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Factors affecting the recycling of industrial waste

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The industrialization process results in the generation of wastes and it is increasing on a regular basis. Its management may be a proactive approach for vulnerable groups, both from an environmental and socio-economic standpoint. Although there is no universally accepted definition of the term "waste material", industrial waste is typically considered to include trash from all sectors of the economy, whether commercial, residential, institutional, or industrial. As a result of urbanization, industrialization, and increased population, the amount of urban and industrial waste produced is inversely proportional to the rate at which urbanization, industrialization, and population growth are taking place. Due to the rapid increase in the world's population over the past few decades, observed that there is a rapid rise in the demand for food, housing, and a variety of natural resources. This article identified the main factors influencing waste management and the factors influencing the reuse and recycling of industrial waste in the construction industry, ferrous and non – ferrous metallurgy, petrochemical industry, textile industry and electric power industry. Meanwhile, the author also observed the importance of using artificial intelligence under the technical factors that have an impact on waste management.

Introduction

As industrial waste management factors covered in the cases may not be comprehensive, they need to be supplemented by literatures. Firstly, this study searches for factors not covered in the case mining from the published English literature on the factors influencing of waste processing. Subsequently, these factors are screened based on the availability of actual quantitative data. Finally, after identifying the suitable influencing factors, their specific effects on wastes utilization are described, and the nature of hazardous waste should be considered. Through this process, the construction of the comprehensive set of influencing factors for industrial waste processing is ultimately achieved. Integrated industrial Waste Management is a widely recognized method of managing industrial waste in a way that is efficient and effective. Using industrial Waste Management, it is possible to carry out a comprehensive analysis of the many dimensions of the waste management system. This analysis aims to assess its effectiveness and efficiency through a comprehensive analysis of the many dimensions of the system. The term integrated waste management has been defined as the selection and implementation of techniques, technologies, and management systems in order to achieve specific waste management objectives and missions.

There are several key aspects of industrial Waste Management system that works together to maximize the benefit for the least cost, the use of resources and the recycling, reusing, and repurposing of items, to improve safety, health standards, and social acceptance. It comprises three primary components including stakeholders' government and non-government sectors, elements (technical aspects of industrial Waste Management), and issues (policies and effects).

In order to achieve success in Integrated industrial Waste Management, has identified three essential elements of the system that must be addressed for it to be successful: health promotion, environmental protection, and the development of natural resources. The information on generated waste as well as its forecasting throughout the entire lifespan of such a project strategy, the physical and chemical properties of waste, the identification of the most appropriate alternative based on their analysis, the establishment of the overall cost of the plan, the assessment of accounting, revenue, and its environmental impact such as greenhouse gas emissions must all be considered before designing an Integrated industrial Waste Management plan for a city. The construction of an Integrated industrial Waste Management system needs to be designed to maintain a balance between societal, ecological, health, organizational, technological, financial, and legal aspects to offer sustainability to the system.

The intersection of environmental protection, Sustainable Development Goals, and the role of information technology (IT) is to foster it. Artificial intelligence addresses environmental challenges, offering solutions such as emissions reduction, cost savings, legal compliance, HR attraction, optimized investments, and waste management. The "three Rs" of green IT emphasize sustainable hardware management through reuse, refurbishment, and recycling [4].

Digital transformation acts as a stimulus for sustainability through the promotion of innovation, enhancement of resource efficiency and enablement of eco-conscious decision-making. Integrating artificial intelligence (AI) and machine learning (ML) facilitates data analysis for the purpose of identifing inefficiencies and optimizing resource deployment, and reducing energy consumption within buildings, factories, and transportation. Digital platforms support circular economy principles through the minimization of waste through product reuse and sharing.

Methodology

The author explored the literature on waste management and identified the relevant factors. This article was developed using a questionnaire addressed to waste management experts.

However, since the influencing factors supplemented from the literature were not found in the case data, and considering the need to effectively integrate the information on industrial waste processing and categories of hazardous waste with the association rules mining, the data for these factors was obtained from statistical yearbooks and official provincial eco-environmental websites in each province. It is important to note that this data is all structured data.

The impact of factors identified by the author on waste management was observed through regression analysis.

Further, the diagrams below show the analysis of variance (correlation coefficient) of the above 7 main factors (Figures 1–7).

Based on the results of regression analysis, it was revealed that the most significant factors influencing the implementation of industrial waste processing are: government incentives; Technological factor; Economic factor and Social factor.

Improving waste collection efficiency and routing is a crucial logistic aspect of industrial waste management. When waste collection is optimized, it reduces costs, time, and efforts involved in

Table 1. Results of regression analysis.

Independent Variables	Regression coefficients	Standardized regression coefficients
β	11,312	
economic	0,712***(0,056)	0,639***
social	0,530***(0,025)	0,598***
technological	0,582***(0,073)	0,491***
informational	0,061**(0,014)	0,165***
Formation of partnerships and development of communications (external environment)	0,325** (0,091)	0,323**
Ecological	0,417**(0,031)	0,438***
Market	0,241**(0,037)	0,242**
government incentives	0,693***(0,055)	0,561***
regulatory framework	0,098**(0,064)	0,176**
Logistics aspect	0,147**(0,014)	0,167***
R = 0,842 R^2 = 0,809 adjusted R^2 = 0,803 Standard error of estimate: 0,359		

Source: compiled by the author.

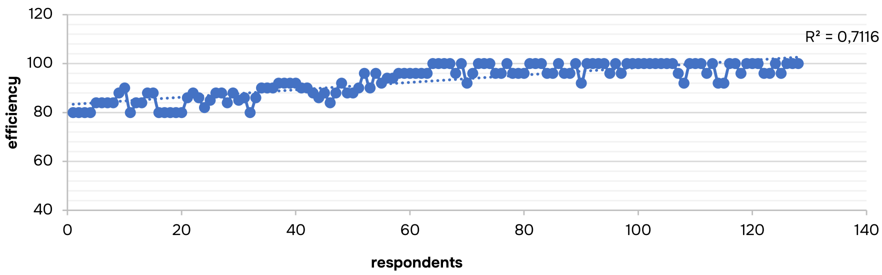

Figure 1. Economic factor.

the collection process while enhancing overall cleanliness and environmental protection. According to author [3], the collection and transportation process alone account for approximately 60–80% of the total cost of industrial waste. Cost reduction with respect to waste collection and transportation is essential if sustainable industrial waste management is to be achieved in developing economies. Efficient waste collection relies on several factors, including the proper planning of routes and schedules. Typically, a limited number of vehicles and teams are assigned to collect waste in specific areas. Therefore, it is essential to determine the optimal routes for vehicles to collect waste from various points in the area with minimal cost and time. This can be achieved by employing smart routing techniques and GIS to analyze data and identify optimal routes [1–3]. Furthermore, waste collection efficiency can be improved through the use of automated control techniques and smart networks. Waste containers can be equipped with automatic sensing devices to monitor their fill levels. When a container becomes full, an automatic notification is sent to the waste management system, enabling teams to prioritize the collection of those containers and plan routes accordingly. This reduces unnecessary costs and enhances waste collection efficiency. Additionally, waste collection efficiency can be enhanced by encouraging community participation and raising awareness about the importance of proper recycling and waste sorting.

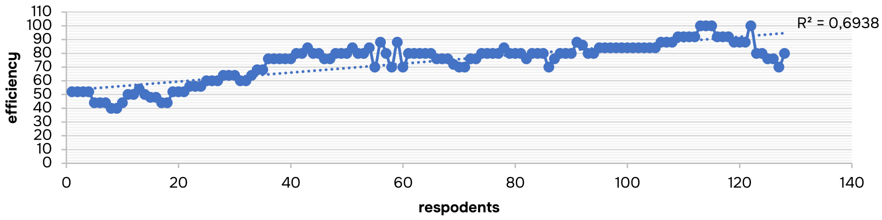

Figure 2. Government incentives.

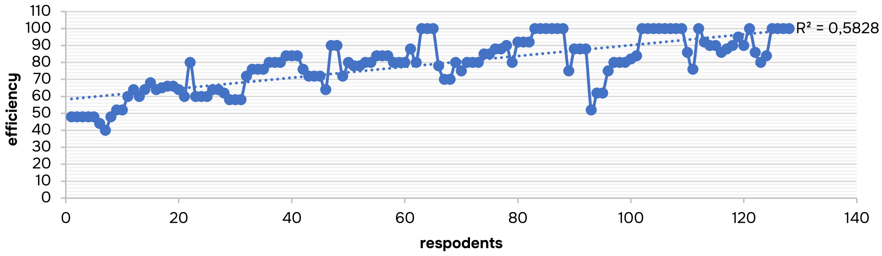

Figure 3. Technological factor.

Internal and external factors affecting industries to recycle waste were identified and the impact was identified through a questionnaire conducted with experts. Below is the regression analysis of factors influencing waste reuse and recycling for construction industry, ferrous and non – ferrous metallurgy, petrochemical industry, textile industry and electric power industry.

Table 2. Analysis of the impact of waste reuse on the electricity industry.

Independent Variables	Regression coefficients	Standardized regression coefficients
β	6,216	
Waste quality	0,125**(0,037)	0,154**
Demand for secondary products	0,325**(0,028)	0,456**
Waste processing costs	0,211**(0,035)	0,185**
Infrastructure	0,491**(0,068)	0,226**
Education and awareness	0,605** (0,011)	0,426**
Partnership	0,256**(0,065)	0,328**
Legal regulations	0,526***(0,046)	0,469**
R = 0,528 R^2 = 0,506 adjusted R^2 = 0,501 Standard error of estimate: 0,126		

Source: compiled by the author.

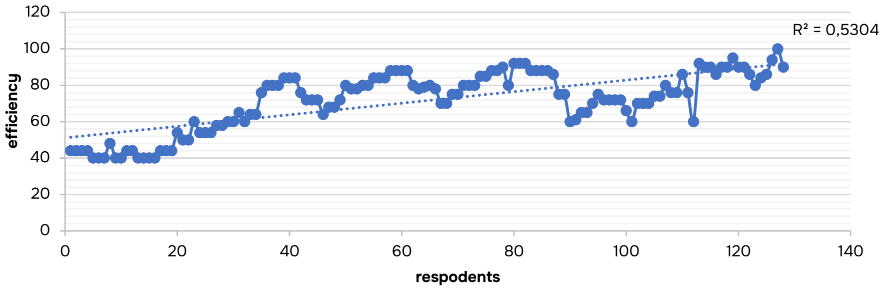

Figure 4. Social factor.

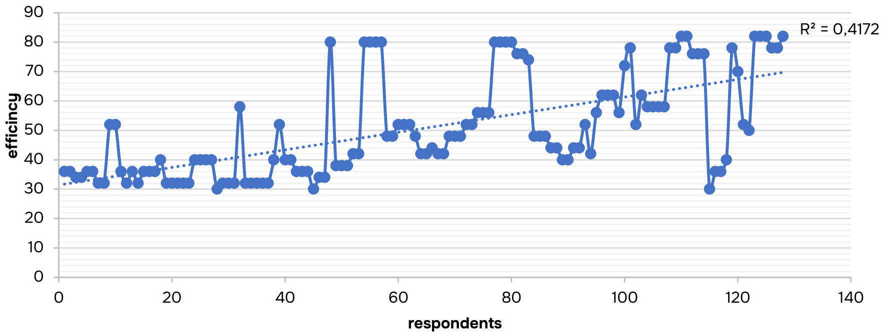

Figure 5. Ecological factor.

Table 3. Analysis of the impact of waste reuse on the construction industry.

Independent Variables	Regression coefficients	Standardized regression coefficients
β	9,221	
Waste quality	0,402**(0,012)	0,326**
Demand for secondary products	0,729***(0,067)	0,598***
Waste processing costs	0,623***(0,058)	0,525***
Infrastructure	0,535***(0,095)	0,476**
Education and awareness	0,358**(0,052)	0,672***; 0,421**
Partnership	0,445**(0,033)	0,562***
Legal regulations	0,611*** (0,052)	0,672***
R = 0,856 R^2 = 0,828 adjusted R^2 = 0,811 Standard error of estimate: 0,472		

Source: compiled by the author.

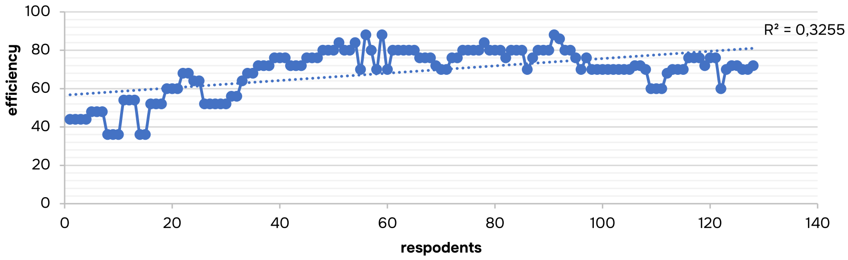

Figure 6. Formation of partnerships.

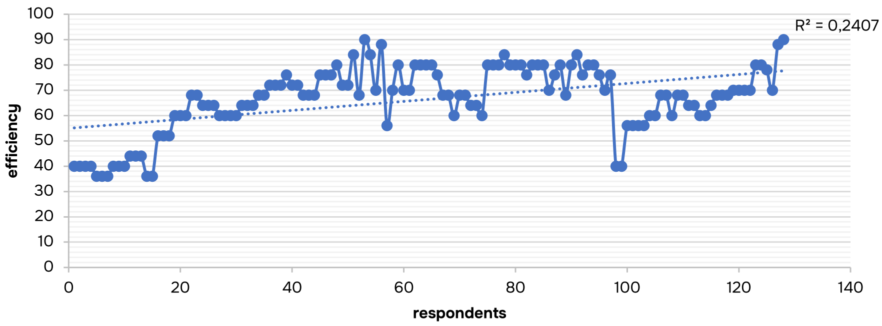

Figure 7. Market factor.

Table 4. Analysis of the impact of waste reuse on the petrochemical industry.

Independent Variables	Regression coefficients	Standardized regression coefficients
β	2,652	
Waste quality	0,194**(0,014)	0,172**
Demand for secondary products	0,135**(0,012)	0,216**
Waste processing costs	0,016**(0,025)	0,128**
Infrastructure	0,341**(0,028)	0,225**
Education and awareness	0,006**(0,002)	0,095**
Partnership	0,229**(0,031)	0,315**
Legal regulations	0,311** (0,045)	0,212**
R = 0,312 R^2 = 0,303 adjusted R^2 = 0,275 Standard error of estimate: 0,156		

Source: compiled by the author.

Table 5. Analysis of the impact of waste reuse on the ferrous and non-ferrous metallurgy.

Independent Variables	Regression coefficients	Standardized regression coefficients
β	3,576	
Waste quality	0,210**(0,065)	0,345**
Demand for secondary products	0,105**(0,004)	0,126**
Waste processing costs	0,526***(0,045)	0,554***
Infrastructure	0,372**(0,076)	0,262***
Education and awareness	0,051**(0,011)	0,112**
Partnership	0,121**(0,067)	0,234**
Legal regulations	0,427**(0,031)	0,353**
R = 0,435 R^2 = 0,411 adjusted R^2 = 0,405 Standard error of estimate: 0,128		

Source: compiled by the author.

Table 6. Analysis of the impact of waste reuse on the textile industry.

Independent Variables	Regression coefficients	Standardized regression coefficients
β	3,145	
Waste quality	0,228**(0,025)	0,151**
Demand for secondary products	0,245**(0,067)	0,176**
Waste processing costs	0,061**(0,014)	0,165**
Infrastructure	0,403**(0,013)	0,354**
Education and awareness	0,432** (0,063)	0,354**
Partnership	0,124**(0,011)	0,196**
Legal regulations	0,228**(0,025)	0,151**
R = 0,396 R^2 = 0,354 adjusted R^2 = 0,327 Standard error of estimate: 0,147		

Source: compiled by the author.

According to the regression analysis, it is confirmed that in all these industries, the effect of government intervention and infrastructure use, that is, formal technologies for handling industrial waste, is very large.

Due to the numerous infrastructure development projects taking place in developing nations, large amounts of construction and demolition waste are unavoidable. Most construction management strategies, however, involve 'isolated' operations with high overhead. Waste data transfers are difficult to watch over. Important information needed for decision-making is, therefore, challenging to obtain.

The author also observed in the following section about the importance of using artificial intelligence under the technical factor that has an impact on industrial waste management.

AI Applications in Waste Management: Russia

The management of waste in Russia is indeed faced with numerous challenges, including inadequate infrastructure, insufficient knowledge on handling healthcare waste, and the lack of recycling initiatives. These challenges are further exacerbated by the rapid urbanization and population growth in the region. In response to these challenges, scalable and adaptable AI solutions have emerged as a promising approach to revolutionize waste management in russia. Mobile applications have been developed to facilitate crowdsourced waste reporting, enabling community engagement and participation in waste management efforts. Additionally, sensor equipped smart bins and real-time route optimization, driven by AI, have been proposed to enhance the efficiency of waste collection and disposal processes.

These AI-driven solutions have the potential to address the shortcomings in waste management infrastructure and promote sustainable practices in the region. Community engagement is recognized as a key component in addressing waste management challenges in Russia. The involvement of communities in waste reporting through mobile applications not only facilitates the identification of waste hotspots but also fosters a sense of ownership and responsibility towards waste management.

Furthermore, the implementation of sensor-equipped smart bins and real-time route optimization not only optimizes waste collection processes but also encourages community participation by providing a transparent and efficient waste disposal system.

The future importance of applying artificial intelligence under technological factors that have an impact on waste management

To address the future directions of AI-driven waste management systems, it is essential to consider potential advancements, continued collaboration and knowledge exchange, integration of emerging technologies, and sustainable and inclusive approaches. The integration of AI and IoT-enabled approaches has been identified as a potential advancement in waste management, empowering cities to enhance waste collection efficiency [5]. Furthermore, the use of low-power ML processors, edge and fog computing-based devices has been suggested as a future direction to overcome limitations in industrial waste management. Additionally, the application of data-driven techniques in modern distributed computing systems has been proposed to optimize resource management tasks in waste management. Continued collaboration and knowledge exchange are crucial for the advancement of waste management systems. Achieving mutual benefits from collaboration has been emphasized as important in the management of industrial waste. Moreover, open innovation has been identified as having the potential to tackle challenges in waste management through collaboration and knowledge exchange. It has been suggested that creating synergies between people in informal settlements and city authorities is essential for effective participatory waste management in such areas.

The integration of emerging technologies is vital for the future of waste management. The use of IoT and machine learning-based approaches has been highlighted as a future direction in urban solid waste management, particularly in addressing climate-induced risks in developing countries. Additionally, the potential of 5G-driven AI-based scaling has been integrated into service management software platforms, indicating the importance of advanced technologies in waste management [5].

Sustainable and inclusive approaches for the future of waste management have been emphasized in various studies. The importance of adopting a sustainable production and consumption approach to tackle food surplus and waste throughout the global food supply chain has been highlighted as a crucial step towards a more sustainable resolution of the industrial waste issue. Furthermore, the social inclusion of recyclable waste pickers in waste management systems has been proposed as part of a sustainable management model for industrial waste. Additionally, the role of the private sector and public-private partnerships has been explored as an emerging aspect of Artificial intelligence waste management in the developing world, emphasizing the need for inclusive approaches.

Conclusion. Managing industrial waste is one of the most difficult tasks for any country. For countries like Russia and China to join the ranks of the industrialized world, they must continue their rapid rate of urbanization and industrialization. It would lead to increased waste all across the world and disorganized urban development. Therefore, the need for healthier and proper disposal of industrial waste is warranted, and emerging countries will face increasing challenges in the near future in dealing with this massive amount of industrial waste management. In developing countries, open dumping is commonplace, endangering local ecosystems and putting people's health at risk. Due to its high moisture content and density, industrial waste from poor countries is unsuitable for energy conversion. This analysis confirms that technological , economic and government incentives affect waste management at a very high level.

Waste management problems in Russia require innovative and adaptable solutions. The integration of AI-driven technologies, such as mobile applications for waste reporting and sensor-equipped smart bins, presents a promising opportunity to revolutionize waste management practices in the region. Moreover, community engagement emerges as a crucial element in ensuring the success and sustainability of these AI-driven solutions.

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