Energy Reports 8 (2022) 4649–4660

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

# Municipal hazardous waste management with reverse logistics exploration

Xu Xu [a,*], Yanbin Yang [b]

[a] Business School, Shanghai Dianji University, 201306, Shanghai, China
[b] College of Transport & Communications, Shanghai Maritime University, 201306, Shanghai, China

ARTICLE INFO

*Article history:*
Received 28 December 2021
Received in revised form 14 February 2022
Accepted 20 February 2022
Available online 8 March 2022

*Keywords:*
Hazardous waste
Treatment
Management hazards
IoT
Municipalities
Reverse logistics
Smart grid
Renewable energy systems

ABSTRACT

Municipal waste is collected and processed by or on behalf of municipalities. The term excludes municipal sewage networks, treatment, and garbage from building and demolition operations. Hazardous waste management (HWM) is concerned with handling waste materials that, if not done correctly, can have serious consequences for the environment and human health. Returning a product that has been damaged or destroyed to its original state is called "reverse logistics", which is distinct from "waste management". The primary focus of waste management is collecting and handling materials that can no longer be recycled with Smart Grid and Renewable Energy Systems. Unscientific treatment, inappropriate garbage collection, and ethical concerns are the main issues influencing solid waste management. Solid waste management is primarily influenced by unscientific treatment, inefficient garbage collection, and ethical concerns. Soil erosion, water pollution, soil degrading, and air-polluting are some of the side effects of this process. Making smart trashcans using IoT (IoT) devices such as smart sensors is possible with Smart Grid and Renewable Energy Systems. Technology, including IoT systems, can be used to alleviate the concern of waste disposal by generating data on how much waste is produced and collected in the first place, and then using that data and implementing more efficient methods of waste reduction in the future via separation and recycling, for example.

The paper presented new municipal hazardous waste management methods and the internet of things. A sensor can be attached to a dumpster to monitor its fill level in Municipal Hazardous Waste Management (MHWM-IoT) municipalities or trash management firms. While still avoiding trash disposal facilities with the room, the IoT enterprise solution may identify the most efficient paths for garbage collectors based on this data. There has been a focus on contamination of the environment and proper waste processing technology implementation. Waste management is a critical issue that the government must address swiftly. Currently, there is limited public awareness of this topic. Too many dangers are associated with bringing out garbage, not today for future generations. As a result, the simulation analysis clarifies waste management and attains data management, sustainability, performance, minimal wastage accomplished by recycling, and achieving an efficiency of 95.09%.

Consequently, the simulation analysis helps to clarify the process of waste management while achieving data storage efficiency of 95.09 percent and sustainability and performance.



## 1. Overview of waste management concepts

The most popular approaches to municipal waste management are reprocessing, composting, combustion, and landfilling/open dumping (Muhammad et al., 2020). Waste management processes and standards rely heavily on the operations strategy (Mostafa, 2020). As a result of its danger involved if handled incorrectly, hazardous waste poses an extremely serious threat to human health and the environment (Yu et al., 2020). These wastes can be extremely harmful to the environment if they are not properly treated or managed (Kargar et al., 2020). Therefore, it is essential to know the primary classifications of each (Nascimento et al., 2019). Wastes can be divided into four distinct categories: listed and characterized, universal, and mixed wastes (Shadkam, 2021). In this mixture, renewable energy refers to energy derived from materials that have been recently grown. As a result, residual waste energy is considered a low carbon energy source because it is partially renewable. It is important to note that trash and garbage are two of the most common forms of solid waste (a wide variety of quasi components resulting from producing goods and products) (Orji and Okwu, 2021). On the

* Corresponding author.
*E-mail addresses:* xux@sdju.edu.cn (X. Xu), yanbinyang321@163.com (Y. Yang).

https://doi.org/10.1016/j.egyr.2022.02.230

other hand, hazardous waste poses a danger to human health and the environment (Javed et al., 2021).

Wastes that pose a risk to human health and the environment are known as hazardous wastes and include any unwanted material that is dangerous or has the potential to be dangerous. Material that can cause significant harm to human health and safety or the environment if it is not properly handled. Inadequate storage, transportation, treatment, or disposal operations may result in damage

Completing hazardous waste can be done using compounds, thermoelectric, biotechnology, and physical methods (Xu et al., 2019). Chemical reactions include ion transfer, precipitation, oxidation/reduction, and neutralization (Wijewickrama et al., 2021b). It is possible to define Solid Waste Management as the field concerned with the management of solid wastes in line with the appropriate principles of public wellbeing, economy, engineering, conservation, aesthetics, and any other relevant principles (Oyola-Cervantes and Amaya-Mier, 2019). Communication, automation, and connectivity are improved by using computer technology in a "smart waste network". By analyzing this data, power generation plants can better anticipate and respond to periods of peak demand. Removing harmful pollutants from municipal wastewater is known as municipal wastewater treatment (Rubio et al., 2019). Domestic use is the primary source of pollution. Health and wellbeing, chemical, and biological processes are used to remove the pollutants from the atmosphere (Wijewickrama et al., 2021a).

Since the 1990s, global consumption of various products has increased due to population growth and varying income levels (Wang et al., 2021). Earth's raw materials are consumed by growth and manufacturing growth worldwide (Ahmed and Zhang, 2021). The post-consumption leftovers are found in the environment regardless of whether they are in the air, water, or land (Sathish, 2019). Manufacturers have recently become more aware of the environmental issues associated with reverse logistics due to this growing awareness (Guarnieri et al., 2020). As a result, they decided to implement green concepts into their return network processes (Valenzuela et al., 2021). Therefore, several initiatives have been launched to reduce the environmental impact of reverse logistics returns (Kaviani et al., 2020). Companies like General Motors and Kodak have embraced this green concept due to environmental concerns, regulations, and the economic benefits that come with it (Jayasinghe et al., 2019b). It was classified as hazardous chemical waste and other non-household waste. Hazardous waste poses a serious threat to the health or the surroundings of the people who handle it (de Oliveira et al., 2019).

For waste management, collecting and disposing of materials that can no longer be recycled is the primary goal of the process. Solid waste management's main factors include a lack of scientific research, improper garbage collection, and ethical concerns. Ethical considerations and ineffective garbage collection are major factors in solid waste management. Some of the consequences of this process include soil erosion, water pollution, soil degradation, and air pollution. Smart sensors and other Internet of Things (IoT) devices can be used to create smart trashcans. Suppose IoT systems are used to gather data on waste production and collection and use that data to develop and implement more efficient waste reduction strategies in the future. In that case, this can help alleviate waste disposal concerns.

Consequently, when discussing hazardous waste, it is important to talk about the waste from cities and towns, like industrial and medical waste and electronic waste (Wang et al., 2019). It is the collection, classification, processing, packaging, transportation, storage, and distribution to specific treatment facilities of hazardous waste in the form of a material flow known as hazardous waste recycling (Waqas et al., 2020). Hazardous waste reverse logistics involves a wide range of considerations, such as the waste's collection center and the routing of vehicles. The building industry is widely regarded as the most polluting industry in terms of waste (Ayvaz and Görener, 2020). When a building is demolished at its end-of-life phase, this waste is left behind, and waste is handled at a much lower volume than at end-of-life buildings at construction sites, where most demolition waste is deposited (Leopoldino et al., 2019).

It is important to include key phrases like "manufacturing toxic waste logistics activities" and "biohazardous material reverse logistics" and Smart Grid and Renewable Energy Systems in the list of relevant keywords. Reverse logistics for e-waste were used to look for new opportunities constantly.

The main contributions of this paper are:

(1) Municipal hazardous waste management (MHWM-IoT) municipalities and waste management can use sensors attached to dumpsters to keep tabs on how full the dumpsters are getting as far as waste disposal.

(2) Garbage collectors can use the IoT enterprise system to identify the most effective routes while still avoiding disposal facilities with the room with the help of Smart Grid and Renewable Energy Systems.

(3) Internet of Things (IoT) devices, such as smart sensors, can be used to create smart trashcans. Waste disposal can be alleviated using technology, such as IoT systems, to gather information about the amount of waste being produced and collected, then using that data to implement a more effective method for waste reduction in the long term via collection and recycling.

Routing optimization is the most common IoT use case in waste management, which reduces fuel consumption while emptying the dumpsters throughout the city. Sensor data is sent to the cloud via gateways, which link the IoT platform and the sensors.

Waste management can be transformed into data-driven collection processes thanks to the Internet of Things, improving collection services and reducing operational costs for cities. An IoT-enabled garbage collection system could significantly reduce operational costs for cities.

The document's organizing structure can be viewed in the following image: There is a general overview of waste management in Section 1. Section 2 provides a context for MHWM-IoT, while Section 3 introduces the concept of MHWM. Section 4 represents the results & discussion. At the end of Section 5, there is a summary of the preceding sections' findings and recommendations.

## 2. Preliminary research

It would like a better understanding of waste management in general. It means that automation and worldwide acclaim are the ultimate objectives due to their wide range of groups and viewpoints in IoT research.

Prajapati et al. (2019) proposed Content Analysis methodology (CAM) used to reverse logistics literature will be systematically reviewed to identify research gaps and determine the direction of future studies. Because of a massive waste generation, reverse logistics is grabbing recognition from industrialists and academicians. Design of research in reverse logistics literature, (i) the areas of reverse logistics that have been explored most extensively, and (ii) the sector in which the investigation can be rerouted, (iv) probably the most common algorithms, Systematic Procedures tool, data analysis technique and Multiple Criteria Making (MCDM) methodologies, and (v) the enablers and obstacles to reverse logistics.

Medromi et al. (2019) developed waste recovery (W.R.); due to this issue's environmental and economic consequences, waste recovery is becoming mandatory in most countries. Natural resources are being depleted as the world's population consumes more and more of various products. A lot of waste is generated by those products because of their short commercial lifespan. However, the yield of used product lines from consumers to manufacturers is important in developing a protection system. Reverse logistics network structure has a significant impact on the treatment and project components of the recovery system.

Xin et al. (2021) framed reverse logistics of municipal hazardous waste (RLMHW). Researchers and practitioners have paid close attention to the importance of hazardous waste transportation and management to human health and public sustainability. The major contributions are the following: (1) pinpointing the most popular RLMHW journals; (2) locating the most famous research fields; (3) summarizing the research methods used; (4) pinpointing the research gaps in specific RLMHW categories; and (6) determining the areas for future research for RLMHW.

Jayasinghe et al. (2019a) elaborated on reverse logistics supply chain (RLSC) to explore this synergy. The research will aid investigators in combining these three concepts to discover new avenues. Building Information Modeling (BIM) was used to develop a research agenda for future studies on BIM use for existing structures under novel technologies and secondary market demand and supply analysis.

Virtual reality headset displays based on smartphone technology include gyroscopes and motion sensors for tracking head, body, and hand positions; small H.D. screens for stereoscopic displays; and small, lightweight, and fast computer processors. Currently, virtual reality simulations fall into three basic categories: non-immersive, semi-immersive, or fully immersive.

There is a growing interest in the integration of these three ideas. Because of this integration, RLSC operations now have an effective system for quality management and efficient disposal of demolition waste.

Agrawal and Singh (2019) enhanced Triple Bottom Line (TBL) where studying reverse logistics in India's electronics industry and determining how disposition decisions affect it are the goals of this research. Theorems relating to TBL performance and disposition decisions were developed. Additionally, it has a significant impact on the efficiency of reverse logistics. The disposition decision can greatly impact reverse logistics performance, one of the most critical considerations from a sustainability perspective. Circular economy concepts can be adopted and implemented through reverse logistics in supply chains. When it comes to reusing or repairing, remanufacturing, or recycling, it is called "the groups of occurrences needed to gather used goods from the customers".

Ottoni et al. (2020) framed best e-waste management (E-WM) option is determined by using these criteria and indicators. Electronic waste (e-waste or WEEE) is a critical category when it comes to waste management. The findings suggest an alternative to a more accurate analysis for a sustainable urban grid design, such as the Gross Domestic Product (GDP) and Municipal Human Development Index.

Hashemi (2021) elaborated fuzzy mathematical programming [FUM] . A multi-objective model for a reverse logistics network is what is needed to be developed. The model's objective functions include minimizing the sum of the ratio of unmet customer demand to the total amount of their demand over time, in order to cover all aspects of this system's costs, such as building facilities, purchasing fuel, and causing environmental damage through the emission of polluting gases.

It is necessary to improve existing methods, and it helps to increase the designs that underlie current methods such as CAM, WR, RLMHW, TBL, and RLSC. It has been presented as a solution to the current model's shortcomings. This innovation uses the MHWM-IoT method to create good models more rapidly and correctly than current models with the help of Smart Grid and Renewable Energy Systems.

## 3. Municipal Hazardous Waste Management (MHWM)

Selection, diagnosis, and disposal of solid waste material that can cause significant harm to human health and security or the environment if handled incorrectly. One of the most common non-hazardous materials generated by the manufacturing process is municipal solid waste (trash or garbage)models with the help of Smart Grid and Renewable Energy Systems. There is a variety of non-hazardous materials in industrial waste, and however, hazardous waste is anything that could endanger the environment or human health somehow. Waste management methods such as recycling/recovery, waste, combustion, and open dumping are all very common in American cities. Solid waste management processes and standards rely heavily on the operations strategy.

The material flow is known as hazardous waste "reverse logistics" includes collecting, classifying, processing, packaging, transportation, and storing hazardous objects from commercial activities. Many factors contribute to the difficulty of transporting hazardous waste, such as the network's structure and organization among different collection points.

Recycling/recovery, waste, combustion, and open dumping are common. Operations strategy has a significant impact on solid waste management procedures and standards.

These wastes can harm the environment if they are not properly handled or managed. That is why it is important to know the main categories of each using models with the help of Smart Grid and Renewable Energy Systems. The four distinct categories are mentioned, character trait wastes, universal wastes, and mixed wastes.

### 3.1. Protocol

Fig. 1 shows the protocol research for this paper. To review the existing research in the field of hazardous waste recycling. This procedure consists of the following four steps: (1) Defining the research question (2) Choosing evidence to support the findings (3) scoring and grading evidence quality and durability (4) making recommendations. According to the model for content analysis method, the following steps are followed:

(1) Material collection
(2) Descriptive analysis
(3) Category selection
(4) Material evaluation.

As an initial step, here conducted a subject search on "hazardous-waste reverse logistics" using the following terms:As a result, "industrial hazardous-waste reverse logistics", "medical waste reverse logistics", and "E-waste reverse logistics" were all used in a search for relevant information. A restricted and advanced search may result in lost valuable literature. Hence, humans used the HistCite tool to track our field's literature and ensure all significant documents were used in the study. For this research area, six journals have published more articles: Waste Management (articles) Waste Management & Study, Journal of Cleaner Production, Resources Conservation and Recycling (RCR), and Journal of Environmental Management (JEM) based on models with the help of Smart Grid and Renewable Energy Systems.

$$\mathrm{a_{bs}} = \sqrt{(\mathrm{cs_y} - \mathrm{ed_y})^2 + (\mathrm{qs_z} - \mathrm{wd_z})^2} + \frac{\mathrm{cs_y}}{\mathrm{qs_z}} - \frac{\mathrm{ed_y}}{\mathrm{wd_z}} + 2\,\mathrm{WR} \tag{1}$$

The Eq. (1) represents waste management where the of bs is defined as $(cs_y, ed_y), (qs_z, wd_z)$ respectively where $\mathrm{a_{bs}}$ is the material evaluation, cs is the controller, ed is the sensor and WR represents the waste ratio. Data analysis is more effective than other models and is achieved from the above equation.

$$\mathrm{R}_{\varnothing,\mathrm{t}} = \mathrm{k}_{\varnothing_{a,t}} + C_t + r_{\varnothing,\mathrm{t}} - \frac{WR}{2} + R \tag{2}$$

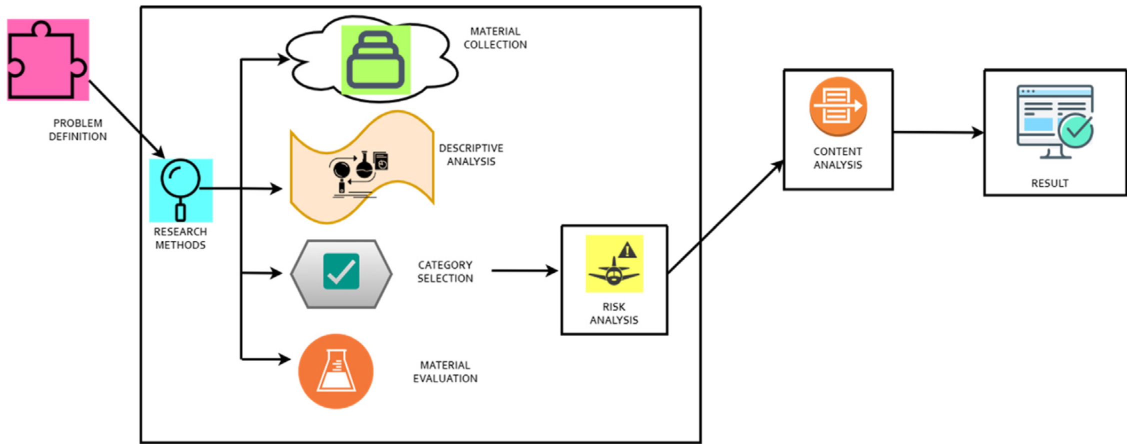


**Fig. 1.** Protocol for research.

As per the given Eq. (2) $R_{\varnothing,t}$ gives the recycling, where $k_{\varnothing a,t}$ represents the velocity, $k$ is the reference frame, $r_{\varnothing,t}$ is the reusing and $C_t$ is the time-varying basis and $R$ is the recycled items. Security is well achieved by removing the waste from the above equation.

$$g_{b,t} = b_{f_t} + D_t + s_{b,t} \tag{3}$$

$$b_{f_t} = b_{Q_{p,t}}(p_{a_t} - p_{g_t}) \tag{4}$$

From the above Eqs. (3) and (4), the raw measurements are found out which is modeled by the above equations where $b_{f_t}$ is the force measured by the waste management, reference b at each time step t, $D_t$ is the time-varying basis, $s_{b,t}$ be the raw material, $b_{Q_{p,t}}$ be the resultant of sewage of $(p_{a_t} - p_{g_t})$ from navigation part $a$ to the sensor part $b$. Accuracy is achieved from this Eq. (3). $p_{g_t}$ be the hazardous and linear part $p_{a_t}$ can be summed up to 0. Hence, the result is substituting (4) in (3).

$$g_{\varnothing,t} = -b_{Q_{p,t}} p_{g_t} + D_t + s_{b,t} \tag{5}$$

The above Eq. (5) gives the accelerometer measurements were the $p_{g_t}$ dominates more than $p_{a_t}$.

Raw measurements and through that accuracy can be calculated using Eq. (3), while accelerometer measurements are calculated using Eq. (5). Sewage resultant is calculated using (4).

$$g_{m,t} = b_{Q_{p,t}} p_m + s_{m,t} \tag{6}$$

As Eq. (6) it indicates that $g_{m,t}$ is the content analysis,raw measurement, which is modeled as shown where the local field is represented by $p_m$, $s_{m,t}$ represents the noise of the sensor used. Here the efficiency is greatly achieved from the above equation.

The articles are broken down into seven categories outlined in the previous section. Risk monitoring and evaluation fall under the first grouping. Additionally, there are issues related to vehicle routing and location routing, qualitative studies, system optimization, and more with the help of Smart Grid and Renewable Energy Systems. This study uses both induction and deduction methods to ensure the validity of the literature review. The use of figures and tables enhances the presentation of the analysis results. Green supply chain management is becoming increasingly popular and important. This part provides detailed research on the autonomous logistics activities of hazardous materials from social responsibility and environmental perspective.

### 3.2. Reverse logistics architecture

The collection, classification, processing, packaging, transportation, and storage of hazardous objects from commercial activities, as well as their distribution to specific treatment facilities, constitute the material flow known as hazardous waste "reverse logistics" Consequently, logistics for hazardous waste is complicated by many factors, such as the design of the network and the organization of various nodes and collections using Smart Grid and Renewable Energy Systems.

Reverse logistics is a term that has been defined by a wide range of authors over the years. In a nutshell, it can be described as a form of reverse engineering, as shown in above Fig. 2. Originally used in the case of product recovery management, reverse logistics aims at maximizing environmental and economic value while minimizing waste. It is called supply chain management when raw materials flow from the point of consumption back to the point of origin to the point where they can be recouped in value or disposed of in an environmentally-friendly manner with the help of Smart Grid and Renewable Energy Systems.

Due to the increasing population and diminishing natural resources, every organization will require reverse logistics shortly. Researchers and industrialists are increasingly interested in reverse logistics, as evidenced by the recent research volume on the subject. Sustainable competitiveness and socially responsible are a few reasons for this shift. The disassembly center receives the materials that have been used and recycles them. A series of tests and a final division into three piles follow.

If a product is convertible to finished good with minor adjustments, it is considered a convertible product. A product that needs major corrections can be converted into raw material, and it is the better option since raw material can be used in the manufacturing process. Some products cannot be used in industry and are thrown away. This study aims to conduct a literature review on reverse logistics to identify research gaps and lay out a course for future investigations using the help of Smart Grid and Renewable Energy Systems. Literature reviews aid in fundamental understanding and lay the groundwork for a specific research area, opening the door to theory development.

Products collected by consumers and then sent back to manufacturers for remanufacturing are known as "backward logistics" or "back-to-back logistics". Reverse logistics entails handling returns and purchasing unsold inventory. Additionally, the procedure involves dealing with any leases or renovations. Industry-specific reverse logistics differ, as do financial incentives for bettering this aspect of supply chain management.

### 3.3. Research method

**Material Collection:** Fig. 3 depicts how reverse logistics analysis research is conducted. In the first phase of collecting material,

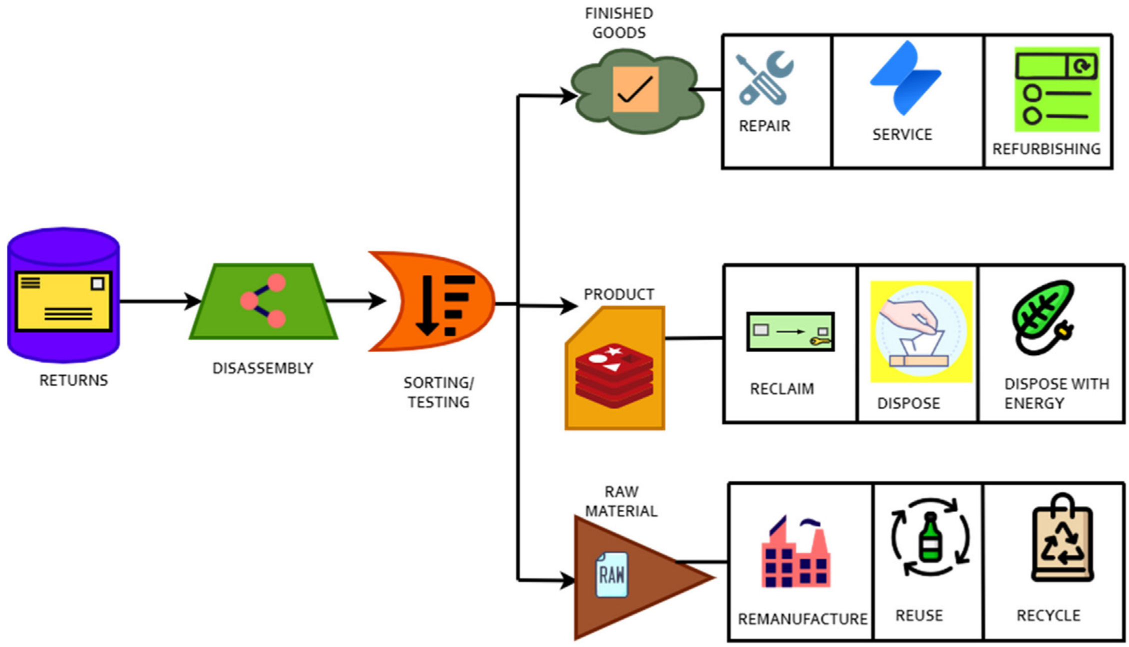


**Fig. 2.** Architecture diagram.

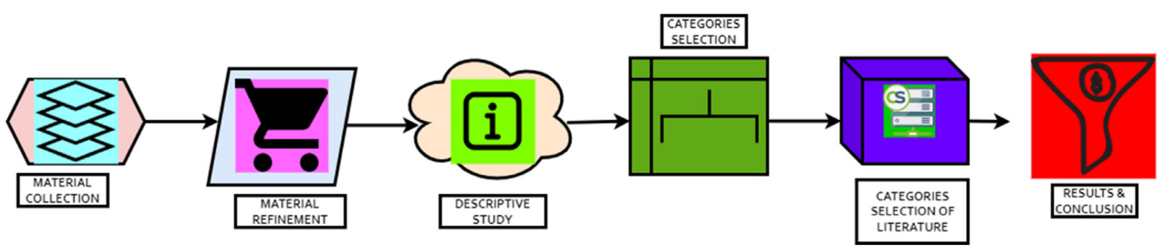


**Fig. 3.** Research method for reverse logistics analysis.

the database and keywords to search for articles are selected. Details of the data and units of analysis are laid out in advance. Retrieved was selected for this project because it is the world's biggest abstract and citation collection of data for peer-reviewed writing.

**Material Refinement:** Fig. 3 depicts the procedure of article filtration after the appropriate filters have been applied. Finally, a data-sheet with the following attributes was created: Author's First and Last Name (s), Author(s), affiliation with the publisher, and a complete abstract are even included in the publication's title, year of publication, and source title.

**Descriptive Study:** The facts of bibliographic details for the chosen literature were tallied in the third step. Several factors go into this: the frequency with which articles are published, the quality of the journals and publishers that publish them, the number of articles a university has, the list of its most notable works, and where its scholars are located. The content analysis is based on this step.

**Selection of Categories:** The fourth step is classifying and analyzing selected articles. There is some overlap between categories, and this is to ensure that the content is as clear as possible. If a researcher decides to conduct content analysis, they have a wide range of options for surveying the paper. If this is a possibility, having two analysts search for and analyze the data can lessen its occurrence".

**Categorical Analysis:** The evaluation of the material is the subject of the fifth step. After careful consideration, the articles used in this study have been thoroughly examined using models with the help of Smart Grid and Renewable Energy Systems.

And they have been categorized into the appropriate section following their inspection.

**Results and Conclusion:** Reverse logistics research now focuses on this study. Finally, the study's findings, gaps in previous research, and future research avenues were discussed in this analysis. The review's constraints have been discussed in the last few paragraphs.

$$L_i^2 = (p - p_i)^2 + (q - q_i)^2 + (r - r_i)^2 \quad (7)$$

In above Eq. (7), $L_i$ be the length of the raw materials used, $p_i$ be the point in 1st trilateral sector of sewage, $q_i$ be the point in 2 and trilateral sector of plant, $r_i$ be the point in 3 rd. The trilateral sector of reusing and the difference between the sum of the squares is found to calculate the raw length, and the rate of sustainability is too observed from the above equation.

At the beginning of the process, it is critical to ensure that waste is properly separated at the source and travels through various recycling and resource recovery streams. After the final residue has been reduced, it is scientifically disposed of in sterile disposal facilities. Additionally, it helps reduce the amount of waste sent to landfills.

$$\partial = \sqrt{F(\mathrm{y})} = f\ (y)^{1/2} \quad (8)$$

The above Eq. (8) $\partial$ is defined as the open square of the size of the residue. It helps to reduce the storage likelihood of huge and increase the caching wastage. Therefore this technique, minimal wastage, is achieved through the above equation.

The open square of the residue's size is given by the Eq. (8). It reduces the likelihood of a large amount of storage and increases

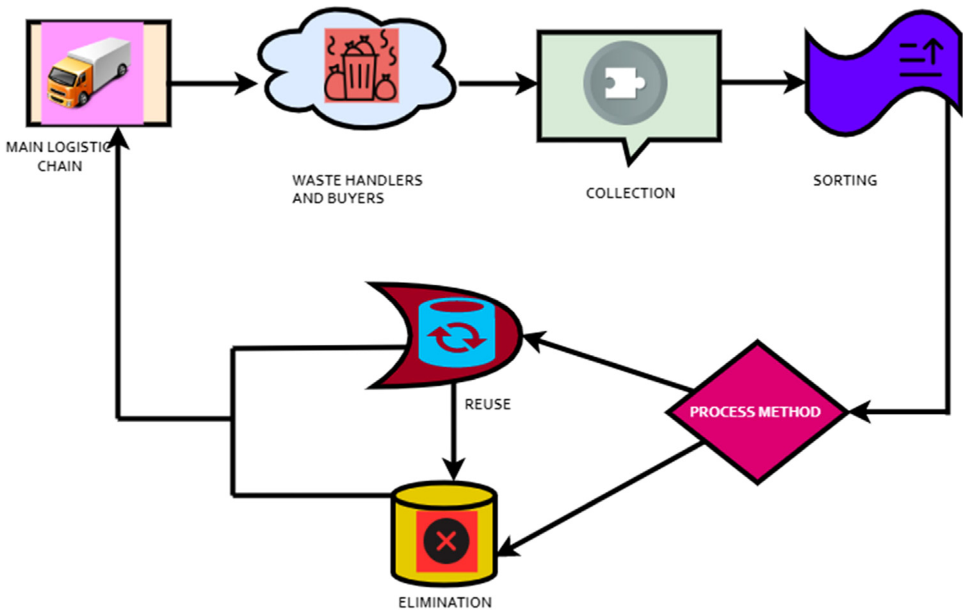


**Fig. 4.** Process flow.

caching waste. By using this formula, the goal of minimizing waste can be achieved.

Buying fewer and better-quality products can help consumers reduce the amount of waste they produce. Additionally, fixing broken or worn clothing or equipment helps to reduce household waste.

### 3.4. Process flow

The reverse logistics process flow is depicted in Fig. 4. The chain's information flow management requirements are quite diverse and complex. Humans need a return management system to function properly; hence Smart Grid and Renewable Energy Systems are used. A strong communication system between the diverse participants and a reliable method of determining what to do with the good or service returned quickly are essential for this system. Classifying the inverse flows allowed us to examine their characteristics and typologies further. They are using this procedure to identify the type of return. Specifically, the waste discussed later in this article.

**Reverse logistics process:** Purchasing and selling of waste, waste collection, waste sorting, and the recycling process. On the contrary, reverse logistics is not at odds with or in conflict with traditional logistics.

**Reuse:** When a product can be used for the purpose it originally intended. Choosing the reuse option led to this decision. Products that customers return or decide against will be included in the new products that are sold.

**Elimination:** Safe capacity for hazardous materials, incineration, and landfilling fall under recovered products' eradication decision. The company usually handles and pays for the disposal of unutilized or unusable products. To do this part, the customer must dispose of the item in question by placing it among the garbage gathered by a public utility. Disposal is still the preferred option for recovered products for organizations that are not yet interested in reverse logistics activities.

**Waste management**: It is harder to predict the outcomes due to the random nature of waste management results. Another distinguishing feature is that the waste is not uniform. A first step in the proposed design is to categorize waste based on its natural state, which will then be recycled based on Smart Grid and Renewable Energy Systems.

**Sorting:** People or dump trucks can either separate recyclables for transportation to landfills or send them directly to a recycling facility. For wrapping (plastic bottles, metal trays, trays, and cardboard boxes), the same holds for this transit center's newspaper magazines, sorted and packaged. As a result, the transportation of waste is being optimized.

### 3.5. SubProgram for recycling waste

As shown in Fig. 5, instead of using a statutory framework to organize waste, use a category-based system. It is done to give the research a more dynamic feel. Indeed, the literature's categorization remains complicated because users have discovered that several different names can refer to the same waste. Furthermore, if a household generates a used battery, it will be classified as hazardous waste. Otherwise, if it is present in large amounts or transmitted by a company, it is considered toxic waste. At this point, it makes sense to categorize the waste according to its nature with the help of Smart Grid and Renewable Energy Systems.

The physical, chemical, or biological properties of waste do not change significantly over time. No matter what it comes in contact with, it does not decompose or produce any physical or chemical reactions, making it environmentally friendly. Agricultural waste, agricultural waste, and forestry are the primary sources of organic waste, which is inert and can be decomposed by the natural process of biodegradation.

Waste that can be recycled, fermented, or incinerated with energy recovery is called "banal waste", It is made up primarily of municipal waste in the broadest sense of the term and ordinary business wastes with the help of Smart Grid and Renewable Energy Systems. A wide range of toxic or destructive substances is found in Toxic or Dangerous waste, some of which have been known to be harmful and are under strict regulation. Dispersed quantities of toxic waste in the home or on the farm are the most common source of these pollutants (plant protection products).

Valorization of electronic waste is closely linked to the management options selected by decision-makers to optimize the entire system and extract as much valuable material from waste as possible. Under the Circular Economic concept, all phases of an electronic product's lifecycle must be linked and directed to

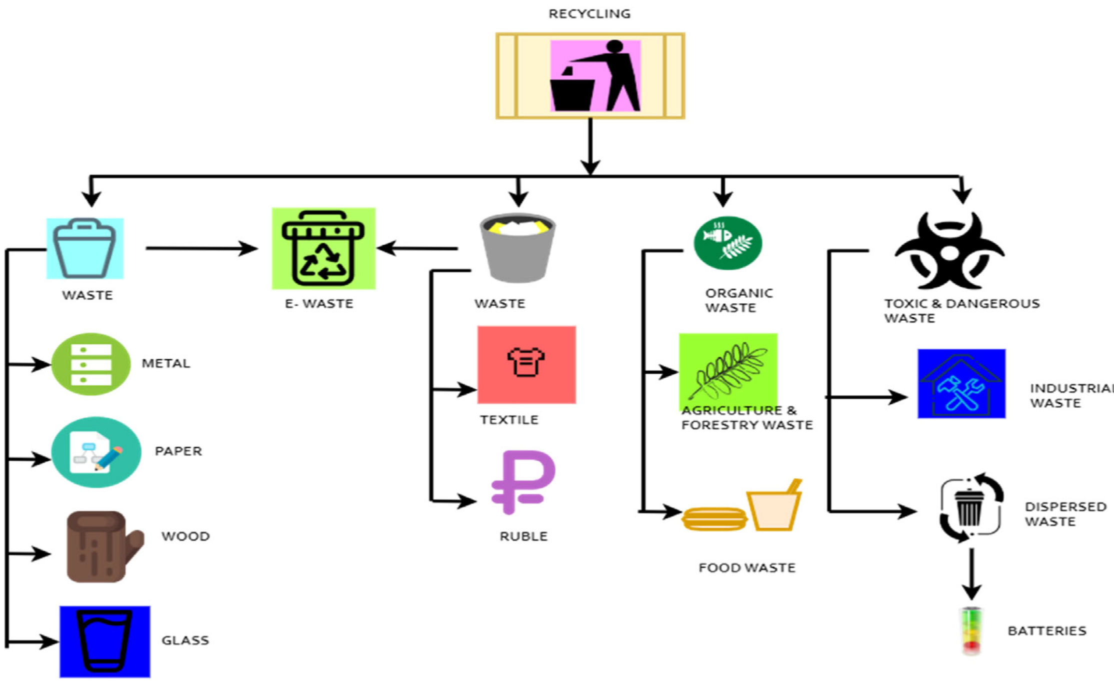


**Fig. 5.** SubProgram for recycling.

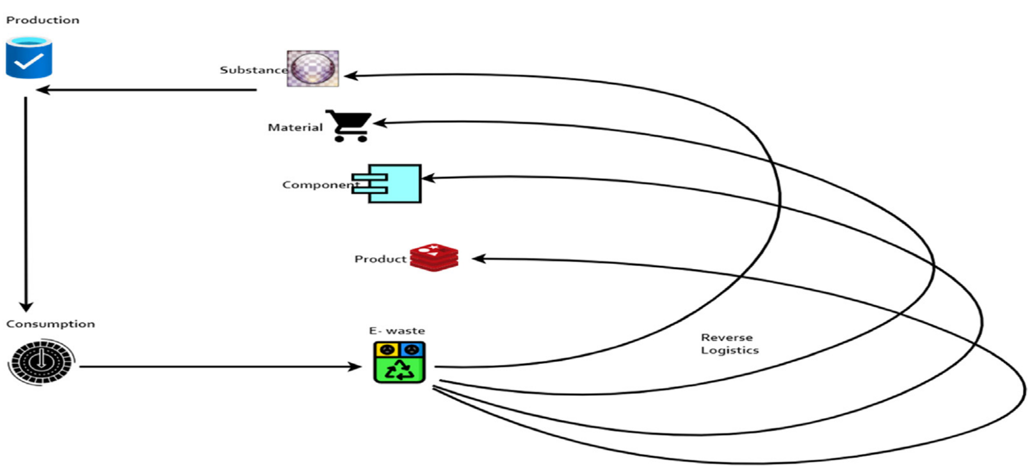


**Fig. 6.** An E-waste circular model using reverse logistics and urban mining.

a return system for e-waste. Reverse Logistics, remanufacturing, and redesigning are all tools in the Circular Economy's toolbox for dealing with e-waste streams, as illustrated in Fig. 6. Recovery, analysis, processing, recycling, and other related activities are all included in urban mining. Secondary Raw Materials (SRM) are to be recovered from stockpiles of materials that have been incorporated into cities or landfills. In this concept, reverse logistics systems return discarded products to the supply chain.

$$w_l^x[a] = S_x + M_x + C_x + P_x \tag{9}$$

In the above Eq. (9) where, $w_l^x[a]$ Implies the e-waste. $S_x$ is the substance, $M_x$ is the material, $C_x$ is the component and $P_x$ is the product.

$$E_{waste} = L_i^2 + w_l^x[a] \tag{10}$$

Substituting Eq. (7) in (10), we get

$$E_{waste} = (p - p_i)^2 + (q - q_i)^2 + (r - r_i)^2 + S_x + M_x + C_x + P_x \tag{11}$$

The above Eq. (11) represents the e-waste.

The Fig. 7 shows the Flow Methodology for the proposed model where the final part is obtained. Accelerometer measurements were taken from the resultant part which is obtained from the Eq. (5) which is represented here as $\mathbf{g}_{\varnothing,\mathbf{t}}$. The flow methodology tells how the measurement is done and framed as per discussion scenario.

Fig. 8 shows the flowchart on waste return management. The following flow charts and sub-programs provide a more in-depth look at the process. A wasteful input characterizes the input in the first as an input for models with the help of Smart Grid and Renewable Energy Systems. It is then decided whether the wastes should be transported directly to a treatment facility with sufficient resources or disposed of more conventionally.

Ineffective waste management can have serious health and environmental consequences. Environmental damage can occur if waste 'leachate' is not properly disposed of, waste is burned, and non-renewable natural resources are not recycled. According to a study, health problems have increased in the area around waste disposal sites.

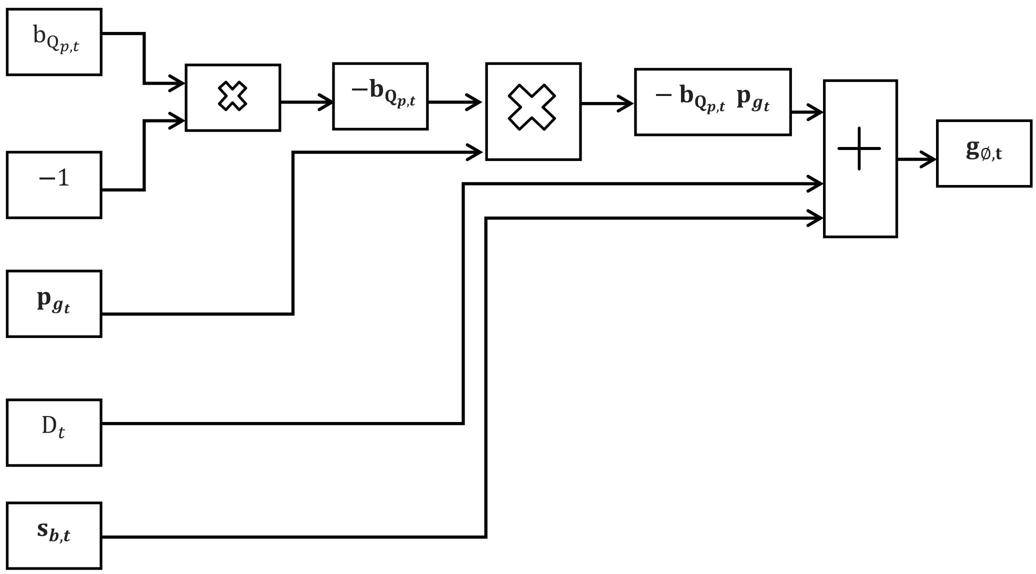


**Fig. 7.** Flow methodology.

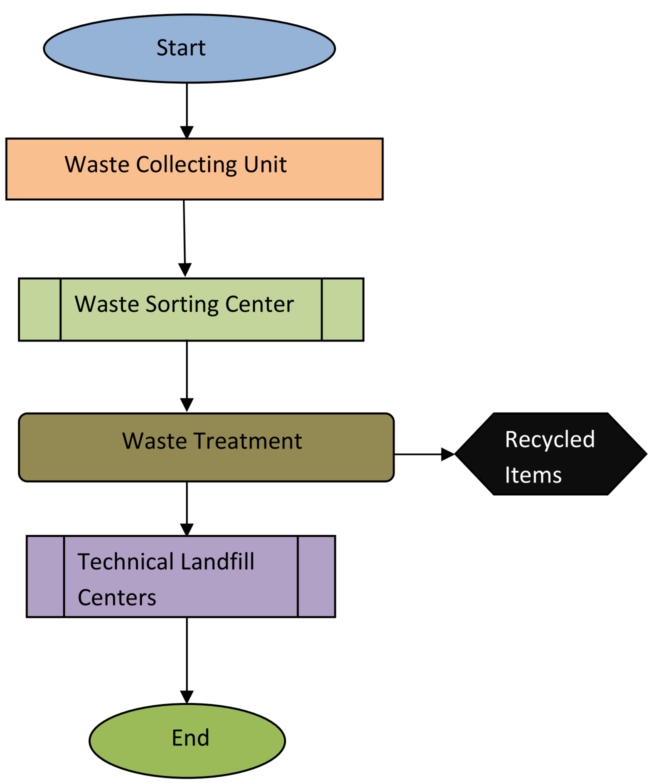


**Fig. 8.** Flow chart on waste return management.

The goal is to give this investigation a more lively feel. Indeed, the categorization proposed in the literature remains complicated because the user has discovered that several names can refer to the same waste. A household's use of utilized rechargeable batteries will make it hazardous waste, as well.

As a result, it is considered hazardous waste if it can be found in large amounts in the environment. A classification based on the type of waste seems appropriate at this point. In this paper, reverse logistics is used to demonstrate how an MHWM can be used for analysis. Using Smart Grid and Renewable Energy Systems, data management, sustainability, performance, minimal waste, and efficiency were all measured and verified.

## 4. Results & findings

Reverse logistics research had never been studied in depth before this study. Finally, the findings from this study, a gap that exists in the literary works, and areas for future research have indeed been discussed in this analysis. The literature review's limitations have been addressed in a few paragraphs. Data analysis, efficiency, sustainability, performance, and wastage analysis in simulations were all examined in the findings based on models with the help of Smart Grid and Renewable Energy Systems.

Hence, this paper uses systematic analysis to review the relevant reverse logistics literature thoroughly. The 449 articles published up until January 10th, 2018, have been selected, reviewed, and categorized according to the classifications stated in Section 3 of this document. Research limitations and future research horizons are highlighted in this section.

### *4.1. Data analysis*

Fig. 9 depicts the results of the analysis. The $x$-axis is the number of samples, and the $y$-axis is the percentage of analyzed data for each. The samples are compared using various techniques, and MHWM-IoT is more important than every method (3). Compared to other models, the data analysis is superior and achieved from Eq. (1).

### *4.2. Efficiency analysis*

After the samples were collected, the efficiency analysis above examined the information. The efficacy study's findings are shown in Fig. 10. A graph shows the number of samples taken and the efficiency analysis ratio on the $x$-axis. Data can be transmitted more efficiently than any other currently used method using Smart Grid and Renewable Energy Systems. To predict outcomes, a content technique to recognize trends in characteristics linked to waste management development is analyzed. With the help of Eq. (6), it is mathematically proven.

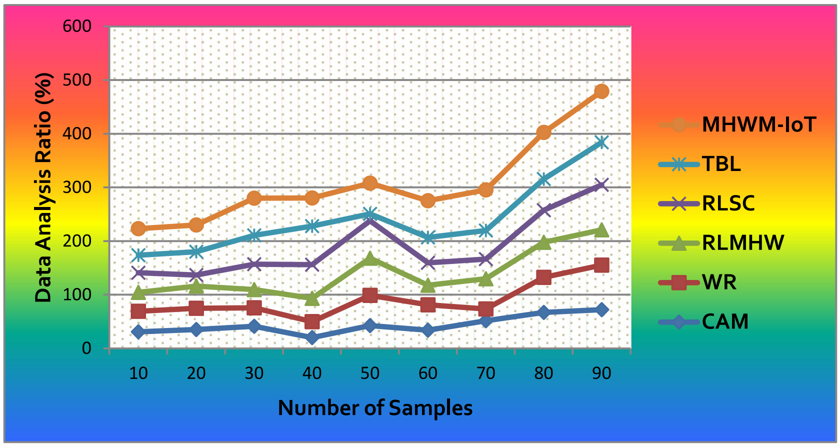


**Fig. 9.** Data analysis.

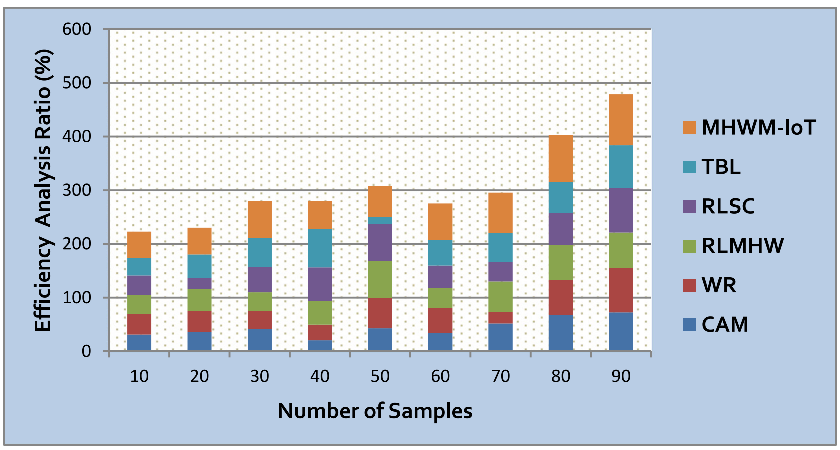


**Fig. 10.** Efficiency analysis.

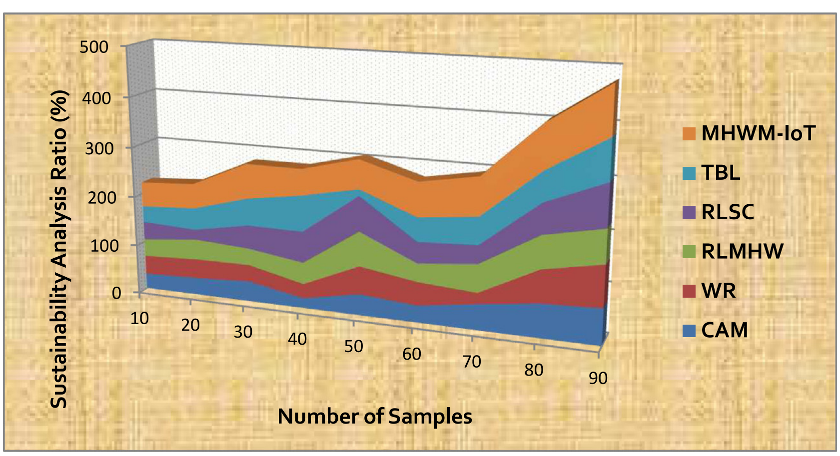


**Fig. 11.** Sustainability analysis.

### *4.3. Sustainability analysis*

Results from the sustainability study are depicted in Fig. 11. Each sample was counted, and their sustainability analysis ratio was calculated using the graph shown here (x-axis and y-axis). More than any other method currently in use, the method has the potential to be long-term sustainable. Predictions are made using a content technique that looks for patterns in characteristics related to waste management growth. It is done using an Eq. (7) and can be mathematically established.

Data were analyzed with the help of the sustainability analysis ratio, as depicted in Fig. 9, which shows the results of the sustainability study. According to the graph shown, the sustainability analysis ratio for each sample was calculated (x-axis and y-axis). The consistency of the results is checked.

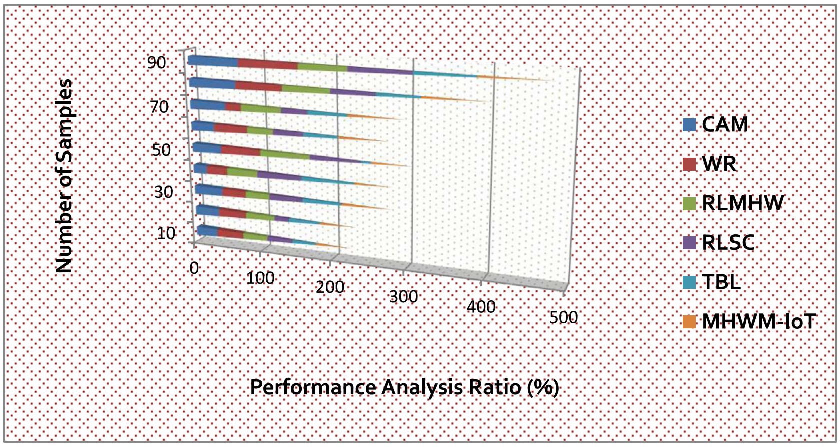


**Fig. 12.** Performance analysis.

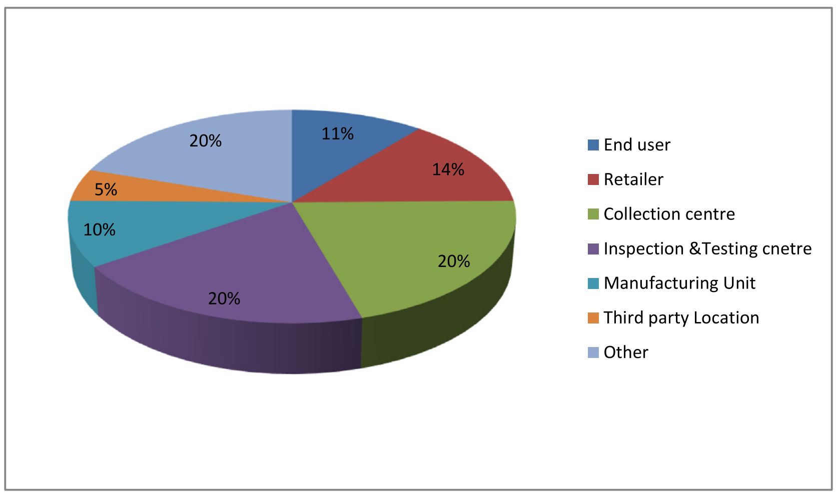


**Fig. 13.** Wastage analysis.

### *4.4. Performance analysis*

Fig. 12 illustrates the advantages of performance evaluation. The *x*-axis plots the different performance analysis ratios, while the *y*-axis plots the number of samples. Therefore, different samples were taken at different ratios to test each method, collected based on this ratio. Compared to current methods, this model sends a greater good in standard with the help of Smart Grid and Renewable Energy Systems. Examples include MHWM-IoT, which shows how waste management development is evaluated.

Main Logistics chain, waste handlers & buyers, collection, reuse, and elimination are the blocks used here for performance evaluation to comprehend.

### *4.5. Wastage analysis*

Fig. 13 shows the wastage analysis indicated in the chart above. Inspection results are used to categorize the products, then sent on to the next step in the production process. Effectiveness depends on the effectiveness of the products used. Depending on the organization's policy, any point in the network can be selected where products are disposed. using with the help of Smart Grid and Renewable Energy Systems. Those who responded to our survey were asked for information about where the final decisions on returning goods are made for further processing and achieved from the Eq. (8).

### *4.6. Energy analysis*

The energy analysis depicted in the graph above is shown in Fig. 14. The inspection results are then used to classify the products, which are then moved on to the next stage of production. The efficiency of the products we use directly impacts our use of energy. Any point in the network can be chosen as a disposal point for products, depending on the organization's policy using the Smart Grid and Renewable Energy Systems.

The inspection results are then used to classify the products, which are then moved on to the next stage of production. To be effective, the products must be effective. Any point in the network can be chosen as a disposal point for products, depending on the organization's policy. We polled our respondents and asked for their contact information to better understand how returns are handled. It is not assessed by the Matlab tool.

According to our research, the MHWM-IoT model outperformed the competition in all the above categories. According to reports, this new feature was developed in response to the competitive pressure outlined in the previous section based on models with the help of Smart Grid and Renewable Energy Systems.

## **5. Conclusion**

Environmental concerns, government regulations, and cost advantages drive organizations to implement reverse logistics

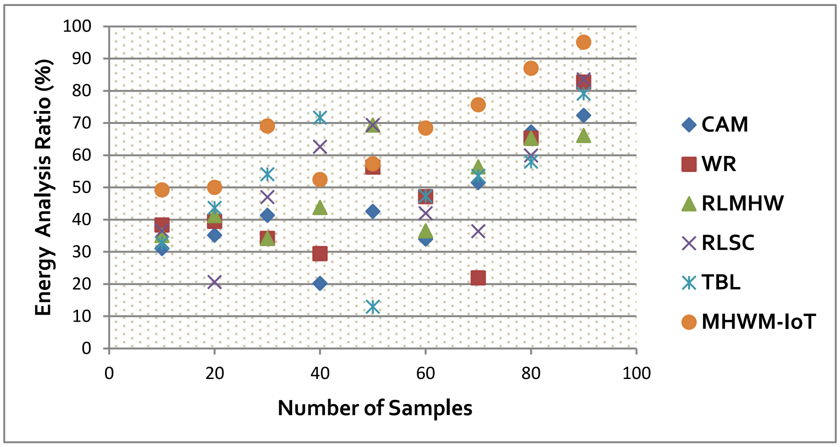


**Fig. 14.** Energy analysis.

practices. It will aid the development of an institution more efficiently and effectively. The purpose of this review is to discover new avenues of research in reverse logistics that have not been previously explored. It is done using content analysis and an abductive research approach. This systematic review investigates research methodologies, industries, algorithms, techniques, and data analysis all play a role in computer science using models with the help of Smart Grid and Renewable Energy Systems. A snapshot of the field's development is provided in this study, which adds to the scholarly discussion and provides information to policymakers for intended cause and policy formulation in this area. Nondeterministic approaches can be improved and integrated with other methods to deal with the increasing number of uncertain parameters. A specific issue with soft or hard time windows suggests several additional instructions for transportation problems or opportunities. As a result, solving problems with multiple objectives rather than one may be the way to go in the future. Use of the developed framework for existing structures under technological support; and analysis of demand and supply for secondary markets and safety practices with the concept of quality in an enabling environment are future research directions. Sustainable management can be applied in a regulated environment as well, according to this study. The study's findings suggested new avenues for integrating more than two managerial viewpoints. Managing the supply chain in reverse has become a new problem; hence models of Smart Grid and Renewable Energy Systems are used. As an industry, technology, consumption patterns, and environmental concerns have evolved, it has too green logistics, and it has changed dramatically in the last few years. In addition to environmental concerns, reverse logistics encompasses all of the issues that arise when consumers return products. As soon as these rates of return, which include waste, are collected, they pose several issues. Hence the proposed model Municipal Hazardous Waste Management (MHWM-IoT) helps solve the issues mentioned in this paper. Consequently, the simulation analysis provides a clear picture of waste management, resulting in minimal waste and an efficiency of 95.09%.

Most of the advancements in thermal technology have occurred, biological technology can be a game-changer. Waste management is an essential tool for reducing greenhouse gas emissions and maintaining a clean and healthy environment. In addition, food waste in urban areas is expected to rise by 44 percent between 2005 and 2025, which will significantly impact global greenhouse gas emissions if proper management is not put in place.

## CRediT authorship contribution statement

**Xu Xu:** Conception and design of study, Analysis and/or interpretation of data. **Yanbin Yang:** Acquisition of data.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

This work was supported by Humanities and Social Sciences Planning fund project, Ministry of Education, China (No. 20YJA880064).

## References

Agrawal, S., Singh, R.K., 2019. Analyzing disposition decisions for sustainable reverse logistics: Triple bottom line approach. Resour. Conserv. Recy. 150, 104448.
Ahmed, R.R., Zhang, X., 2021. Multi-stage network-based two-type cost minimization for the reverse logistics management of inert construction waste. Waste Manage. 120, 805–819.
Ayvaz, B., Görener, A., 2020. Reverse logistics in the electronics waste industry. In: Waste Management: Concepts, Methodologies, Tools, and Applications. IGI Global, pp. 1664–1680.
de Oliveira, C.T., Luna, M.M., Campos, L.M., 2019. Understanding the Brazilian expanded polystyrene supply chain and its reverse logistics towards circular economy. J. Clean. Prod. 235, 562–573.
Guarnieri, P., Cerqueira-Streit, J.A., Batista, L.C., 2020. Reverse logistics and the sectoral agreement of packaging industry in Brazil towards a transition to circular economy. Resour. Conserv. Recy. 153, 104541.
Hashemi, S.E., 2021. A fuzzy multi-objective optimization model for a sustainable reverse logistics network design of municipal waste-collecting considering the reduction of emissions. J. Clean. Prod. 318, 128577.
Javed, H., FazalFirdousi, S., Murad, M., Jiatong, W., Abrar, M., 2021. Exploring disposition decision for sustainable reverse logistics in the era of a circular economy: Applying the triple bottom line approach in the manufacturing industry. Int. J. Supply Oper. Manag. 8 (1), 53–68.
Jayasinghe, R.S., Chileshe, N., Rameezdeen, R., 2019a. Information-based quality management in reverse logistics supply chain: A systematic literature review. Benchmarking: Int. J..
Jayasinghe, R.S., Rameezdeen, R., Chileshe, N., 2019b. Exploring sustainable post-end-of-life of building operations: A systematic literature review. Eng. Constr. Archit. Manag..
Kargar, S., Pourmehdi, M., Paydar, M.M., 2020. Reverse logistics network design for medical waste management in the epidemic outbreak of the novel coronavirus (COVID-19). Sci. Total Environ. 746, 141183.
Kaviani, M.A., Tavana, M., Kumar, A., Michnik, J., Niknam, R., de Campos, E.A.R., 2020. An integrated framework for evaluating the barriers to successful implementation of reverse logistics in the automotive industry. J. Clean. Prod. 272, 122714.

Leopoldino, C.C.L., de Mendonça, F.M., de Lima Siqueira, P.H., Borba, É.L., 2019. The disposal of fluorescent lamps of industries of the metropolitan region of Belo Horizonte-MG. J. Clean. Prod. 233, 1486–1493.

Medromi, H., Casablanca, C.E., Ifrassen, Y., Benhadou, S., 2019. Reverse logistics: methodological framework for industrial waste management. Int. J. Comput. Sci. Inf. Secur. (IJCSIS) 17 (8).

Mostafa, N., 2020. Logistics of waste management with perspectives from Egypt. In: Waste Management in MENA Regions. Springer, Cham, pp. 171–191.

Muhammad, A., Hussein, M.Z.S.M., Veera, M.H.Z., Sundram, P.K., 2020. Reverse logistics activities for household E-waste management: A review. Int. J. Sup. Chain. Mgt Vol 9 (1), 312.

Nascimento, D.L.M., Alencastro, V., Quelhas, O.L.G., Caiado, R.G.G., Garza-Reyes, J.A., Rocha-Lona, L., Tortorella, G., 2019. Exploring industry 4.0 technologies to enable circular economy practices in a manufacturing context: A business model proposal. J. Manuf. Technol. Manag..

Orji, I.J., Okwu, M., 2021. Analyzing the barriers to reverse logistics (R.L.) implementation: A hybrid model based on IF-DEMATEL-EDAS. Sustainability 13 (19), 10876.

Ottoni, M., Dias, P., Xavier, L.H., 2020. A circular approach to the e-waste valorization through urban mining in Rio de Janeiro, Brazil. J. Clean. Prod. 261, 120990.

Oyola-Cervantes, J., Amaya-Mier, R., 2019. Reverse logistics network design for large off-the-road scrap tires from mining sites with a single shredding resource scheduling application. Waste Manage. 100, 219–229.

Prajapati, H., Kant, R., Shankar, R., 2019. Bequeath life to death: State-of-art review on reverse logistics. J. Clean. Prod. 211, 503–520.

Rubio, S., Jiménez-Parra, B., Chamorro-Mera, A., Miranda, F.J., 2019. Reverse logistics and urban logistics: Making a link. Sustainability 11 (20), 5684.

Sathish, T., 2019. Profit maximization in reverse logistics based on disassembly scheduling using hybrid bee colony and bat optimization. Trans. Can. Soc. Mech. Eng. 43 (4), 551–559.

Shadkam, E., 2021. Cuckoo optimization algorithm in reverse logistics: A network design for COVID-19 waste management. Waste Manag. Res. 0734242X211003947.

Valenzuela, J., Alfaro, M., Fuertes, G., Vargas, M., Sáez-Navarrete, C., 2021. Reverse logistics models for the collection of plastic waste: A literature review. Waste Manag. Res. 0734242X211003948.

Wang, J., Cevik, M., Amin, S.H., Parsaee, A.A., 2021. Mixed-integer linear programming models for the paint waste management problem. Transp. Res. Part E: Logist. Transp. Rev. 151, 102343.

Wang, Z., Huang, L., He, C.X., 2019. A multi-objective and multi-period optimization model for urban healthcare waste's reverse logistics network design. J. Comb. Optim. 1–28.

Waqas, M., Qianli, D., Ahmad, N., Zhu, Y., Nadeem, M., 2020. Modeling reverse logistics barriers in manufacturing industry of Pakistan: An ISM and MICMAC approach. J. Adv. Manuf. Syst. 19 (02), 309–341.

Wijewickrama, M.K.C.S., Chileshe, N., Rameezdeen, R., Ochoa, J.J., 2021a. Information sharing in reverse logistics supply chain of demolition waste: A systematic literature review. J. Clean. Prod. 280, 124359.

Wijewickrama, M.K.C.S., Chileshe, N., Rameezdeen, R., Ochoa, J.J., 2021b. Quality assurance in reverse logistics supply chain of demolition waste: A systematic literature review. Waste Manag. Res. 39 (1), 3–24.

Xin, C., Wang, J., Wang, Z., Wu, C.H., Nawaz, M., Tsai, S.B., 2021. Reverse logistics research of municipal hazardous waste: a literature review. Environ. Dev. Sustain. 1–37.

Xu, J., Shi, Y., Zhao, S., 2019. Reverse logistics network-based multiperiod optimization for construction and demolition waste disposal. J. Constr. Eng. Manag. 145 (2), 04018124.

Yu, H., Sun, X., Solvang, W.D., Zhao, X., 2020. Reverse logistics network design for effective management of medical waste in epidemic outbreaks: Insights from the coronavirus disease 2019 (COVID-19) outbreak in Wuhan (China). Int. J. Environ. Res. Public Health 17 (5), 1770.