Original Paper

An Integrated Model for Circular Waste Management Using the Internet of Things, Semantic Web, and Gamification (Circonomy): Case Study in Indonesia

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Abstract

Background: The waste problem is a global issue all developed and developing countries face. Like many developing countries, Indonesia has inadequate infrastructure to process an extremely high volume of waste produced throughout the country and minimal public participation in proper waste management. Although the Indonesian government regulates Waste Bank as a community-based waste management solution, there is lack of integrated technological innovation to support Waste Bank. This study fills the gap by developing Circonomy, a model combining IoT, gamification, and semantic web technologies to advance community-based circular waste management.

Objective: The proposed model Circonomy is inspired by the Waste Bank, the Indonesian Government's community-based waste management initiative. This research has objective to develop Circonomy as a circular waste model that integrate IoT-based smart-bin, semantic web, and gamification as an innovative technological solution.

Methods: We identify the problem faced by the Indonesian Waste Bank from three locations in Jakarta and Yogyakarta as a basis for the Circonomy model and prototype development. The evaluation of the model focuses on Technical Performance and User Experience. The Technical Performance has three indicators, i.e., Bin Capacity Accuracy with a minimum of 80% precision, Bin Lid Response Time should be less than 5 seconds at a minimum of 80% of trials, and Data Transmission Success Rate at a minimum of 80%. While User Experience Metrics has two indicators, i.e., a minimum of 80% reported high usability and ease of use, and at least 80% of users feel more motivated using the prototype than the traditional Waste Bank. We select 10 random participants from ages 18 to 60 to perform User Experience evaluation on our prototype.

Results: The Circonomy prototype demonstrates sound and stable performances related to Technical Performance and User Experience. Circonomy performs with at least 80% technical performance accuracy, comparable to industry standards. The accuracy problem lies in the placement of the ultrasonic sensor. The waste should be placed directly under the ultrasonic sensor to ensure the bin's capacity measurement accuracy. The User Experience testing results from 10 participants indicate that Circonomy has excellent user engagement, whereas 100% felt motivated by gamification, and 80% found the mobile application easy to use.

Conclusions: The testing result shows that Circonomy has acceptable performances for early-stage prototyping with at least 80% accuracy rate in technical performance and user experience. This ensures that Circonomy operates effectively in real-world conditions while remaining cost-efficient and scalable. For future development, Circonomy will prioritize enhancing the accuracy and reliability of sensor-based occupancy detection through improved sensor placement, multiple sensor integration, and exploring alternative technologies for regions with limited IT resources. In addition, more gamification features such as challenges and quiz should be added to improve the user experience and motivation.

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KEYWORDS

IoT; gamification; semantic web; waste management; circular economy; smart bin; Circonomy; semantic; game; games; gamification; gamified; Indonesia; developing country; developing countries; reuse; reduce; recycle; 3Rs; prototype; circular economy; circular waste

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