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Analysis on Android-Based Waste Management Evaluation: Toward Efficiency and Sustainability

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Abstract: The rapid development of information and communication technology is widely utilized by numerous private sector and governmental entities to enhance services and foster innovations aimed at establishing an accessible, effective, and efficient service system. In addressing the waste issue, the Government of Banyumas Regency is dedicated to innovating for the sake of achieving effective and efficient waste management through the application of digital technology. The examples encompass the utilization of the Salinmas and Jeknyong applications. The innovation in Android application-based waste management aims for public accessibility but encounters certain implementation challenges. This research aims to offer an insight into mobile-based waste management services and to identify the factors, both supportive and inhibiting, in the implementation of Android-based waste management through a Penta Helix approach. The research employed a descriptive method and qualitative approach. Descriptive analysis of the service coverage of Android-based waste management utilized a spatial overlay analysis. Qualitative analysis adopted a thematic approach to identify the supportive and inhibiting factors in the implementation of Android-based waste management through the Penta Helix approach. The research findings indicate that Android-based waste management services are predominantly utilized by urban communities, while rural areas have limited access to Android application services. The analysis of supportive and inhibiting factors in the implementation of Android-based waste management, using the Penta Helix approach, underscores that significance of collaborative synergy and active involvement of all stakeholders, including the public, private, and local communities, in conceptualization and planning processes. Integration of technical, environmental, social, financial, institutional, and political aspects is imperative to ensure the system's sustainability. The strategic considerations that can be suggested as a solution for Android-based waste management in Banyumas Regency encompass technology, educational aspects, economic factors, institutional framework, policies, collaborative efforts, active participation, and coordination.

Keywords*: Android-Based Waste Management, Efficiency, Sustainability, Penta Helix, Management Evaluation*

Introduction

By 2030, every country significantly reduces waste generating through prevention, reduction, recycling, and reuse. This aligns with the Sustainable Development Goals (SDGs) target, aiming to ensure sustainable patterns of production and consumption (SDGs target 12.5). It is in line with the target of reducing and managing Household Waste (SRT) and Similar Household Waste (SSRT) as outlined in Presidential Regulation (Pepres) of the Republic of Indonesia Number 97 of 2017 on the National Policy and Strategy for SRT and SSRT Management, which targets a 30 percent reduction in household waste and a 70 percent handling rate by 2025.

Banyumas Regency is the fourth most populous regency in Central Java, and in 2021, it produced a total waste generation of 195,357.75 tons per year, averaging 535.23 tons of daily waste generation (source: https://sipsn.menlhk.go.id). The daily waste volume in Banyumas increases each year, reaching 657.21 m^3. The predominant types of waste produced are organic waste at 52.6% and plastic waste at 27.13%. Serious measures are required to address this significant waste production. One of the approaches chosen by the local government of Banyumas Regency to solve waste management is the utilization of information technology, specifically by creating the Sampah Online Banyumas (Salinmas) and Jeknyong applications. The Banyumas Regency Government

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has initiated an online waste management system through Android-based applications. This system can be utilized by residents for waste disposal.

In line with the widespread advancement of technology, governments have increasingly embraced e-government mechanisms. Technological tools have enhanced the efficiency of monitoring, data collection, and gathering feedback from citizens to improve the provision of public services. Local governments, in particular, have harnessed digital and mobile technologies such as tablets, smartphones, and sensors to "fundamentally transform various aspects of urban service delivery" (Greenberg, 2015).

Developing countries also employ ICT to streamline city services. Many cities in the Global South utilize technology for "seamless information flow," enabling "faster and cost-effective delivery of goods and services, quicker and better decision-making processes, and the removal of unnecessary paper barriers" (Ndou 2004).

In relation to Municipal Solid Waste (MSW) collection and management, there is significant potential to automate and simplify processes using information and communication technology. Existing literature demonstrates that various technologies, such as Geographic Information Systems (GIS) and RFID, have proven successful in enhancing municipal waste management. Governments worldwide also employ geospatial analysis for policy implementation. GIS enables users to combine spatial data with other quantitative and qualitative data about a specific location. This technology has been utilized in Pondicherry, India, and Lemnos, Greece, to select optimal landfill locations and minimize economic, environmental, health, and social costs (Sumathi, Natesan, and Sarkar, 2008). The same technology is also employed to reduce fuel and transportation costs in municipal waste management by determining the most cost-effective routes for waste collection vehicles in India (Ghose, Dikshit, and Sharma, 2006), Praia, Cape Verde (Tavares et al. 2009), and Pudong, China (Zhu et al. 2009).

RFID is also used worldwide in developed countries to automate processes in SWM (Solid Waste Management). RFID chips utilize electromagnetic fields to automatically identify and track tags containing electronically stored information attached to objects. These devices can assist in identifying, segregating, and disposing of hazardous materials and electronic waste in an environmentally friendly manner. In Germany, RFID-enabled waste bins allow collection vehicles to identify households, weigh waste bins, and charge fees accordingly (Abdoli 2009).

Integrating GIS and RFID technology can revolutionize solid waste management. Faccio et al. (2011) employed a model to gather static inputs from waste collection bins equipped with sensors and RFID, combined with dynamic inputs from vehicles through the GIS system. This allowed them to determine when waste collection bins reached their maximum capacity. Hannan et al. (2011) developed a similar model, replacing sensors with cameras on vehicles to assess the level of container fullness. Anagnostopoulos et al. (2015) used real-time data from St. Petersburg, Russia, to demonstrate how an integrated model involving sensor-based bins, tracked vehicles, and driver coordination through smartphones can assist in serving high-priority areas.

Although existing literature demonstrates simulations and trials of how technology can be utilized in integrated SWM systems, there is still no study that shows the widespread applicability of this technology in monitoring provision of services. This research aims to determine the impact of ICT in monitoring every process in municipal SWM, starting from input (such as waste collection), output (in the form of total waste transported to landfills), and the end result (such as citizen satisfaction and financial gains). The use of ICT in monitoring creates greater accountability among field staff and establishes a feedback loop for managers. Panel data is required to illustrate trends in waste collection/retrieval efficiency and profit gains resulting from the implementation of ICT technology interventions in Banyumas Regency.

Changes in lifestyle patterns, urbanization, and increased income levels have paved the way for consumerism, indirectly leading to increased waste generation. There is much inefficiency in current waste collection:

1. Time consumption - due to unsorted waste.
2. Soaring costs due to increased volume.
3. Traffic congestion and crowded transportation routes.
4. Unnecessary fuel consumption.

With the declining prices and improved accessibility of mobile services in recent years, smart waste management solutions can be provided by applying technology to existing operational systems to enable two-way communication between

operators and structured infrastructure within the city (Vance, 2022).

There are also other aspects to consider when contemplating the use of mobile technology for recycling and waste management. Since waste is a persistent issue in every region, it is not just about how it is disposed of but also how waste management can positively impact an area. In today's development, waste management innovation can be carried out by every sector. This means that waste management is a collective effort involving all stakeholders collaborating to create programs and policies established by the region. Collaboration is the key to accelerating the implementation of a program. Stakeholders involved in a program collaborate with each other to add value to the program and achieve the desired goals. Stakeholder collaboration is the process where individuals or groups influence a program based on different perspectives to create value through shared responsibility and mutual benefit. According to the Pentahelix concept, there are five stakeholder elements involved in an activity or initiative, namely ABCDGM (Academic, Business, Community, Government, and Media) (Suherlan et al., 2020). Each involved stakeholder has a distinct role based on the functions and capabilities of their respective institutions (Destiana et al., 2020).

Stakeholder collaboration is indeed an important aspect to consider since it can influence the quality and effectiveness of program implementation (Suherlan et al., 2020). According to Munt (2003) in Darwis et al. (2019), collaboration is crucial in fostering cooperation to achieve shared goals that result in meaningful and sustainable outcomes. Additionally, according to Kinanthi (2017) in Dachi & Djakman (2020), managing relationships with stakeholders is a vital aspect that needs to be optimized to create harmonious relationships that support the achievement of organizational objectives.

The issue of urban waste is highly significant as it directly relates to public health and the economy. Therefore, the collaborative management of waste requires multidisciplinary convergence between technology or engineering solutions and the design of public policies, taking into account socio-economic factors (Chalhoub, 2018). This research aims to analyze the evaluation of android-based waste management in Banyumas Regency and the supporting and inhibiting factors through the Penta Helix method.

Methodology

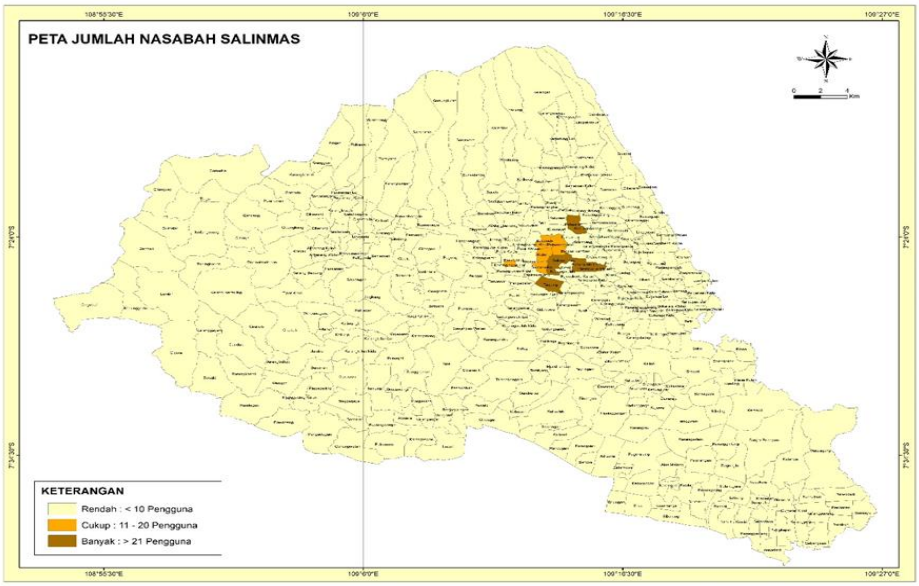
This research employed a descriptive-qualitative method. Descriptive analysis of android-based waste management service coverage was conducted using spatial overlay analysis. Meanwhile, the qualitative analysis was carried out with a thematic approach to identify supporting and inhibiting factors in the implementation of Android-based waste management. This research gathered primary data through focus group discussions (FGD), where each participant could share their contributions to waste management, their perceptions of waste issues, and the solutions they suggested to address these problems. This allowed each participant to understand the perspectives of others. Secondary data sources include documentation studies from reports of various institutions and information obtained from the internet. The researcher actively observed and participated during the FGD sessions. The FGD took place on 9 September 2023, with 5 participants and lasted for 6 hours. The data were transcribed and analyzed using data reduction techniques. The sources were triangulated by confirming the findings with the staff of the Department of Communication and Information of Banyumas Regency, the Sub-Coordinator of Application Development, and the Head of the Environmental Agency of Banyumas Regency.

Result And Discussion.

Based on secondary data obtained from the Department of the Environmental Agency of Banyumas Regency and the Department Communication and Information Agency (Kominfo) of Banyumas Regency, a description of waste management service coverage using the android-based applications Salinmas and Jeknyong in Banyumas Regency is as follows:

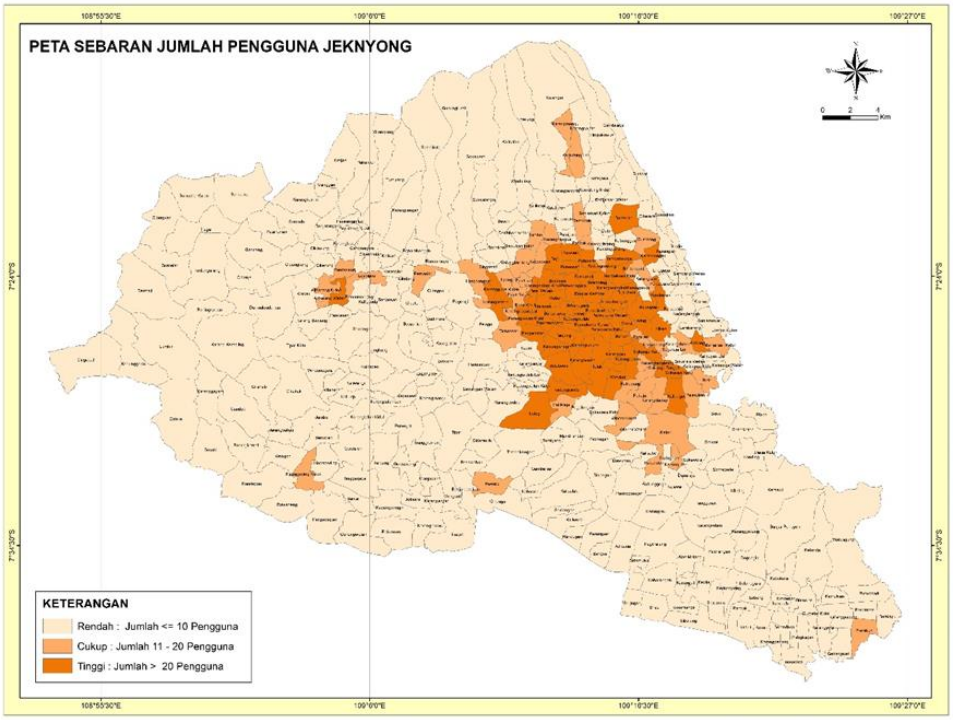
1. Spatial analysis of the number of Salinmas and Jeknyong application users.

a. The following is an overview of the distribution of Salinmas application users.



Based on the map above, the majority of Salinmas application users are located around the Purwokerto town area.

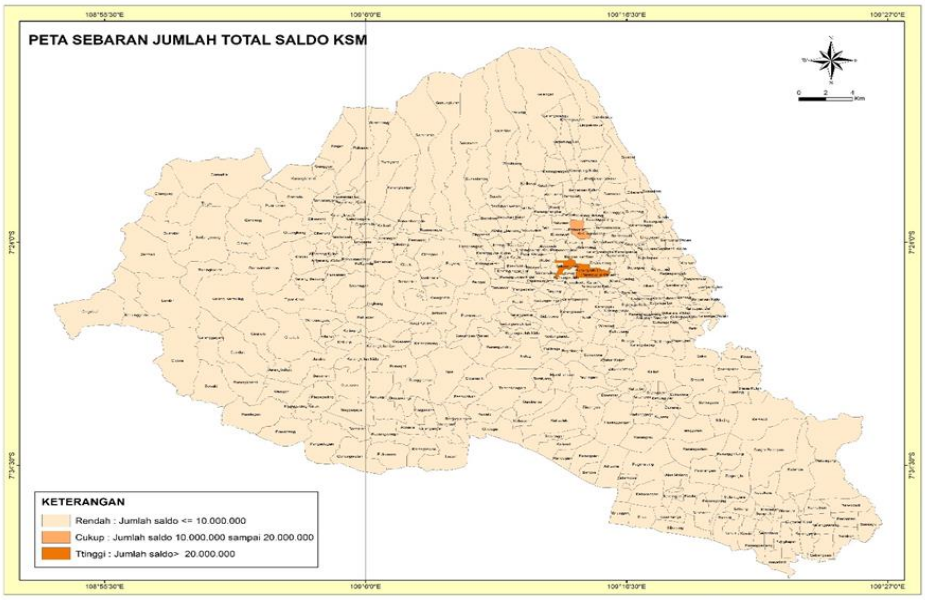
b. The following is an is an overview of Jeknyong application users.



Based on the map above, Jeknyong users are spread across the Banyumas Regency. Many application users are located in both urban and rural areas on the outskirts of Purwokerto town.

2. Spatial analysis of savings account balances in the Salinmas and Jeknyong applications.

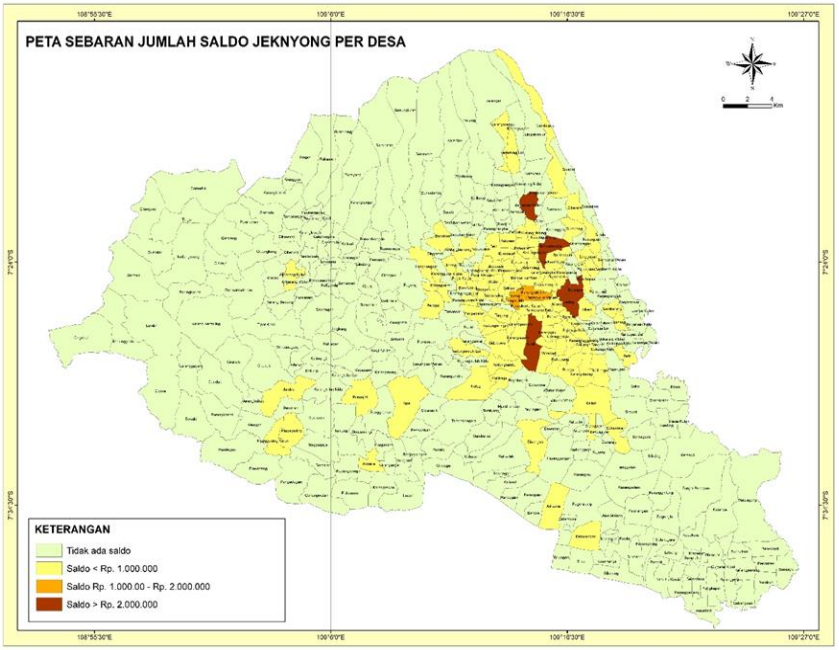
a. The following is a map representation of the savings balance acquired by Salinmas users.



Based on the map above, it is evident that areas with high savings balances are in the villages around Purwokerto town, while those with moderate income are in the villages on the outskirts of Purwokerto town."

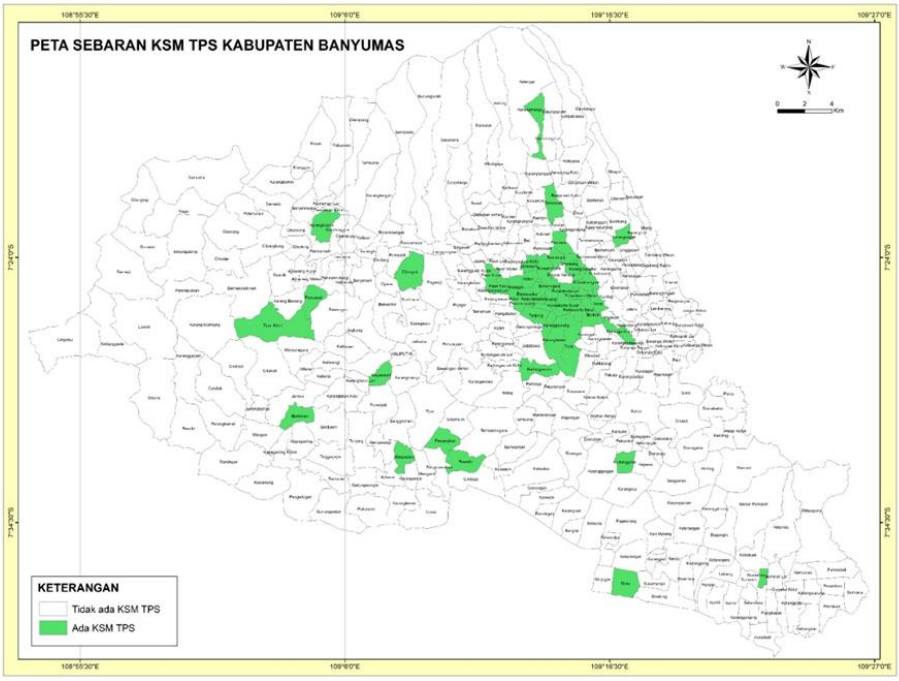
b. The following is a map representation an overview of the savings balance acquisition by Jeknyong users.

Based on the map above, it is known that areas with high savings balances are in the villages around Purwokerto city, and those with sufficient income are in the villages on the outskirts of Purwokerto city. However, there are rural areas that have a wider savings balance coverage, even though the balance amounts are lower.



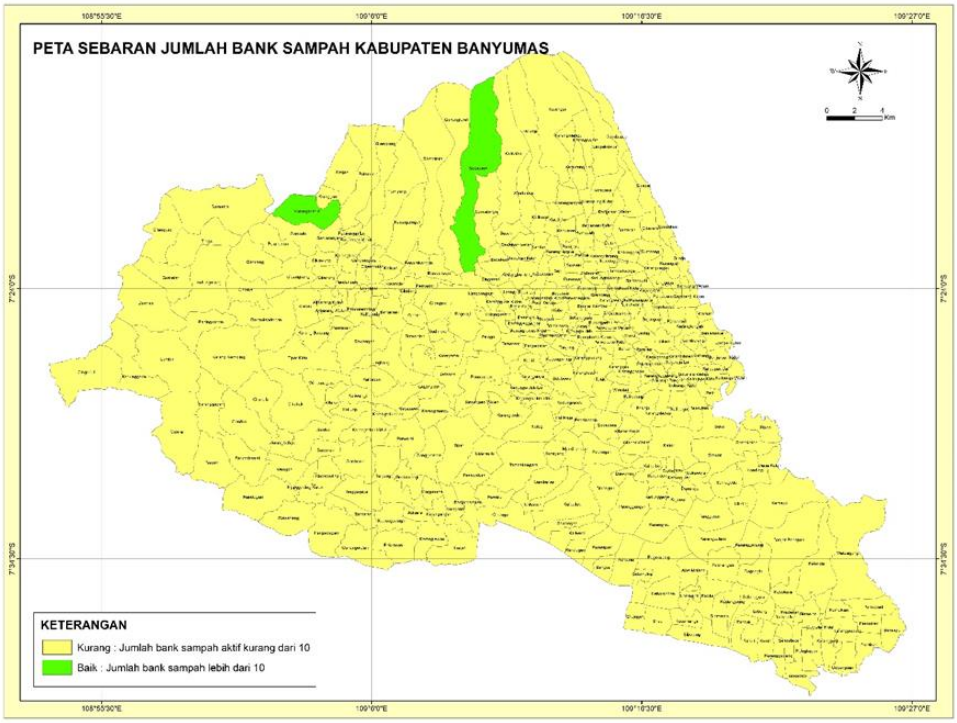
3. Spatial analysis of the distribution of Community Self-Help Groups, Waste Banks, and Managed Waste Verification.

a. Overview of the distribution NGO of managing waste in Banyumas Regency.



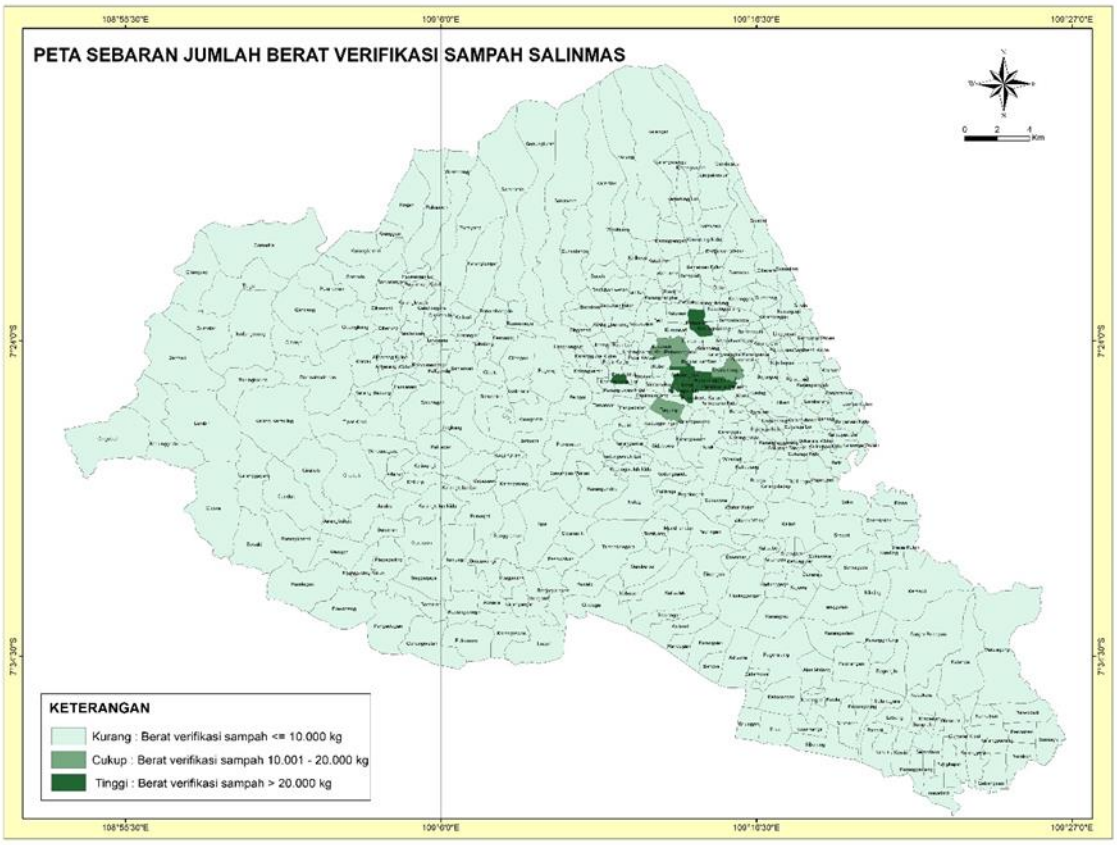
Based on the map above, it is evident that NGOs are predominantly located in urban areas. In areas far from the city center of Banyumas or Purwokerto, their numbers are fewer.

b. Overview of the distribution of active waste banks in Banyumas Regency.



Based on the map above, it is evident that active waste banks are mostly located in rural areas, far from the town center of Banyumas or Purwokerto. In areas far from the city center of Banyumas or Purwokerto, there are more active waste banks.

c. Overview of waste verification managed by NGO and waste banks.



Based on the map above, it is known that waste managed by NGO is primarily located in urban areas. In areas far from the town center of Banyumas or Purwokerto, the number of verified waste items managed is lower.

2. Thematics analysis

Based on the interview results, which were analyzed using a thematic approach, the following information was obtained the strategic issues in mobile-based waste management in Banyumas Regency**:**

1. Technology

Businesses (Regional-Owned Enterprises - PT Banyumas Investama Jaya (BIJ)) informed about the Jeknyong application. In addition to saving up to 70% of the regional budget (APBD) for waste processing, it can also reduce waste processing from 142 garbage trucks per day to 24 garbage trucks per day. The Jeknyong application has 100 partners. These Jeknyong motorcycle taxi (ojol) partners use three-wheeled motorcycles when on duty to collect waste. They suggest increasing the number of ojol partners to serve the entire population of Banyumas Regency. They also recommend incorporating recycling technologies, such as plastic recycling into plastic pellets due to its high market value, and plastic waste processing into paving blocks.

Waste Banks (Community) recommend integrated waste processing technology (TPST) for residential areas, such as the implementation of integrated urban farming to support the circular economy of waste. The effectiveness of TPST in villages depends on several factors, apart from community awareness, institutional aspects often pose challenges to the smooth implementation of programs and financing.

Academics state that there are four alternative waste processing technologies: incineration, sanitary landfill, composting, and recycling, but there is still a need for the development of better technologies. Integrated urban farming and maggot cultivation can also be implemented on a family scale.

The government is working on strengthening the system for sustainability and efficiency, such as increasing Salinmas program facilitators and evaluating the applicability of Salinmas and Jeknyong.

Waste processing technology is highly needed as it simplifies processing and reduces production costs amid the high demand for raw materials from waste processing. Business opportunities in the recycling of waste are very promising. Appropriate

technology is also required at the Final Processing Site (TPA). According to Chamdra et al. (2015), there are four alternative technologies, namely incineration, sanitary landfill, composting, and recycling, but there is still a need for the development of better technologies.

2. Education

As a manifestation of the campus's concern for the environment, the issue of waste has become part of the research roadmap for faculty members. Waste banks have conducted awareness campaigns on waste with circular economic value in the community and schools. Empowering the community is expected not only to provide education but also to result in behavioral changes among residents. Environmental care movements educate the public to raise awareness of environmental cleanliness. The government suggests that all environmental care activities can be implemented in government institutions, academia, schools, the community, and mass media. Mass media should maximize their promotional role in fostering environmental awareness and can influence the public's mindset.

It is recommended to the Environmental Agency of Banyumas Regency and Department of Communication and Information of Banyumas Regency, the Sub-Coordinator of Application Development, to add education-related features on waste management in the Salinmas or Jeknyong applications.

3. Economic

The government states that there must be sustainable waste management that collaborates with village-level economic institutions, promoting recycled products such as crafts marketed both offline and online. With good information, awareness campaigns, proper planning, and supportive policies, waste-related issues can be transformed into a prospective economic potential for the community. The local government is making efforts to encourage the industry to allocate a budget for CSR (Corporate Social Responsibility) related to waste management in the areas surrounding the industry. Good information, socialization, proper planning, and supportive policies, waste-related issues can be transformed into a prospective economic opportunity for the community (Nugraha et al., 2007; Ramadhani, 2014)."

4. Institutionalization

The ideal institutional form for waste management suggests that a Regional Public Service Agency (Badan Layanan Umum Daerah - BLUD) should be established as the operator, with the department playing a regulatory role. The strengthening of field facilitators and NGOs, as well as the development and activation of waste banks, needs to be enhanced. The formulation of policies at the village level related to family-based waste management.

5. Policies

Government regulations, whatever they may be, require multi-element support for their implementation. Regulatory aspects such as regent regulations or regional regulations governing waste management linked to village funds. Policies related to the concept of a zero waste city should already be formulated by local governments. Government policies on domestic waste management will run optimally if accompanied by effective monitoring and evaluation mechanisms by the local government. Husodo et al. (2014) stated that government policies regarding domestic waste management will work optimally if accompanied by a good monitoring and evaluation mechanism from local government authorities.

6. Coordination

The government needs to provide space for all stakeholders, waste activists, managers, and entrepreneurs to share information and coordinate in the future through community activities. There must be synergy to change the public mindset by involving all components of the pentahelix. Before expecting community participation, coordination and government-level policies need to be established first. Adequate infrastructure development also needs to be carried out by the government, accompanied by communication and collaboration among relevant departments. The performance of decentralization strategies must be continuously monitored to ensure that local administrators are responsible and perform their functions effectively.

In development programs, stakeholders are classified based on their roles, including (Benn et al., 2016):

a. Policymakers, who play a role as decision-makers and determinants of a policy;

b. Coordinators, who coordinate other involved stakeholders;

c. Facilitators, who act as facilitators to facilitate and meet the needs of the target groups;
d.Implementers, who are policy implementers that may include the target groups themselves;
e. Accelerators, who play a role in accelerating and contributing to ensure that a program runs according to its objectives or even achieves its goals ahead of schedule.

7. Collaboration

Collective action involving all elements of society is essential, as cooperation can make a significant contribution to addressing various societal issues, including waste management. Collaborating in seeking alternative solutions for more diverse waste management. These alternatives can include partnerships with businesses, improving the operational systems of landfill sites with more advanced technology, revitalizing waste banks, and involving the community, entrepreneurs, and the government. Collaboration between the community, entrepreneurs, and the government in waste management is a good first step in creating a healthy and clean environment.

Collaboration between villages and NGO (KSM) in waste management should be more synergistic. Cooperation and communication between villages and NGO (KSM) in implementing the 4R principles, namely reduce, reuse, recycle, and replant, will be highly beneficial in revitalizing waste banks and the sustainability of the Salinmas and Jeknyong programs. Collaboration between government entities such as the Environmental Agency and the Communication and Information Agency is beneficial for further developing features in the Salinmas and Jeknyong application services. Collaboration with businesses such as Banyumas Investama Jaya will greatly assist in the economic aspects of the community and promote the circular economy of waste management. The "Sumpah Beruang" (Trash Turns into Money) initiative is gaining momentum. Collaboration with industries has also established cooperation with the cement factory owned by PT Solusi Bangun Indonesia Tbk in Cilacap (Semen Indonesia Group), involving the sale of RDF (Refuse Derived Fuel) or alternative fuel from waste (as a substitute for coal) averaging 24 tons per day at a price of Rp.375,000 per ton. All integrated waste treatment facilities (TPST) and Recycling Centers (PDU) in Banyumas District are now able to produce 3.5 tons of maggot per day, with a selling price of Rp5,000 per kilogram. The income from the sale of RDF and maggot is used for the needs of Community Self-Help Groups (KSM) managing waste in TPST and PDU. Currently, there are nine pyrolysis machines in Banyumas to process waste into RDF, four of which are in PDU and five in Environmental and Educational-Based Landfill (TPA BLE). The existence of TPA BLE plays a vital role in waste management in Banyumas, as it handles the waste slurry resulting from the sorting process carried out in PDU and TPST, which currently amounts to 60 tons per day. The pyrolysis machines, with a total capacity of 15 cubic meters per hour, require one day for the RDF production process because the processed waste has been sorted or separated into organic and inorganic by the sorting machine.

To address the daily waste production in Banyumas, which reaches around 600 tons per day, the Banyumas Regency Government in 2023 will add waste management facilities in the form of Recycling Centers (PDU) in 10 locations, with seven PDUs funded by Special Allocation Funds (DAK) and three PDUs funded by the national budget (APBN). Currently, Banyumas has a total of 29 PDUs, with 15 of them located in the Purwokerto area. The addition of PDUs is expected to further reduce waste issues in Banyumas, gradually resolving them. Additional infrastructure includes the procurement of waste slurry drying machines to handle the pile of waste slurry when it becomes RDF.

Esteria et al (2017) stated that local actions for waste bank management through environmental communication strategies and collaborative approaches for a healthy city explain that collaborative approaches to waste management can stimulate the creativity and innovation of residents. Support from local governments, Non-Governmental Organizations (NGOs), companies, and other stakeholders through collaborative approaches can enhance citizen participation based on inter-stakeholder communication. Capacity-building activities for residents, entrepreneurs, and the government provide knowledge and skills to help manage the environment by implementing waste management policies. Collaboration among all stakeholders in accordance with the Minister of Environment Regulation of the Republic of Indonesia Number 13 of 2012 on environmental care with the application of the 4R principles, namely reduce, reuse, recycle, and replant, is done by developing waste banks. This process can educate

the community to be disciplined in waste management and provide economic benefits to the population, allowing them to save and purchase daily necessities.

8. Participation

Community participation in waste management activities indeed needs to be continually improved. The community should be encouraged to separate waste, at the very least, into organic and inorganic categories. When utilizing the Jeknyong application to sell inorganic waste, community members are required to have sorted their waste beforehand. For organic waste, the community can use the Salinmas application service by involving NGO (KSM) in their villages. Village governments can actively participate in mobilizing the community, KSM, and waste banks to engage in 4R activities, which are reduce, reuse, recycle, and replant. Village governments can participate in creating village regulations for the regulation of reduce, reuse, recycle, and replant to enhance compliance with waste separation by the community. People are reluctant to separate their waste simply because there is no underlying regulation, and because they have already paid a certain fee for waste management every month.

Urban communities are hesitant to separate inorganic waste due to limited temporary storage space for their sorted waste. For inorganic waste, the reason for reluctance in processing it is that KSM may not collect their organic waste every day, causing it to rot and result in air pollution. So, community participation in waste processing at its source, in this case, at the household/family level, still faces these challenges. Village governments can participate as coordinators who monitor the smooth operation of KSM and facilitate the Salinmas program.

The participation of formal or informal stakeholders significantly influences program management. According to Salsabila and Santoso (2018), stakeholders are groups or individuals whose support is necessary for the well-being and sustainability of an organization or a country. Meanwhile, according to Hisam (2016), stakeholders are members of a community, groups, communities, or individual human beings who have relationships and interests in an organization or company. Stakeholder categories are labeled as investors, contributors, observers, and end-user stakeholders (McGrath & Whitty, 2017). Based on their level of importance, stakeholders are divided into three groups (Thijssens et al., 2015):

a. Primary Stakeholders: Primary stakeholders are those who are directly affected, both positively and negatively, by a plan and have a direct interest in the activities. Stakeholders who have influence and interest are considered primary stakeholders and should be fully engaged in the various stages of the activities.
b. Key Stakeholders: Key stakeholders are those who have legal authority in decision-making.
c. Secondary or Supportive Stakeholders: Supportive stakeholders are those who do not have a direct interest in a plan but have a significant concern for the development process.
d.

Conclution

The strategic considerations that can be suggested as a solution for Android-based waste management in Banyumas Regency encompass technology, educational aspects, economic factors, institutional framework, policies, collaborative efforts, active participation, and coordination.

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