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Leveraging ICT in Karachi's Solid Waste Management System by Involving Waste Pickers, Recyclers, and Community—An Integrated Approach

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Abstract

The authors of this article argue that connecting informal waste pickers and recyclers to the formal waste management system can potentially improve the efficiency and sustainability of the waste management system, as well as provide economic opportunities for the informal waste pickers and recyclers themselves. To do so, this study analyzes the current solid waste management practices and prospects in Karachi, Pakistan. Data were obtained through semi-structured interviews and workshops with a sample of five officials from governmental institutions Sindh Solid Waste Management Board (SSWMB), Karachi Metropolitan Corporation (KMC), District Municipal Committees (DMCs) and several waste pickers. Findings that need to be addressed revealed that solid waste management in Karachi faces significant challenges. Potential strategies for addressing them include involving and integrating waste pickers in the formal waste management system, promoting the use of reusable and or recyclable materials, and developing and improving waste reduction and recycling programs. This can be achieved by exploring new technologies and approaches. Leveraging the potential of Information Communication Technologies (ICT) practices such as mobile and web applications, data analytics, and social media are used here to help improve solid waste management practices in Karachi. As a result, the authors conclude that connecting waste pickers and recyclers to the waste management system through partnerships that include government, and/or organizational programs, independent collection and processing of recyclable materials can contribute to a more sustainable and efficient waste management system for the city of Karachi and scaled to other cities currently using a system similar to that of Karachi.

1. Introduction

Waste accumulation has become a global concern due to existing excessive production and consumption patterns in economies (Aslam et al., 2022; Hossain et al., 2022). Waste production tends to increase with the increasing levels of population, urbanization, and income (Ahmed, Le, & Shahzad, 2022; Lee & Ho, 2022). The amount of meat, cars, electricity, and other goods consumed by the population is increasing and more natural resources are being used in the production of these products because of which more waste is generated (Atstaja et al., 2022; Boukhelkhal, 2022). It is estimated that 8 million tons of waste including plastic are disposed of into oceans every year which has given raise to aquatic debris contamination (Jung et al., 2022; Sulaiman & Ahmad, 2023). The pollution created as a result of inadequate waste reduction practices generates an atmosphere that is unsustainable for the natural ecosystem and for human health (Dermawan et al., 2022; Tian et al., 2022). The levels of urbanization and population growth are higher in middle- and low-income countries (Khan et al., 2022).

The statistics indicate that 87,000 metric tons of solid municipal waste per day are generated in Pakistan with a yearly growth rate of 2.5% (Aslam et al., 2022). Poor planning and insufficiencies in solid waste reduction practices have created various environmental and public health issues across the country (Salam et al., 2022; Shahid et al., 2022). Inadequate planning, outdated waste statistics, political rivalry, insufficient resource allocation, corruption, and ineffective administration are some of Pakistan's biggest issues when it comes to solid waste reduction (Salam et al., 2022; Shahid et al., 2022).

Figure 1 shows the current Mechanism of Solid Waste Management System in Karachi (source Sindh Solid Waste Management Board, Karachi). The waste collection process involves Front-end, Middle-end, and Back-end services. Front-end is the collection of waste from households where street sweepers (formal and informal) are involved from which 90% is collected and goes to Bin/Kachra Kundi and 10% goes to illegal dumpsites, Nullahs, burning, etc. Middle-end services/transfer starts from Bins/Kachra Kundi where it is dumped by the street sweepers and the public as well, The informal waste pickers (Scavengers) come into play they take the recyclables or leftovers from those Bins and they throw waste/garbage outside of bins and sometimes burn the rest of garbage to take the mettle means 15% from those bins goes again to illegal dumpsites, nullahs, burning etc means only 75% from those bins is collected and transferred by the
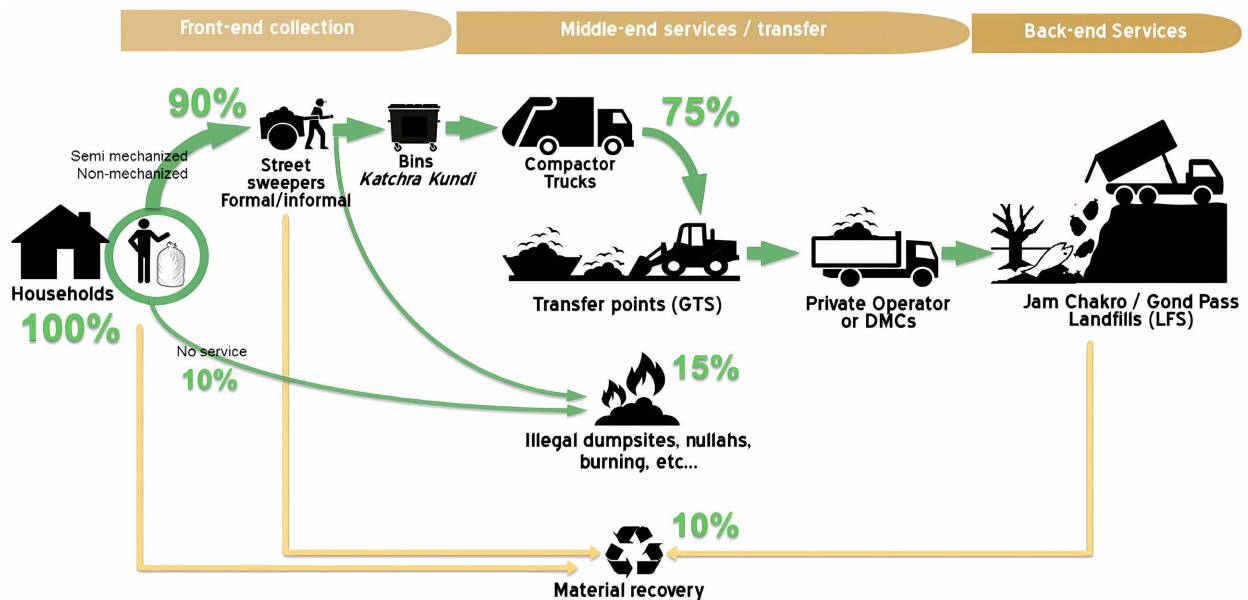
Figure 1. Current mechanism of solid waste management system in Karachi.

compactors trucks to Garbage Transfer Stations (GTS). Then from those GTS some informal waste pickers (Scavengers) come to collect the remaining recyclables like plastic bags etc Finally that waste is then transferred from the Garbage Transfer Station to Landfill sites which is called back-end by the private contractors hired by the Sindh Solid Waste Management Board, Karachi.

This research will explore the overall situation of waste management practices in Karachi. The core objectives of the study include: 1) To explore the challenges in solid waste management practices in Karachi; 2) To identify the services of waste pickers for solid waste management practices for improving the city's waste management system; 3) To highlight possible solutions for improving solid waste management practices in Karachi, including the use of ICT practices such as mobile and web applications and to 4) analyze how the Recyclers can be connected to the system.

The research on involving waste pickers and leveraging ICT in Karachi's solid waste management can provide benefits for the city, waste pickers, and policymakers. For the city, the study offers recommendations for improving solid waste management practices, which can enhance the city's environmental health and livability. For waste pickers, the study may identify ways to better integrate them into solid waste management, leading to improved working conditions and livelihoods. Finally, policymakers and other stakeholders in solid waste management may gain a deeper understanding of the challenges and opportunities of involving waste pickers and using ICT in these efforts.

2. Methodology

2.1. Tankyu Chart

Tankyu Practice is a practical technique for solving problems. Tankyu consists of

two Japanese words, which are 探 (Tan) and 究 (kyu). Tan means to search, quest, inquiry, and kyu means to pursue research and ultimate. Tankyu Practice was developed and introduced by the President, the Kobe Institute of Computing (KIC), Prof. Tochiki Sumitani Sensei. Tankyu practice has three major components: identifying an issue, developing a possible solution, and implementing it. The implementation component consists of three solution enablers: the technologies used for the solution, the business model which are financial resources for the project, and the human resources which are to be required for implementation. Figure 2 shows the Tankyu Chart details which are developed for this research.

Issue Identified:

In our initial investigations conducted in Pakistan, we employed the Tankyu Practice techniques and discovered a significant problem related to waste management in Karachi, Pakistan. The issue pertains to the mounting quantity of urban waste and the surging number of informal waste pickers including a lack of awareness among the masses about 3R (Reuse, Recycle, Reduce) and the public does not know much about recycling methods and Recycling shops.

Possible Solution:

We developed a mobile application to unite all stakeholders involved in the waste management of Karachi. Our goal is to increase awareness and promote proper waste disposal and segregation using the 3R approach of Reuse, Reduce, and Recycle. Additionally, our app includes an incentivization platform that offers job opportunities to users, thus creating income for households by implementing Reuse and Recycle and also for the informal waste pickers and recyclers. The app aims to reinforce positive waste management practices throughout the city.

Solution Enablers:

When implementing a solution, three main factors to consider are the business model, technologies, and necessary human resources. These are known as solution enablers:
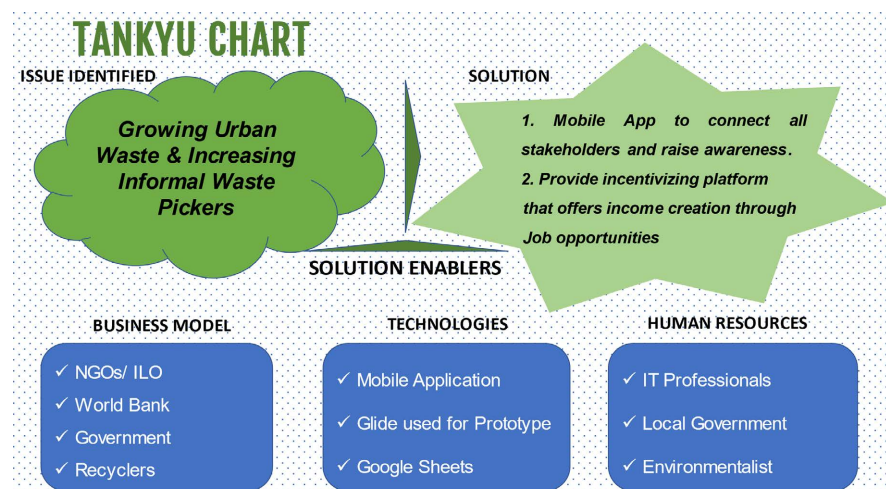

Figure 2. Tankyu chart.

Business Model:

After identifying the problem and proposing a solution, we developed a business model to ensure the sustainability of our solution. Upon research, we found that the World Bank is already collaborating with the Government's Solid Waste Management Board (SSWMB) for the waste management system in Karachi. To further promote the 3Rs and keep the city clean, we suggest involving NGOs, ILO, and Recyclers in this initiative.

Technologies:

To take advantage of new technologies like ICT and the growing prevalence of smartphones, it is recommended to utilize mobile applications as a technological solution. These applications can be expanded into web-based technologies, and for the prototype, Glide (a No Code Tool) is being used.

Human Resources:

Human resources play a crucial role in the sustainability and maintenance of any project or system. Thus, it was given the utmost importance in our ICT-based system. The team would consist of IT professionals, the Local Government (SSWMB), and an environmentalist who will be hired.

Overall, the Tankyu chart highlights the potential of Information and Communication Technology practices in improving solid waste management in Karachi, Pakistan, it suggests that leveraging mobile applications, web applications, data analytics, and social media can help connect all stakeholders including Sindh Solid Waste Management Board, waste generators, waste pickers, and recyclers to the waste management system leading to more efficient and more sustainable system for the mega city.

2.2. Literature Review

The management of solid waste in Karachi, Pakistan has been a significant challenge due to the city's large population and high levels of industrialization. This has led to issues with environmental contamination, including risks to groundwater and marine life, and an increase in greenhouse gas emissions. Studies have shown that advanced recycling and waste-to-energy systems may be viable solutions to these problems. Khan et al. (2018) found that Karachi has the capacity to produce 90 Gg of methane annually through the anaerobic breakdown of biodegradable organic waste, and a well-developed recycling industry could bring in annual revenue of over $20 million while offsetting greenhouse gas emissions.

Sabir et al. (2016) also examined the issues surrounding solid waste management in Karachi and found that the current approaches were not satisfactory to the general public and that the municipalities responsible for waste management lacked sufficient funding and were inefficient. The researchers suggested the need for significant changes in waste collection and disposal practices, as well as education and awareness campaigns to encourage behaviors such as recycling.

In another research, Bhatt et al. (2018) discuss the various types of information and communication technology (ICT) tools and technologies that have been

used in solid waste management, including mobile and web applications, geographic information systems (GIS), and radio-frequency identification (RFID). The authors discuss the potential benefits of using ICT in solid waste management, such as improved efficiency and transparency, better coordination between stakeholders, and increased public participation. They also discuss the challenges of using ICT in solid waste management, such as the high cost of implementation and the need for reliable infrastructure and skilled personnel. The authors also discuss the factors that influence the adoption of ICT in solid waste management, including the availability of resources, the level of institutional support, and the regulatory environment. The article concludes by stating that the use of ICT has the potential to improve solid waste management practices, but more research is needed to understand the best practices for implementing and using these technologies effectively.

Informal recyclers are individuals or groups who engage in the collection, segregation, and sale of recyclable materials informally, outside of the formal waste management system. The authors review three main options for connecting informal recyclers to the formal waste management system: partnerships, cooperatives, and waste-to-energy initiatives. Partnerships involve the collaboration between the formal waste management system and informal recyclers, with the goal of integrating the informal sector into the formal system. Cooperatives involve the formation of a cooperative organization by informal recyclers, which is then recognized by the formal waste management system. Waste-to-energy initiatives involve the conversion of waste into energy, with the involvement of both the formal waste management system and informal recyclers. The authors also review the experiences of different countries in implementing these options, including Brazil, India, and South Africa. They discuss the potential benefits and challenges of each option, as well as the factors that influence their adoption. These factors include the legal and regulatory framework, the availability of resources and infrastructure, and the level of institutional support.

The study utilizes a qualitative research paradigm to answer the proposed research questions. Qualitative research explains "how" and "why" a certain social phenomenon operates in a given setting. It assists in comprehending the social context and the importance of the events around us. Qualitative research describes situations or events from the participants' points of view and facilitates the generation of new ideas (Hennink et al., 2020).

Within the qualitative research design, the researcher has followed phenomenology since it investigates the existing practices of solid waste management. Semi-structured interviews were conducted with five officials from governmental institutions, i.e., SSWMB, KMC, DMCs, responsible for solid waste management, and several waste pickers. Data collected were analyzed using methods prescribed by Corbin and Strauss (2015) which follow the process of open coding, axial coding, and categorization. Corbin and Strauss (2015) describe open coding, axial coding, and categorization as key stages in the data analysis process

of grounded theory. They view open coding as the initial stage of analysis, where the data is broken down into smaller segments and assigned codes to identify emerging themes and patterns. Axial coding is seen as a means of building upon the themes and patterns identified through open coding, by exploring the relationships between codes and the conditions and consequences of these relationships. Finally, categorization involves grouping similar codes into categories, which form the building blocks of a substantive theory.

3. Field Work

3.1. Research Questions

1) What are the challenges in solid waste management practices in Karachi?

2) How services of waste pickers for solid waste management practices can be utilized to improve the city's waste management system?

3) What are the possible solutions for improving solid waste management practices in Karachi, including the use of ICT practices such as mobile and web applications?

4) How the Recyclers can be connected to the waste management system?

3.2. Observations/Results

Challenges in Solid Waste Management Practices in Karachi

In answer to the research question regarding the challenges in waste management practices the researcher identified that the challenges include insufficient funding and resources for waste management infrastructure and services, lack of enforcement of waste management regulations, limited public awareness and participation in waste reduction and recycling programs, inefficient collection and transportation systems, limited processing and disposal options for solid waste and limited capacity for recycling and reuse of waste materials.

Representatives from solid waste management explained that the lack of enforcement of waste management regulations has resulted in a number of problems. As an officer said one major issue is the inadequate collection and disposal of solid waste. This has led to the buildup of garbage on the streets and in open areas, creating a breeding ground for pests and diseases.

It was suggested by all officials that there is a lack of public awareness and participation in waste reduction in Karachi. For example, by an official, it was described.

In Karachi, it is likely that there is a lack of public awareness and participation in waste reduction initiatives. This can be due to a variety of factors, including a lack of education about the importance of waste reduction and recycling, as well as a lack of convenient access to recycling facilities. Many areas of the city do not have trash bins or waste collection points which affect the appearance of the city. By providing sufficient bins and waste collection points the system could be improved.

The following Table 1 lists the major challenges in waste management.

Services of Waste Pickers for Solid Waste Management Practices

In an answer to research question 2, it was identified that involving waste pickers in the formal waste management system, promoting the use of reusable or recyclable materials, developing waste reduction, and recycling programs, and exploring new technologies and approaches can be possible ways to utilize the services.

Moreover, Waste pickers may have valuable insights and ideas about new technologies or approaches that could be used to improve solid waste management practices in the city. For example, they may be familiar with innovative sorting or recycling techniques that could be adopted more widely.

The following Table 2 represents how the services of waste pickers can be utilized.

The Use ICT Practices as a Possible Solution

Regarding the use of ICT it was identified that implementing a digital waste management system: ICT practices such as mobile and web applications could be

Table 1. Major challenges in waste management.

Responses	Explanation
Insufficient funding and resources	Lack of adequate funding and resources for waste management infrastructure and services.
Lack of enforcement of regulations	Lack of enforcement of waste management regulations, leading to a buildup of garbage and health concerns.
Limited public awareness and participation	Lack of education and participation in waste reduction and recycling initiatives.
Inefficient collection and transportation systems	Poor collection and transportation systems for solid waste, affect the appearance of the city.
Limited processing and disposal options	Limited options for processing and disposal of solid waste, leading to negative environmental impacts.
Limited capacity for recycling and reuse	Reliance on landfills for waste disposal due to limited capacity for recycling and reuse of waste materials.

Table 2. Services of waste pickers for waste management.

Responses	Explanation
Involve waste pickers in the formal waste management system	Improves efficiency and effectiveness of waste collection and transportation, provides waste pickers with a secure source of income
Promote the use of reusable or recyclable materials	Reduces the amount of waste, waste pickers can play a role in promoting and collecting these materials for reuse/recycling
Develop waste reduction and recycling programs	Waste pickers could be involved in educational initiatives and programs to collect and process recyclable materials
Explore new technologies and approaches	Waste pickers may have valuable insights and ideas about new technologies that could improve solid waste management practices

used to develop a digital waste management system that allows for the efficient tracking and management of waste collection, transportation, and disposal. This could include tools for scheduling pickups, tracking waste volumes, and identifying areas where improvements could be made.

Promoting public participation through digital platforms: Mobile and web applications could be used to promote public participation in solid waste management efforts in Karachi. For example, residents could use a mobile app to report problems with waste collection or to request additional recycling bins.

Data could be used to optimize routes for waste collection vehicles or to identify areas with high levels of waste generation that might benefit from additional recycling infrastructure.

Also, it was identified by an official that Leveraging social media and other online platforms: Social media and other online platforms could be used to raise awareness about solid waste management issues and to engage the public in efforts to improve waste management practices in Karachi.

The following Table 3 represents the potential use of ICT as a solution based on the responses obtained.

Recycler connection to the system

Regarding the last research question, it was identified that there are several options for connecting recyclers to the system including partnering with the formal waste management system, developing informal networks for recycling, establishing collection points for recyclables, and encouraging the use of reusable or recyclable materials.

Recyclers can partner with the city's formal waste management system, either as contractors or as part of a public-private partnership. This will involve working with the city to develop and implement recycling programs or to collect and process recyclable materials.

Table 3. Potential use of ICT in solid waste management in Karachi.

Responses	Explanation
Implement a digital waste management system	Mobile/web applications for efficient tracking and management of waste collection, transportation, and disposal, including scheduling pickups, tracking waste volumes, identifying areas for improvement
Promote public participation through digital platforms	Mobile/web applications for public reporting of waste collection issues and requesting recycling bins
Use data to optimize routes and identify areas for improvement	Use data to optimize routes for waste collection vehicles and identify areas with high levels of waste generation for additional recycling infrastructure
Leverage social media and online platforms	Raise awareness and engage the public in solid waste management efforts through social media and online platforms

A possible solution can be to provide support and resources to help waste pickers become more organized and efficient by providing training, equipment, or other resources to help recyclers improve their operations.

Another option could be to set up designated collection points throughout the city where recyclers can bring materials to be sorted and processed.

Moreover, encouraging the use of reusable or recyclable materials was also indicated.

Promoting the use of reusable or recyclable materials can help to reduce the overall volume of waste that needs to be managed and can provide more opportunities for recyclers to collect and process materials.

The following Table 4 represents options for connecting recyclers to solid waste management systems based on the responses obtained from interviews.

4. Discussion

The findings from this study suggest that the solid waste management system in Karachi, Pakistan is facing several significant challenges. This is not surprising given the rapidly increasing population and urbanization in the city, which has led to a corresponding increase in waste generation. The potential solutions identified in this study, such as involving waste pickers in the formal waste management system, promoting the use of reusable or recyclable materials, and exploring new technologies and approaches, are commendable steps toward addressing these challenges.

The involvement of waste pickers in the formal waste management system is a promising approach as they can play a significant role in collecting and managing waste. By providing waste pickers with proper training, equipment, and support, they can become valuable stakeholders in the waste management system and help to reduce waste and promote recycling. This can also help to improve their living standards and reduce the negative impact of informal waste picking on their health and the environment.

Table 4. Options for connecting recyclers to solid waste management system.

Responses	Explanation
Partner with the formal waste management system	Recyclers can partner with the city's formal waste management system as contractors or through a public-private partnership, working with the city to develop and implement recycling programs and collect recyclable materials
Develop informal networks for recycling	Provide support and resources such as training, equipment, or resources to help waste pickers become more organized and efficient in their operations
Establish collection points for recyclables	Set up designated collection points throughout the city where recyclers can bring materials to be sorted and processed
Encourage the use of reusable or recyclable materials	Reduce the overall waste volume and provide opportunities for recyclers to collect and process materials by promoting the use of reusable or recyclable materials

Promoting the use of reusable or recyclable materials is another important step toward reducing the waste burden in Karachi. By increasing public awareness about the benefits of reducing waste, recycling, and using reusable materials, individuals can be encouraged to adopt more sustainable practices and reduce the amount of waste they generate. This can be achieved through educational campaigns, media outreach, and community involvement.

The potential of ICT practices such as mobile and web applications, data analytics, and social media should not be underestimated. These tools can help to improve the efficiency of the waste management system, increase transparency, and enhance communication between waste management stakeholders. They can also help to monitor waste collection and disposal and provide real-time data and feedback on the waste management system.

Connecting recyclers to the waste management system through partnerships, government or organizational programs, or independent collection and processing of recyclable materials can help to create a more sustainable and efficient waste management system for the city. By providing recyclers with the necessary support and incentives, they can become valuable stakeholders in the waste management system and contribute to the reduction of waste and promotion of recycling.

5. Conclusion

In conclusion, the management of solid waste in Karachi, Pakistan has been a significant challenge due to the city's large population and high levels of industrialization, leading to issues with environmental contamination and an increase in greenhouse gas emissions. Studies have suggested that advanced recycling and waste-to-energy systems may be viable solutions to these problems, as well as the implementation of more efficient and effective waste collection and disposal practices. Public involvement, including through education and awareness campaigns and the use of digital platforms, is also important in improving solid waste management in the city. Other potential strategies include involving waste pickers in the formal system and promoting the use of reusable or recyclable materials.

Recommendations

Based on the findings of this study, the following recommendations are made:

- The government and waste management institutions in Karachi should work to involve waste pickers in the formal waste management system. This can be achieved by providing waste pickers with proper training, equipment, and support.
- The government and waste management institutions should launch educational campaigns, media outreach, and community involvement programs to increase public awareness about the benefits of reducing waste, recycling, and using reusable materials.

- The government and waste management institutions should explore the potential of ICT practices such as mobile and web applications, data analytics, and social media to improve the efficiency and transparency of the waste management system.
- The government and waste management institutions should work to connect recyclers to the waste management system through partnerships, government or organizational programs, or independent collection and processing of recyclable materials.
- The government and waste management institutions should provide recyclers with the necessary support and incentives to become valuable stakeholders in the waste management system and contribute to the reduction of waste and promotion of recycling.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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