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Application of Material Flow Cost Accounting for Waste Reduction and Management

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ABSTRACT

This article discusses the application of Material Flow Cost Accounting (MFCA) in industrial waste reduction and management. With increasing industrialization and environmental awareness, hazardous waste generation poses a significant challenge to ecosystems and human health. MFCA, based on ISO 14051, provides comprehensive information on material usage and efficiency that can help companies reduce costs and environmental impacts. In addition, Environmental Management Accounting (EMA) plays a role in collecting data on waste management costs, allowing companies to monitor emissions and comply with regulations. The research method used is a literature review, focusing on the analysis and synthesis of relevant literature. The findings show that the application of MFCA and digital technology in environmental accounting can improve transparency, efficiency, and sustainability in waste management. In the context of a circular economy, accounting serves as a vital tool in driving more sustainable management strategies, as well as supporting environmental impact reduction.

Keywords: Material Flow Cost Accounting, waste management, environmental accounting, sustainability, circular economy

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INTRODUCTION

Rapid industrial development, depletion of natural resources, and increasing environmental awareness have caused corporate companies to shift their attention from short-term profits to long-term strategies to achieve sustainable management and smooth progress towards a new era. Increasing industrialization has led to increasing waste production which is one of the major environmental challenges (Huang *et al.* , 2019) . These industries produce hazardous waste which is mainly organic in nature and is therefore disposed of or processed in the environment. This waste causes increased contamination which leads to increased mortality, both physical and morphological changes in organisms/animals that come into contact with it (Gaur *et al.* , 2020) . Although the waste produced is hazardous, most of it contains macromolecules and bioactive compounds so that it can be efficiently utilized for the extraction and production of value-added products. (Scarpellini *et al.,* 2020) . Therefore, a more effective waste management approach is needed, including recycling and reuse technologies to reduce the negative impacts of industrial waste and support sustainable development (Peng *et al.* , 2023) .

Industrial waste and garbage have a major impact on the environment. Air, water, and soil pollution due to hazardous waste disposal can damage ecosystems and threaten human health. Poorly managed waste, especially chemical and plastic waste, causes water pollution, soil contamination, and impacts biodiversity. In addition, the large amount of greenhouse gas emissions from waste management and landfills also exacerbate climate change (Alola and Adebayo, 2023) . Ineffective waste management results in significant economic costs. The costs of addressing pollution, repairing damaged ecosystems, and managing public health are enormous. On the other hand, companies that do not implement waste reduction or recycling strategies will face increased production costs, especially when raw materials become scarce and energy prices rise. In addition, companies that do not comply with environmental regulations can face fines and bad reputations, which are detrimental to profitability and image (Universitas Brawijaya *et al.* , 2023) .

Solutions such as Material Flow Cost Accounting (MFCA), based on ISO 14051, have been implemented to reduce waste and improve material efficiency in the production

process. MFCA provides companies with information on the overall use of materials, identifies areas where efficiency can be improved, and reduces environmental impacts and costs (Huang *et al.* , 2019) . The implementation of MFCA in several industries has been shown to help improve sustainability and reduce production costs, such as in companies in Taiwan (Schmidt, 2015) .

Environmental Management Accounting (EMA) focuses on collecting and analyzing environmental cost data related to waste management. Through EMA, companies can monitor their environmental impact, including the amount of waste generated and the costs associated with waste disposal and treatment (Di Vaio *et al.* , 2023) . Environmental accounting, as outlined in Emission Accounting Methods, helps companies measure the emissions generated from waste management processes. This includes calculating greenhouse gas emissions, carbon footprints, and the environmental impact of waste generated. (Gaur *et al.,* 2020) . This data allows companies to monitor how effectively they are reducing emissions and meeting emission standards set by national or international regulations.

Material Flow Cost Accounting (MFCA) approach focuses on measuring the flow of materials in the production process, including waste. MFCA can help companies identify areas where resources are wasted and reduce costs by increasing efficiency. With this approach, waste is not only measured but also analyzed from an economic perspective to determine hidden costs that are often invisible (Huang *et al.* , 2019). An Accounting Information System for Waste Management using data from environmental accounting, companies can create more effective waste management strategies. For example, waste can be categorized and managed specifically according to its type, such as solid, liquid, or hazardous waste, to minimize environmental impacts (Chen *et al.* , 2020) . Use of Technology and Digitalization: Accounting is now increasingly utilizing digital technologies, such as blockchain and big data, to monitor and report waste flows and manage more transparent and sustainable supply chains (Latifah and Soewarno, 2023) .

Sustainability Reporting: This reporting is important to demonstrate compliance with environmental regulations and promote transparency (Chisholm *et al.* , 2021) . Reporting standards such as the Global Reporting Initiative (GRI) and ISO 14001 encourage companies to report on resource use and waste management (Gaur *et al.* ,

2020) . Regulatory Compliance: Accounting ensures that companies comply with local and international regulations, such as greenhouse gas (GHG) emissions regulations and laws related to hazardous waste management. Accurate reporting helps reduce the risk of fines or sanctions (Maalouf and El-Fadel, 2018) . Sustainability and Environmental Reporting using Environmental Management Accounting (EMA), helps companies identify and report environmental costs, including costs associated with waste management. EMA allows companies to track resource use and record the financial impact of waste generated. Accounting also plays a role in encouraging companies to reduce greenhouse gas emissions and waste by recording the use of materials such as biomass that can reduce emissions in the waste management and industrial sectors (Spišáková, Mésároš and Mandičák, 2021) .

In some cases, digitalized accounting systems and reporting automation are used to manage waste data and provide real-time information to support better decision-making. This improves the efficiency of waste management in the industry (Verma *et al.* , 2020) . Accounting plays a vital role in supporting the Circular Economy Transition by monitoring the flow of recycled materials and the management of reusable raw materials. This data is used to support sustainability policies and the circular economy that focus on optimal resource reuse (Jatnika and Siregar, 2023) . Thus, through structured financial management and reporting, accounting helps improve transparency, efficiency, and sustainability in industrial waste management.

SYSTEMATIC METHODOLOGY (SLS)

1. Research Approach

This study uses the literature review method. Literature review study is a method used by researchers to collect data or find out sources related to this topic that can be obtained from various sources such as journals, books, the internet, and other sources. Literature review is a systematic, explicit and reproducible method for identifying, evaluating and synthesizing research works and ideas that have been produced by researchers and aims to make an analysis and synthesis of existing knowledge related to the topic to be

examined to find empty space for the research to be carried out (Yulianti et al., 2023).

2. Research Object

Data is taken from journal databases such as Scopus, Google Scholar and Sinta. Data retrieval from these databases is representative because the database contains many journals, and the majority are in the database. Data sources are only articles. Books, proceedings, notes, and others are not included in the search. After obtaining the article, the article is re-identified based on predetermined criteria (Anggraeni, 2023) .

3. Data Types and Sources

In the search for articles that will be used as data for this review using relevant keywords for analysis (Mohamed Shaffril, Samsuddin and Abu Samah, 2021) . The search produces different results that sometimes do not match what is specified. Therefore, the search is added with the words "and" / "and" and “or” / "or" / "or" to get search results according to what is specified. The choice of database for SLR studies depends on the purpose and scope of the study. This study uses the Scopus, Scholar and Sinta databases to search for published research on Application of Material Flow Cost Accounting (MFCA) in reducing and managing industrial waste, using the following keywords: "Material Flow Cost Accounting" or "waste management" or "environmental accounting"

After entering the keywords, articles will be selected whose titles match the specified topic. The articles that will be used in this review are articles published between 2015 and 2024.

ELECTRONIC DATA SOURCE TABLE

DATA SOURCE	URL
Google Scholar	**https://scholar.google.com/**
Science Direct	**http://www.sciencedirect.com/**
Scopus	**https://www.scopus.com/**
Springer	**http://www.springer.com/**
Taylor & Francis	**http://taylorandfrancis.com/**
Wiley Online Library	**http://onlinelibrary.wiley.com/**

Sinta	**http://sinta.kemendikbud.go.id/**

4. Research Stage

This study follows a series of steps to provide a systemic, transparent and scalable methodology as conducted by (Santisteban and Mauricio, 2017) , namely:

1. Review planning: in this phase, the research question is outlined and the search protocol is established.
2. Review development: in this phase, the established protocol is applied and primary articles are obtained according to the established criteria.
3. Review results: in this phase, we present the search results and analysis of the selected studies. This analysis will be explained in the Analysis section.

5. Data collection technique

During the data collection stage, several steps will be taken, namely sorting articles based on title, abstract and overall content of the article.

6. Data Validity Techniques

In ensuring the validity of the data, researchers use Triangulation Techniques. Triangulation is an important technique to ensure the validity of data in qualitative studies. In the context of this study, it is done by comparing and confirming information obtained from several sources of relevant literature articles. This aims to ensure the consistency and accuracy of the data obtained.

In addition, researchers triangulate data sources by collecting articles from various reputable journal databases, such as Scopus, Google Scholar, and Sinta. In order to meet the confirmability criteria, researchers ensure that the findings are supported by the data collected, not by the researcher's preferences or motivations.

7. Data Analysis Techniques

The analysis conducted is a demographic analysis, in which this analysis is used to map the country of origin of the studies reviewed. The analysis begins by conducting a systematic review of relevant literature. At this stage, researchers will collect and select journal articles that match the established criteria, such as the year of publication, keywords, and related topics. Material Flow Cost Accounting (MFCA).

The article selection process will be carried out carefully to ensure that the data used is of good quality and relevance.

After collecting the data, the researcher will identify and classify the various themes, concepts, and patterns that emerge from the literature. The researcher will read and carefully examine the contents of each article, then code and categorize to find the common thread between the findings.

Next, the researcher will integrate and interpret the findings obtained from various articles, so as to produce a comprehensive understanding of the application of Material Flow Cost Accounting (MFCA) in reducing and managing industrial waste, the models and technologies that have been applied, their effectiveness in reducing poverty, and the challenges and opportunities identified. To strengthen the analysis, the researcher will also compare and contrast the existing articles. This will help the researcher to identify similarities, differences, and trends that occur in literature. This technique is also useful for exploring more deeply the factors that influence the adoption and application of Material Flow Cost Accounting (MFCA) in reducing and managing industrial waste. The entire data analysis process will be documented in detail, including notes, memos, and justifications for each decision taken. This aims to increase transparency and the ability of the research to be replicated in the future. Finally, the results of the analysis will be synthesized and presented in the form of a comprehensive discussion, which can provide theoretical and practical contributions in the development of the application of Material Flow Cost Accounting (MFCA) in reducing and managing industrial waste that is more effective and has an impact on reducing poverty.

RESULTS AND DISCUSSION

ACCOUNTING FOR WASTE MANAGEMENT: CONCEPTS AND DEFINITIONS

Accounting concepts related to waste management include the measurement, reporting, and management of costs required to manage industrial waste effectively. Measurement in this context involves identifying and assessing the quantity and type of waste generated, which can serve as a basis for calculating management costs (Safitri and Sari, 2022) . Accounting reporting related to waste aims to provide transparent

information on the environmental impacts of industrial activities, including costs incurred for waste management, recovery, and recycling (Reno, 2015) . In addition, cost management related to waste management includes controlling operational costs and investing in more environmentally friendly technologies (Anis, Sabijono and Walandouw, 2020) . By applying accounting principles in waste management, companies can increase efficiency, reduce environmental impacts, and comply with applicable regulations.

The relationship between accounting and waste management is essential in supporting efficient management strategies. Accounting plays a role in identifying costs associated with reducing, recycling, and managing hazardous waste. Through accurate measurement, companies can monitor spending on recycling programs and waste reduction initiatives, allowing them to better allocate resources (Safitri and Sari, 2022) . In addition, transparent reporting on waste generated and its management costs helps companies meet regulatory obligations and increase public accountability (Reno, 2015) . Thus, accounting not only serves as a cost control tool, but also as a basis for strategic decision-making that supports sustainability and efficiency in waste management.

WASTE REPORTING APPROACHES IN ACCOUNTING

Waste reporting in sustainability reports is an important element that demonstrates a company's commitment to environmental responsibility. In this context, companies must describe how they manage the waste they produce, including waste reduction, recycling and processing strategies. Commonly used reporting standards are the Global Reporting Initiative (GRI) and ISO 14001. (Adams and Abhayawansa, 2022) . GRI provides a comprehensive framework for companies to report their environmental impacts, including waste management. Meanwhile, ISO 14001 provides guidance on environmental management systems that help companies identify and manage the environmental impacts of their operations. By following these standards, companies not only increase transparency but also build trust with stakeholders (Ferramosca, 2019) .

Disclosure and transparency in waste management are essential to ensure environmental accountability and sustainability. Clear reporting on resource use and waste generation allows stakeholders to understand the impact of an organization’s operations. With transparency, companies can demonstrate effective waste management

strategies, such as recycling and waste reduction, which aim to minimize negative impacts on the environment. This also helps in complying with applicable environmental regulations and strengthens the company's reputation in the eyes of the public. For example, research at RSU GMIM Kalooran Amurang showed that although the waste management process was good, there were still shortcomings in the disclosure of cost elements related to waste management (Moses C. Liando, Victorina Z. Tirayoh, and Lady D. Latjandu, 2023) .

Challenges in waste reporting often become a barrier for companies in achieving transparency and accountability. One of the main difficulties is measuring and reporting waste data accurately. Many companies face data uncertainty due to the lack of an integrated system to collect and analyze waste information (Singh *et al.* , 2014) . The complexity of the supply chain also contributes to this problem, where waste can be generated from multiple sources and processes, making it difficult to track the origin and volume of waste. In addition, different regulations in different regions can make it difficult for companies to ensure that their reports meet all applicable requirements. As a result, companies may not fully understand the environmental impact of their operations, which can hinder efforts to reduce waste and improve sustainability. In the context of RSU GMIM Kalooran Amurang, this challenge is seen in the lack of disclosure of cost elements related to waste management, which can interfere with data-driven decision making (Cintia Wulandari, Alwan Sri Kustono, and Norita Citra Yuliarti, 2021) .

WASTE MANAGEMENT IN THE SUPPLY CHAIN

Accounting plays a crucial role in helping companies track waste generated throughout the supply chain. By implementing an effective accounting system, companies can identify, measure, and report all types of waste generated, both upstream and downstream. Good waste management practices upstream, such as reduction and recycling, can reduce the amount of waste generated, thereby affecting operational costs and increasing efficiency (Vološinová *et al.* , 2023) . Downstream, effective waste management not only supports compliance with environmental regulations but also improves the company's image in the eyes of stakeholders. In addition, transparent sustainability reporting reflects a company's social responsibility, which can have a

positive impact on its reputation and competitiveness in the market. Through an integrated accounting strategy in waste management, companies can achieve better sustainability and increase long-term value (Umaini and Arimurti, 2024) .

Effective waste management requires a comprehensive accounting approach to monitor waste impacts throughout the product life cycle, from raw material use to final waste management. By implementing environmental accounting, companies can identify and evaluate waste generated at each stage of production, allowing for better reduction and management (Kurnia, Syamsinar and Afdaliah, 2020) . Accounting helps in mapping environmental costs, such as waste treatment costs, which can influence strategic decisions in raw material selection and production processes. In addition, accurate sustainability reporting reflects a company's commitment to environmental preservation and social responsibility (Anggraeni, 2023) . Thus, an integrated accounting approach not only supports operational efficiency but also contributes to sustainability and reducing environmental impacts throughout the product life cycle.

ACCOUNTING FOR WASTE MANAGEMENT COSTS

Measuring waste management costs involves using cost accounting to identify and report the various costs associated with waste management activities, including processing, recycling, and disposal. In this context, processing costs include expenses for labor, materials, and equipment required to process waste into safer or more useful products (Maysaroh and Kusmilawaty, 2023) . Recycling costs include the costs of collection, transportation, and technology used to convert waste into new products, which can help reduce the burden of disposal costs and provide added value (Taleb and Al Farooque, 2021) . In addition, disposal costs include all expenses associated with the disposal of waste that cannot be further processed, such as landfill costs. By analyzing all of these cost components, companies can make more informed and efficient decisions in waste management, as well as optimize existing resources (Kurnia, Syamsinar and Afdaliah, 2020) .

The benefits that can be received from waste management are minimizing the possibility of environmental damage that endangers public health so that the environmental conditions around the community become cleaner. (Anis, Sabijono and

Walandouw, 2020) . By implementing cost accounting analysis, companies can identify and evaluate expenses related to waste management, including energy and material costs. For example, investing in efficient waste treatment technology can reduce the need for energy and raw materials, which in turn results in significant cost savings. In addition, sustainable practices not only reduce environmental impacts but can also improve a company's reputation and attract customers who are more concerned about environmental issues. Thus, cost-benefit analysis provides a clear picture of the economic and strategic value of sustainable waste management, encouraging companies to invest in more efficient and environmentally friendly solutions. (Das *et al.,* 2019) .

REGULATIONS AND STANDARDS IN WASTE MANAGEMENT ACCOUNTING

Waste management in the European Union focuses on the Waste Framework Directive implemented in 2008. This directive establishes a legal framework for waste management and treatment, emphasizing the “polluter pays” principle and extended producer responsibility. This policy encourages member states to develop more sustainable waste management programs, and to increase recycling and waste recovery rates. In addition, regulations from the Environmental Protection Agency (EPA) in the United States also serve as a reference for many countries in formulating waste management policies. The impact of these regulations on accounting practices is seen in the need for more transparent and accurate recording of waste management costs, as well as the financial responsibilities resulting from these policies (Bernhard and Nordmark, 2024) .

Thus, these regulations not only affect the way waste is managed, but also have significant implications for accountability and accounting reporting in the related sector. Regulations related to waste management, such as the EU Landfill Directive (ELD) and policies issued by the Environmental Protection Agency (EPA) in the US, have led to significant changes in waste management practices in the UK, especially in Nottingham. The ELD, implemented in 1999, emphasizes the reduction of biodegradable waste going to landfill, encouraging member states to adopt more sustainable strategies, such as recycling and energy recovery. These policies have not only reduced the volume of waste disposed of, but also increased public awareness and community involvement in waste

separation and management. The impact of these regulations is seen in increasing recycling rates and decreasing the amount of waste going to landfill, which in turn affects accounting practices in resource management and environmental reporting (Wang, Tang, *et al.* , 2020) .

The role of international standards, such as ISO 14001, is crucial in promoting transparency and consistency in waste management reporting. This standard provides a framework for organizations to develop an effective environmental management system, which can assist in managing the environmental impacts of their activities, including waste management. By adopting ISO 14001, companies can ensure that their reporting practices follow internationally recognized guidelines, thereby increasing stakeholder accountability and trust. In addition, the adoption of this standard can help organizations meet institutional pressures that encourage them to be more proactive in their environmental management strategies (Gunarathne, Lee and Hitigala Kaluarachchilage, 2021) . This shows that international standards serve not only as guidelines, but also as vital tools for improving environmental performance and transparent reporting.

CHALLENGES IN WASTE MANAGEMENT ACCOUNTING

Challenges of Industrial Waste Engineering in Society 5.0 The diverse and complex nature of industrial waste presents significant challenges in waste management. Industrial waste can include a variety of materials and by-products generated during manufacturing processes, such as ash, gravel, masonry, concrete, scrap metal, oil, solvents, chemicals, used wood, and even vegetable matter from restaurants. The heterogeneous nature of industrial waste streams makes accurate assessment and effective treatment difficult, and disposal of these wastes to landfills can lead to air, soil, and water pollution, as well as contamination of groundwater, lakes, rivers, streams, and coastal waters (Industrial Waste, 2023).

The challenges in dealing with these heterogeneous waste streams include the need for innovative technologies and resource efficiency to effectively manage and recycle industrial waste. Significant progress has been made in the field of industrial waste recycling, and innovative technologies such as advanced sorting systems, pyrolysis and gasification, anaerobic digestion, composting techniques, waste compaction and resource

efficiency. However, the complexity of industrial waste streams and the variety of materials present ongoing challenges in waste management. The increasing number of contaminants, such as pharmaceuticals, microplastics and other complex pollutants, poses a major challenge in industrial waste management. These contaminants can enter the environment through various sources, including wastewater, which can cause water pollution and subsequently have adverse impacts on human and wildlife health (Richardson & Ternes, 2018). Identification and management of these new and complex pollutants are critical to ensure environmental protection and human health (Rachmat and Susiati, 2024) .

The concept of waste accounting often emphasizes the systematic and harmonized measurement of waste generated, including a breakdown between reusable and non-reusable waste. However, in practice, companies often face challenges in integrating waste accounting into their business operations. These challenges include a lack of representative data, difficulty in obtaining accurate measurements, and differences in terminology used within the industry (Srivastava *et al.* , 2022) . Many companies do not have adequate systems in place to effectively track waste, resulting in a lack of transparency and understanding of the environmental impacts of their operations. In addition, cultural factors and attitudes towards waste management also influence companies' commitment to implementing better accounting practices (Gao and Yang, 2024) . Therefore, despite progress in the development of accounting methodologies, challenges in practical application remain a significant barrier to achieving sustainable waste management in a business context.

Measuring the long-term impacts of industrial waste on the environment and society, the main challenge lies in the complexity of the waste system itself. Accurate measurement is often hampered by data uncertainty, sample representativeness, and diverse methodologies (Eckelman *et al.* , 2014) . Effective waste accounting can help address these challenges by providing a clear framework for measuring and reporting waste, enabling better decision-making. By identifying the most significant waste streams and adapting harmonized methodologies, agencies and policymakers can design more efficient and sustainable interventions to manage the impacts of industrial waste (Corrado

et al. , 2019) . This is essential to achieving sustainable development goals, especially in the context of waste reduction and environmental security enhancement.

BENEFITS OF EFFICIENT WASTE MANAGEMENT FOR COMPANIES

Efficient waste management is key for companies to gain financial and operational benefits. The use of appropriate technology and good management facilities can reduce operational costs associated with improper waste disposal. Recycling, for example, not only reduces the volume of waste but also saves costs by reducing the need for new raw materials. In addition, reducing resource use through efficient waste management practices can result in significant cost savings. Economies of scale also play a role, where larger facilities can lower unit costs, making interactions between local governments in waste management very beneficial (Kojima, 2019) . Furthermore, public-private partnerships in waste management offer opportunities for cost sharing and increased efficiency. Regulations that support better waste management can also encourage investment in environmentally friendly technologies, thereby supporting operational cost reductions (Ahmmed *et al.* , 2023) . Through this approach, companies not only contribute to environmental sustainability but also achieve significant financial benefits.

Proactivity in waste management and transparent reporting are very important strategies. A journal discussing waste management in Bandung City shows that community participation in waste management can increase awareness and knowledge about the benefits of good waste management (Adzawla *et al.* , 2019) . By implementing sustainable waste management practices, companies not only fulfill environmental obligations but also build a positive image in the eyes of stakeholders, including the community and investors. In addition, transparency in waste reporting shows a company's commitment to social and environmental responsibility, which can attract investors who are increasingly concerned about the sustainability and social impact of their investments (Lee *et al.* , 2020) . Thus, companies that implement effective and transparent waste management will be able to improve their reputation and competitiveness in an increasingly competitive global market.

Sustainable Approaches to Industrial Waste Management Circular economy principles can be applied to industrial waste management to promote sustainability and

reduce waste generation (Zhang *et al.* , 2022) . According to Vinod Kumar Garg, 2023 Environmentally friendly processes for waste-generating activities can also be applied to industrial waste management. For example, innovative technologies such as advanced sorting systems, pyrolysis and gasification, anaerobic digestion, and advanced composting techniques are being developed to improve waste management and resource efficiency. In addition, circular economy strategies can be applied to industrial waste management to promote sustainability, reduce waste generation, and contribute to a more sustainable and resilient future. By applying green chemistry principles and alternative environmentally friendly processes to waste-generating activities, industrial waste management can promote sustainability, reduce waste generation, and contribute to a more sustainable and resilient future (Rachmat and Susiati, 2024) .

CASE STUDIES AND BEST PRACTICES IN ACCOUNTING FOR WASTE

Case studies in Australia show how service sectors, such as education and hospitality, generate significant tonnages of waste, reflecting the need for improved waste management practices. Successful waste management companies often employ detailed waste estimation methodologies, allowing them to more accurately identify the sources and types of waste. By leveraging available accounting data, companies can implement efficient strategies to reduce waste, while improving operational sustainability. The benefits of improved waste management not only include cost reductions and increased efficiency, but also create a positive image in the eyes of the public and stakeholders and support environmental sustainability goals. (Reynolds *et al.* , 2016) .

The Value Stream Mapping (VSM) method as a management tool that supports the identification and evaluation of industrial waste streams, with a focus on a case study in the iron and steel industry in South Africa. The study shows how VSM can help a company reduce waste by up to 28% and reduce waste disposal costs by up to 45% in the first year of implementation. This successful example illustrates an innovative accounting practice, where companies can visualize and analyze waste streams, identify opportunities for efficiency, and achieve zero-waste goals. The benefits derived from better waste management include cost savings, increased operational efficiency, and positive contributions to environmental sustainability, which in turn supports the company's goal

of maintaining competitiveness in an increasingly competitive industrial market (Schoeman, Oberholster and Somerset, 2020) .

Construction and decomposition waste (CDW) management was identified through a pre-demolition waste audit conducted on a shopping mall renovation project in Slovakia. The audit demonstrated the importance of systematic waste segregation and management to increase waste recovery rates, which is in line with the European Union directive to achieve 70% recycling of construction waste. One of the best practices implemented was the use of efficient recycling technologies, such as concrete crushing and wood waste processing, which not only reduce waste volume but also provide alternative materials that can be reused in construction. In addition, waste reduction strategies were adopted, including better design planning to minimize waste from the start and implementing a producer responsibility system in construction material management. Thus, innovation in technology and a proactive approach to waste reporting and management are key to achieving sustainable and environmentally friendly waste management (Spišáková, Mésároš and Mandičák, 2021) .

One of the best practices is the use of accurate waste estimation methodologies, which allow companies to analyze in detail the types and sources of waste generated. Innovations in recycling technologies are also highlighted, with companies adopting more efficient and environmentally friendly recycling processes, thereby reducing the volume of waste generated. In addition, waste reduction strategies, such as the implementation of circular economy principles, are increasingly being implemented. (Wang, He, *et al.* , 2020) . Companies strive to redesign products and production processes to minimize waste, and reuse existing materials. By implementing these practices, companies not only improve operational efficiency but also contribute to environmental sustainability, which in turn can improve their reputation and competitiveness in the market (Jiao *et al.* , 2023) . The use of input-output (IO) models in waste management analysis highlights the importance of accurate modeling to support best practices in waste management. By analyzing 78 case studies, the authors identified that the WIO (Waste Input-Output) and WEIO (Waste Extended Input-Output) models were the most widely applied. Best practices implemented by companies include transparent reporting of waste flows, the application of innovative recycling technologies, and efficient waste reduction strategies.

They also emphasize the need for better data collection and development of monitoring methods to improve the effectiveness of waste management policies, ultimately supporting the transition to a circular economy (Towa, Zeller and Achten, 2020) .

RECOMMENDATIONS FOR THE FUTURE

Developing better waste reporting standards is essential to improve consistency and transparency in industrial waste management across sectors. Recommendations for developing these standards include adopting frameworks that integrate best practices from across industries, such as the use of international standards such as ISO 14001 and the Global Reporting Initiative (GRI), which can help companies accurately identify, measure, and report the environmental impacts of their operations. In addition, it is important to create guidelines that take into account different types of waste and their management processes, and to encourage the adoption of digital technologies to facilitate more efficient and real-time reporting. In this way, developing more consistent standards can help companies meet environmental regulations, improve public accountability, and more effectively support sustainability goals.

Accounting for waste management needs to focus on several areas that are still underexplored. First, new methods for waste measurement, such as the application of sensor technology and the Internet of Things (IoT), can improve the accuracy and efficiency of tracking waste flows in real time. In addition, research can explore the use of big data analytics to analyze waste patterns and identify better reduction opportunities. Second, it is important to develop frameworks that assess the long-term impacts of waste on the environment and public health, including methods to account for external costs that are not measured in traditional accounting. Finally, studies on the integration of circular economy strategies into accounting practices can provide new insights into how companies can maximize the value of waste and reduce its negative impacts, thereby supporting sustainability more comprehensively.

Companies need to promote the integration of efficient waste management into their sustainability strategies to achieve long-term sustainability. First, companies can conduct comprehensive waste audits to identify the sources and types of waste generated, thereby formulating more effective reduction strategies. Second, the adoption of circular

economy principles should be an integral part of the business model, where waste is viewed as a resource that can be recycled or reused, rather than simply as a burden. Third, companies should adopt innovative technologies, such as IoT-based monitoring systems and data analytics, to improve waste management efficiency and minimize environmental impact. In addition, engaging stakeholders in open dialogue about waste management practices can increase transparency and accountability. Finally, it is important to set clear and measurable sustainability goals related to waste management, and regularly report on progress, so that companies can continuously adapt and improve their strategies over time.

CONCLUSION

The application of Material Flow Cost Accounting (MFCA) in industrial waste management provides an effective solution to reduce the negative impact of waste on the environment. MFCA helps companies identify areas where efficiency can be improved and reduce costs associated with waste management. With the increasing awareness of the importance of sustainability, companies are expected to shift from focusing on short-term profits to long-term sustainable strategies. In addition, environmental accounting and sustainability reporting play a vital role in increasing transparency and accountability of companies for their environmental impact. Through the application of technology and digitalization in accounting, companies can monitor and report waste flows more effectively.

However, challenges in waste management remain, including difficulties in accurate measurement and reporting, as well as the need to comply with increasingly stringent regulations. To achieve sustainability goals, companies need to continue to innovate and improve their waste management practices, including the adoption of circular economy principles. In doing so, effective waste management not only benefits the environment but also improves operational efficiency and a company's reputation in an increasingly competitive market.

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