decisions based on graphical representations of the data, leading to a more efficient and productive process.

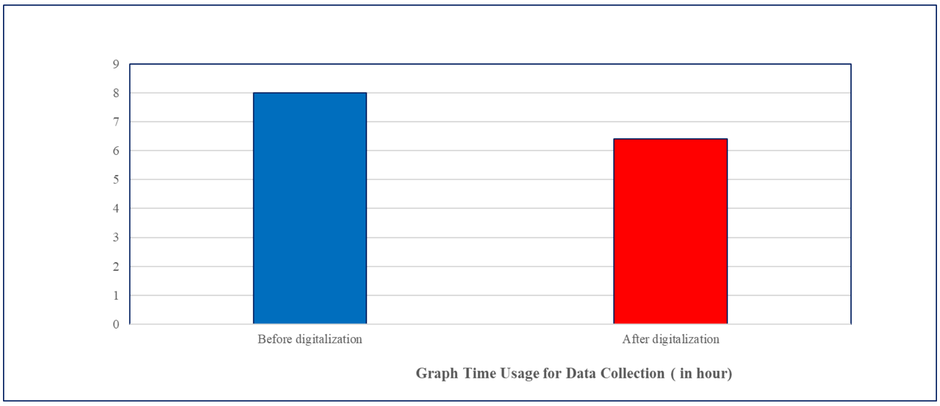

Figure 6. Time usage for data collection

Digitalization has also led to a decrease in material costs, primarily due to the implementation of an incentivization system. By reducing the buying price and managing market price fluctuations through incentivization, RBU has navigated the middle ground in price wars. The more volume a supplier sells to RBU, the more incentive they receive, providing a strong motivation for increased sales.

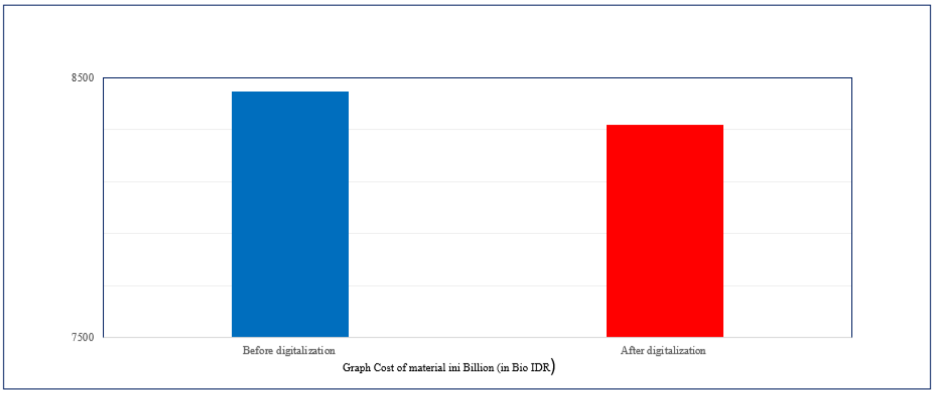

Figure 7. Cost of material in billion IDR

5. CONCLUSION

Digitalization has the potential to significantly improve the effectiveness of the circular economy, particularly in waste management and recycling, through applications and platforms. By leveraging incentivization systems, digital platforms can enhance recycling collection rates while reducing material costs. The cornerstone of this system's success is user education—ensuring that consumers, waste traders, scavengers, and waste banks understand and utilize the technology effectively.

However, education alone is insufficient. Ongoing training and consistent assistance are critical to building trust and fostering a culture of collaboration between Recycling Business Units (RBU), waste traders, scavengers, and other stakeholders in the waste ecosystem. These elements support smooth operations and help embed digitalization into daily waste management practices. A personal approach is necessary to handle waste collection's diverse and challenging nature, where each stakeholder has unique needs and circumstances.

Furthermore, digital applications have the transformative power to revolutionize waste management. These platforms can integrate creative approaches like gamification and community gatherings to cultivate enthusiasm. For instance, a point redemption system or competitive challenges among users can engage traders and scavengers, motivating them to deposit more waste. This dynamic engagement fosters a sense of ownership and participation, thereby strengthening the circular economy. In essence, digital applications can metamorphose the traditional waste management model into a collaborative, incentivized, and efficient system, driving sustainability and reducing environmental impact.

Digitalization improves the recycling collection rate and reduces the cost of materials through an incentivization system. The critical success factor of digitalization is the education of the users. Training and consistent assistance are not just tasks, but crucial elements that need to be done to build the trust and culture between RBU and the waste trader, scavanger and waste bank. However, the nature of waste collection and management is challenging and requires a personal approach to manage. Providing creative approach like community gathering or gamification through point redemption system will help build dynamic enthusiasm among the users, encouraging the traders and scavengers to deposit more waste.

6. REFERENCES

Aroral, H. K. (2021). Waterfall Process Operations in the Fast-paced World: Project Management Exploratory Analysis. *International Journal of Applied Business and Management Studies*, *6*(1), 2021.

Arruda, E. H., Melatto, R. A. P. B., Levy, W., & Conti, D. de M. (2021). Circular economy: A brief literature review (2015–2020). *Sustainable Operations and Computers*, *2*, 79–86. https://doi.org/10.1016/j.susoc.2021.05.001

Bhubalan, K., Tamothran, A. M., Kee, S. H., Foong, S. Y., Lam, S. S., Ganeson, K., Vigneswari, S., Amirul, A. A., & Ramakrishna, S. (2022). Leveraging blockchain concepts as watermarkers of plastics for sustainable waste management in progressing circular economy. *Environmental Research*, *213*. https://doi.org/10.1016/j.envres.2022.113631

Buch, R., Marseille, A., Williams, M., Aggarwal, R., & Sharma, A. (2021). From waste pickers to producers: An inclusive circular economy solution through development of cooperatives in waste management. *Sustainability (Switzerland)*, *13*(16). https://doi.org/10.3390/su13168925

Corvellec, H., Stowell, A. F., & Johansson, N. (2022). Critiques of the circular economy. *Journal of Industrial Ecology*, *26*(2), 421–432. https://doi.org/10.1111/jiec.13187

Cowan, E., Booth, A. M., Misund, A., Klun, K., Rotter, A., & Tiller, R. (2021). Single-use plastic bans: Exploring stakeholder perspectives on best practices for reducing plastic pollution. *Environments - MDPI*, *8*(8). https://doi.org/10.3390/environments8080081

Gall, M., Wiener, M., Chagas de Oliveira, C., Lang, R. W., & Hansen, E. G. (2020). Building a circular plastics economy with informal waste pickers: Recyclate quality, business model, and societal impacts. *Resources, Conservation and Recycling*, *156*. https://doi.org/10.1016/j.resconrec.2020.104685

Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, *178*, 618–643. https://doi.org/10.1016/j.jclepro.2017.11.207

Hahladakis, J. N., & Iacovidou, E. (2019). An overview of the challenges and trade-offs in closing the loop of post-consumer plastic waste (PCPW): Focus on recycling. *Journal of Hazardous Materials*, *380*. https://doi.org/10.1016/j.jhazmat.2019.120887

Kannan, D., Khademolqorani, S., Janatyan, N., & Alavi, S. (2024). Smart waste management 4.0: The transition from a systematic review to an integrated framework. In *Waste Management* (Vol. 174, pp. 1–14). Elsevier Ltd. https://doi.org/10.1016/j.wasman.2023.08.041

Kibria, M. G., Masuk, N. I., Safayet, R., Nguyen, H. Q., & Mourshed, M. (2023). Plastic waste: Challenges and opportunities to mitigate pollution and effective management. In *International Journal of Environmental Research* (Vol. 17, Issue 1). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s41742-023-00507-z

Kurniawan, T. A., Meidiana, C., Dzarfan Othman, M. H., Goh, H. H., & Chew, K. W. (2023). Strengthening waste recycling industry in Malang (Indonesia): Lessons from waste management in the era of Industry 4.0. *Journal of Cleaner Production*, *382*. https://doi.org/10.1016/j.jclepro.2022.135296

Maitlo, G., Ali, I., Maitlo, H. A., Ali, S., Unar, I. N., Ahmad, M. B., Bhutto, D. K., Karmani, R. K., Naich, S. ur R., Sajjad, R. U., Ali, S., & Afridi, M. N. (2022). Plastic waste recycling, applications, and future prospects for a sustainable environment. In *Sustainability (Switzerland)* (Vol. 14, Issue 18). MDPI. https://doi.org/10.3390/su141811637

Mangold, H., & von Vacano, B. (2022). The Frontier of plastics recycling: rethinking waste as a resource for high-value applications. *Macromolecular Chemistry and Physics*, *223*(13). https://doi.org/10.1002/macp.202100488

Mihai, F. C., Gündogdu, S., Markley, L. A., Olivelli, A., Khan, F. R., Gwinnett, C., Gutberlet, J., Reyna-Bensusan, N., Llanquileo-Melgarejo, P., Meidiana, C., Elagroudy, S., Ishchenko, V., Penney, S., Lenkiewicz, Z., & Molinos-Senante, M. (2022). Plastic pollution, waste management issues, and circular economy opportunities in rural communities. *Sustainability (Switzerland)*, *14*(1). https://doi.org/10.3390/su14010020

Nobre, G. C., & Tavares, E. (2021). The quest for a circular economy final definition: A scientific perspective. *Journal of Cleaner Production*, *314*. https://doi.org/10.1016/j.jclepro.2021.127973

Pargaonkar, S. (2023). A Comprehensive Research Analysis of Software Development Life Cycle (SDLC) Agile & Waterfall Model Advantages, Disadvantages, and Application Suitability in Software Quality Engineering. *International Journal of Scientific and Research Publications*, *13*(8), 120–124. https://doi.org/10.29322/ijsrp.13.08.2023.p14015

Sarkis, J., Kouhizadeh, M., & Zhu, Q. S. (2021). Digitalization and the greening of supply chains. *Industrial Management and Data Systems*, *121*(1), 65–85. https://doi.org/10.1108/IMDS-08-2020-0450

Singh, N., & Walker, T. R. (2024). Plastic recycling: A panacea or environmental pollution problem. *Npj Materials Sustainability*, *2*(1). https://doi.org/10.1038/s44296-024-00024-w

Sitadewi, D., Yudoko, G., & Okdinawati, L. (2021). Bibliographic mapping of post-consumer plastic waste based on hierarchical circular principles across the system perspective. In *Heliyon* (Vol. 7, Issue 6). Elsevier Ltd. https://doi.org/10.1016/j.heliyon.2021.e07154

Tejaswini, M. S. S. R., Pathak, P., Ramkrishna, S., & Ganesh, P. S. (2022). A comprehensive review on integrative approach for sustainable management of plastic waste and its associated externalities. In *Science of the Total Environment* (Vol. 825). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2022.153973

Torres-Pereda, P., Parra-Tapia, E., Rodríguez, M. A., Félix-Arellano, E., & Riojas-Rodríguez, H. (2020). Impact of an intervention for reducing waste through educational strategy: A Mexican case study, what works, and why? *Waste Management*, *114*, 183–195. https://doi.org/10.1016/j.wasman.2020.06.027

Woldemar D'ambrières. (2019). Plastics recycling worldwide: current overview and desirable changes. *Field Actions Science Reports*. https://journals.openedition.org/factsreports/5102

Yang, H., Ma, M., Thompson, J. R., & Flower, R. J. (2018). Waste management, informal recycling, environmental pollution and public health. *Journal of Epidemiology and Community Health*, *72*(3), 237–243. https://doi.org/10.1136/jech-2016-208597