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# Management of battery waste recycling by electric motorbike workshops: A literature review

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**ABSTRACT**

Battery waste needs to be managed immediately and thus electric vehicles (EVs) become more popular as a sustainable replacement for internal combustion engine vehicles. This review discusses waste battery recycling industry practices and emphasizes the need for authorized battery management services for electric motorcycles. This gap allows third-party businesses not affiliated with the primary manufacturer to emerge and potentially grow sustainably. The literature review methodology involves an in-depth search of relevant literature using the Scopus database with strategically selected keywords. The VoS Viewer collects, organizes, and graphically maps references to synthesize them orderly. The search initially yielded 138 relevant articles. This number was then narrowed to 66 articles published in English journals. Thirty-nine articles were found when the search was modified to focus on full-text availability. These findings indicate an important need for more targeted research to design effective management frameworks for recycling waste batteries in electric motorbike workshops. All critical components increased waste management awareness and expertise among workshop managers, government policies, funding support, and a well-coordinated supply chain. This assessment identifies barriers to developing a viable battery waste recycling sector and makes recommendations for future policy and research initiatives.

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## 1. INTRODUCTION

Government regulations (Presidential Regulation Number 55 of 2019) regarding the Acceleration of the Battery Electric Motor Vehicle (BEV) Program show that migration to electric motorbikes (EM) is urgent to reduce air pollution and prevent climate change [1]. Various efforts have been undertaken, including subsidies for the purchase of EMs and conversion from conventional motorbikes to EMs. Subsidies are offered to the user community, conversion service providers, and electric charging station power providers. However, the adoption rate for EMs in Indonesia still needs to be higher. According to Yuniaristanto [2], only around 45.63% of respondents have a strong desire to purchase EM.

Some research results from Yuniaristanto et al. [2] stated that social influence is a significant factor influencing the intention to purchase an EM. People are more likely to accept and use new technology that is popular and widely used in their social environment. An analysis of the socio-demographic factors of age, education level, monthly income, and environmental awareness found that a lack of public knowledge about EM and conventional motorbikes caused the low adoption rate of EM [3].

The application process hampers the electric motor conversion program as a conversion workshop, which is not easy [4]. There need to be standards for the form, components, and power required, which must be reliable and safe. The government recognizes that this is due to insufficient human resources. Another obstacle is that people see conversion programs as requiring very high costs [5]. Public workshops must prepare for the automotive electrification process [6]. They need to upgrade existing knowledge and resources to handle electric vehicle maintenance. Electric vehicle maintenance does not require changing oil, gaskets, fuel filters, etc. Yet, it requires the ability to check the battery's condition and repair as well as replace damaged battery cells.

The total sales of EMs up to October 2023 have only reached 20% of the sales target. Evaluation and anticipation strategies for several factors inhibiting sales provide a spirit of optimism for the success of the shift from combustion motorbikes to electric vehicles in 2030 [7].

Like gasoline in combustion motor vehicles, batteries are important in electric vehicles. The batteries currently widely used in EMs are from Chinese manufacturers and have a service life of 3–4 years [8]. Optimism about EM sales in 2023 will impact optimism about increasing batteries that can no longer be used as traction batteries – in other words, it could be called battery waste.

Referring to Ministry of the Environment Regulation Number 1 of 2021, manufacturers are asked to be responsible for product waste after the it useful life ends. Management of product waste can be undertaken by making the recycling process more effective. Recycling is collecting and processing materials that would otherwise be discarded as waste and turning them into new products [9]. Solid waste management strategies include reduction, reuse, and recycling activities [10]. Only now has the manufacturer implemented the recycling concept. Third parties outside the main manufacturers and waste collectors will be involved in this case.

The literature review highlights a significant research gap in the absence of a detailed management framework for recycling battery waste in electric motorbike workshops. This gap is crucial due to the rapid increase in electric vehicle adoption and the subsequent rise in battery waste that is not being adequately managed. The research shows that although there are some management models available, they are not adequately designed to meet the specific needs of motorbike workshops, which is a key area for further research. This highlights the need for further investigation. The research aims to systematically explore and establish the foundational steps required for third-party businesses to become sustainable enterprises focusing on recycling battery waste. Furthermore, it also aims to provide a structured approach to understanding existing practices and identifying crucial areas that lack sufficient coverage through methodical analysis of selected literature and comprehensive data mapping.

This research highlights the importance of enhancing workshop managers' awareness and knowledge of environmental management, supported by robust funding, policy backing, and supply chain logistics. The aim is to improve sustainability and operational efficiency in the developing field of electric vehicle maintenance and repair. The paper not only fills a vital academic gap by outlining potential pathways for future research but also contributes practical solutions.

## 2. MATERIALS AND METHODS

This systematic review article uses the approach [11] which consists of three stages (Figure 1): planning the review, conducting the review, and reporting the review.

### *2.1. Planning*

This review was carried out to find answers to several problems in the introduction. Although intended initially to anticipate the availability of non-renewable fuel oil and playing a major role in the impact of greenhouse gas emissions, Ems still require much study. The sales target for EMs and conversion of EMs has yet to be achieved; there are no manufacturers who practice reverse logistics; in this case, the practice of

recycling, third parties have the opportunity but need help with human resources and facilities. As the main component of EMs, batteries will become waste in the next 3 - 4 years. Thus, it is necessary to study the appropriate handling of third parties outside the main manufacturer.


**Figure 1**. Kitchenham Approach

2.1.2. Determining the steps for literature study:

1) Search for EM battery waste management referring to any waste, so the first keyword is "waste." The battery supply chain will be traced to an open supply chain considering third parties. Searches will be limited to third parties, in this case, EM repair workshops; the keywords chosen are "small, medium enterprise." This study's hoped-for contribution is finding a framework for extending battery life rather than immediately becoming waste. Extending the service life means managing the supply chain in reverse, and the treatment that can be done is recycling. Therefore, the keyword "recycling" was used in this search. Table 1 displays writing search keywords.

**Table 1**. Research Keyword

| Rule | Topic | Keywords |
|---|---|---|
| 1 | waste | "waste" |
| 2 | small medium enterprise | "small" AND "medium" AND "enterprise" |
| 3 | recycling | "recycling" |

2) Use the Scopus database, limited to 2014 - 2024. It will also be limited to the subject areas "Engineering, Energy, Business, Management and Accounting, Decision Science, Social Science, Material Science, Psychology, Multidisciplinary". The articles searched were "in the form of journals" and "in English."
3) Analyze the search records to see the collection of articles that have been obtained.
4) Download full articles of all articles obtained in the search record.
5) Analyze all articles to find out how previous studies help frame and work to extend a product's life.

*2.2. Conducting*

It consists of several steps, such as:

1. Identification of research (Searching). This review article aims to find as many primary studies as possible related to the research question using a systematic search strategy.
2. Selection of primary studies (Screening). Once potentially relevant primary studies have been obtained, they need to be assessed for their actual relevance.
3. Study quality assessment (Synthesis). In search steps one to three because it is carried out in the Scopus database, the selection process is carried out by the search engine.
4. Data synthesis. The data synthesis stage is summarizing the results, interpreting the articles, and analyzing the research linkage's heterogeneity for each article.
   - Identify the main themes, typology of waste and recycling processes as well as the business management framework in small and medium enterprises
   - conceptual business model and categorization possibilities
   - identify examples of practice: waste management on small and medium enterprises

*2.3 Reporting*

The objective of this step is to ensure that every step, from the initial planning phase onwards, is completely documented. It is essential to provide a detailed account of all the processes involved in the execution of the tasks. Finally, the compiled information should be presented in a comprehensive and complete report.

## 3. RESULTS

### *3.1. Data Collection*

As a result of identifying articles by searching using keywords, as in Table 1, a total of 138 articles were obtained (Figure 2 and Figure 3) and then 85 articles were obtained in the second search step. At this stage, the first stage's search results were selected as articles in journals and in English. After that, selection is made based on subject areas: engineering, business, management and accounting, decision sciences, social sciences, material sciences, psychology, and multidisciplinary. In this third stage, 66 articles were obtained, and the results of this third stage were then pulled from the Scopus database in the form of a database (csv) and full articles (pdf). These data are the main data in this systematic review article.

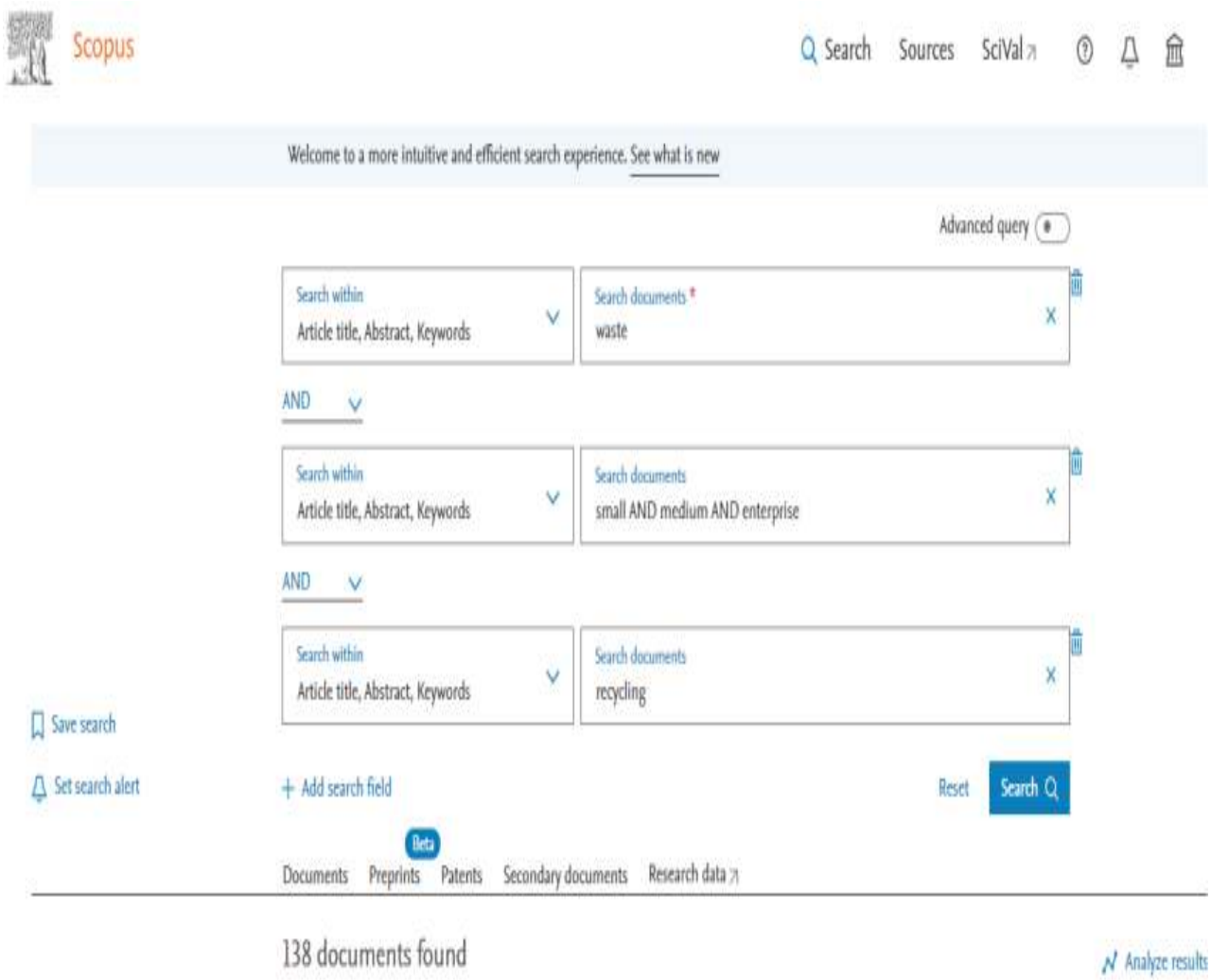


**Figure 2**. Search display using three keywords

Figure 4 is a summary of the article selection process from planning to obtaining full articles. There were only 28 full articles that can be downloaded. The next stage is to carry out the process of reading, extracting, and synthesizing all the full articles.

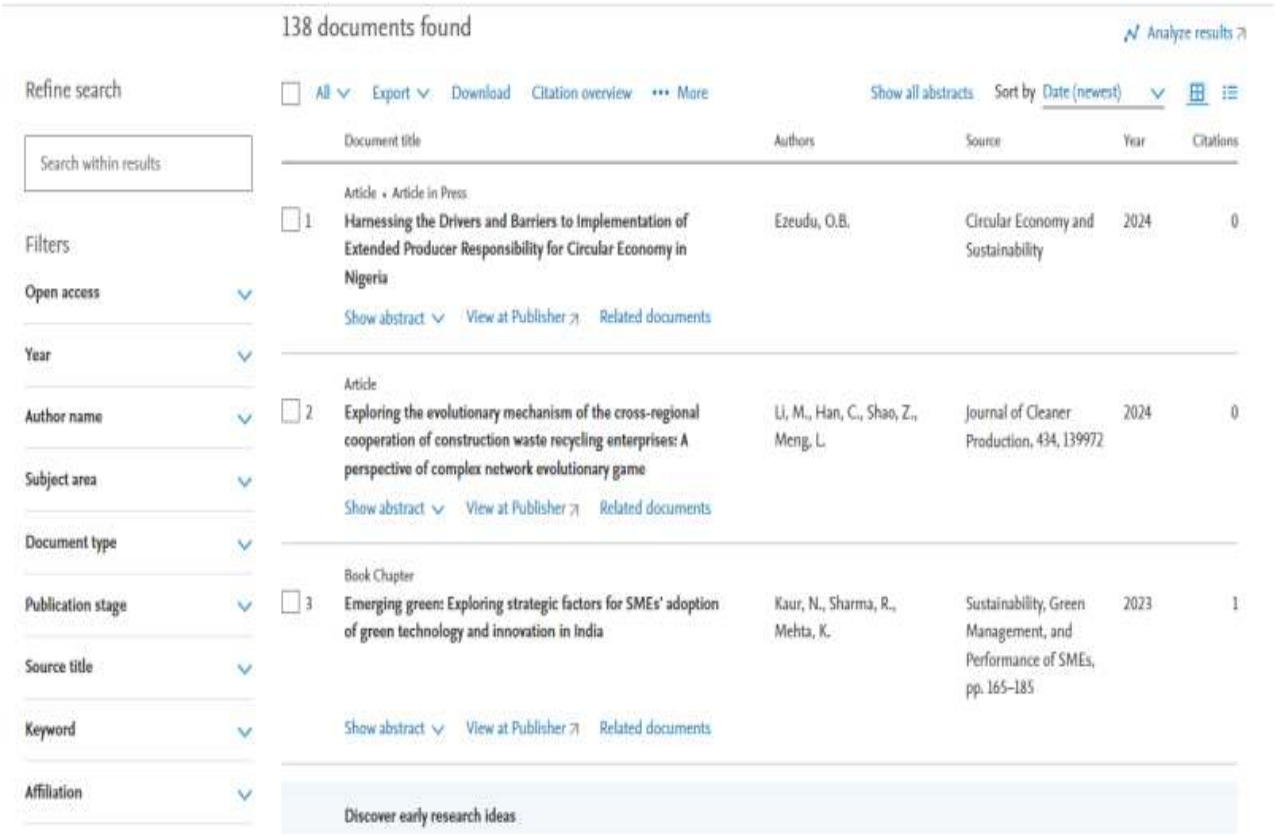


**Figure 3**. Scopus search engine home page display

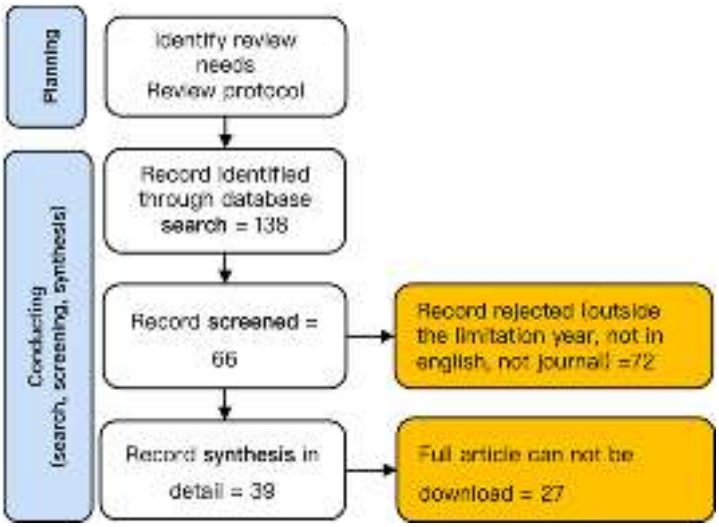


**Figure 4**. Selection Process

*3.2. Conducted: Identifying the main themes, waste typology, and recycling processes in SME*

Searching for screened records is assisted by Vos Viewer, a software that can be used to visualize publication data. Figure 5 shows mapping results using Vos Viewer on 66 article data. The word "recycling" is the most frequently mentioned in the list of articles, followed by "small, medium enterprise" and "waste management," as can be seen from the size of the circle in the image. The yellow indicates that there are few research networks related to that word. The author raises problems related to EV batteries, which apparently have not appeared in the mapping results. A word close to EV batteries, especially related to the hazardous waste group, is "electronic waste." The group of keywords obtained is shown in Figure 6. Management of

"electronic waste" in SMEs will mainly be related to "energy use," "supply chain management," "circular economy," "life cycle assessment," and "sustainability."

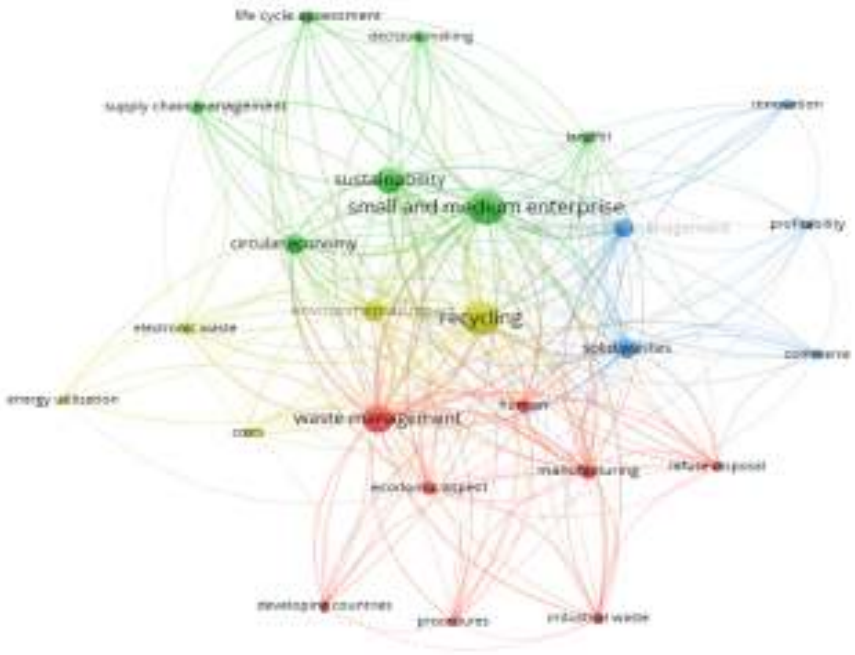


**Figure 5**. Keyword mapping display using Vos Viewer

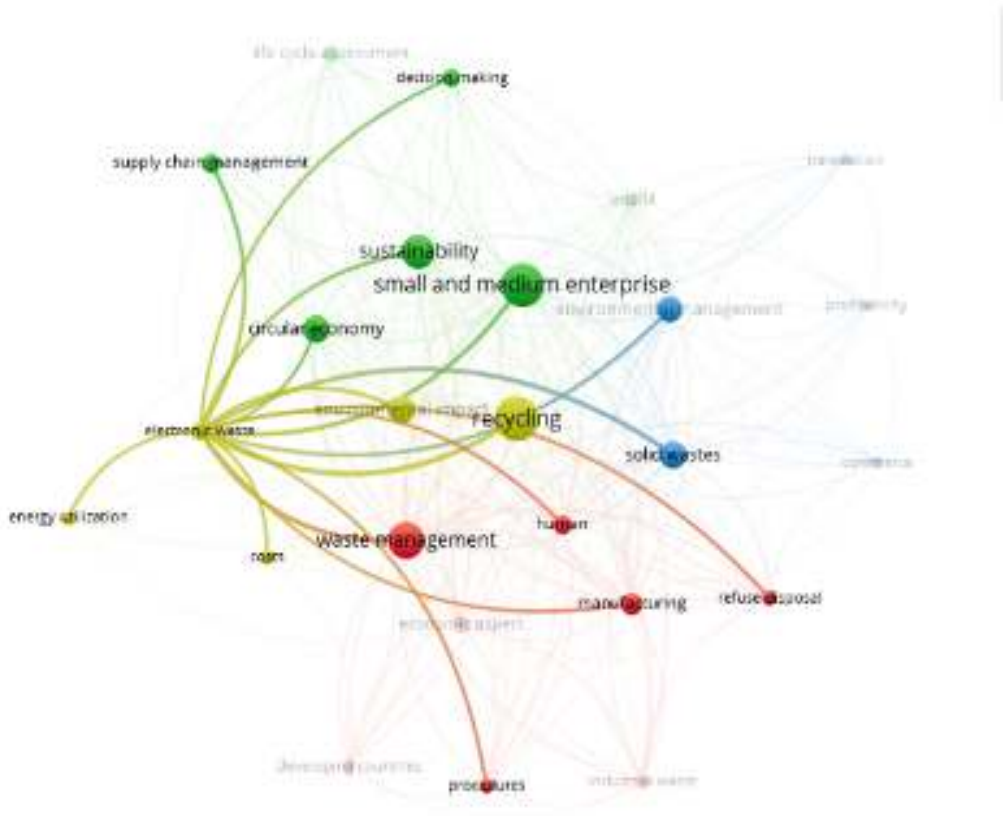


**Figure 6**. Mapping display for the keyword "electronic waste"

To map the novelty of the series of keywords, it was analyzed based on the publication of several articles by year. Figure 7 is a map of the keyword "electronic waste" against the year of publication. Research

related to "electronic waste," "supply chain management," and "circular economy" are topics that are still relatively new and very open to research.

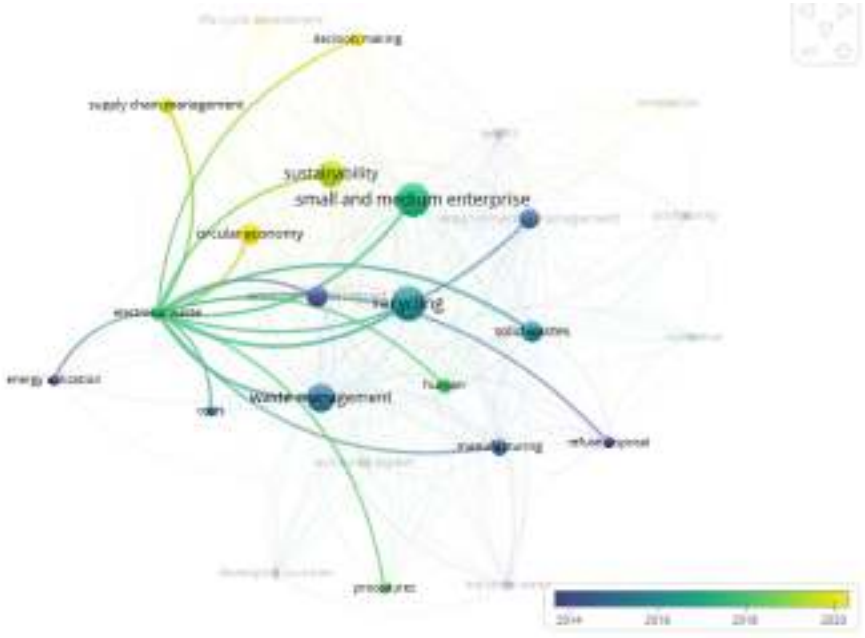


**Figure 7**. Mapping display of the keyword "electronic waste" based on year of publication

The screened records obtained are in accordance with the expected keywords, especially regarding small and medium businesses that consider environmental impacts. Based on the help of analysis from the VoS viewer, the grouping can be divided into six clusters as seen in Figure 8. The groupings that are close to the problems and phenomena of this article are Cluster 1 or Cluster 2.


**Figure 8**. Cluster results from VoS viewer mapping

*3.3. Conducted: Literature review for SMEs as outside parties from main manufacturers in managing waste, conceptual business models, and possible categorization*

In general, the abstracts of the 66 articles (record screened) are research from SME objects. All articles were the result of research between 2014 - 2024. Research related to SMEs began to develop in 2020. This research was carried out in almost all countries in this hemisphere. For example, the European continent,

comprising countries such as England, Romania, France, Czechia, Poland, Serbia, Torino, and CEI Europe; the Australian continent; the American continent, comprising countries such as Brazil, New York, Mexico, and Columbia; the Asian continent, comprising countries such as India, Bangladesh, South Korea, Myanmar, Indonesia, Malaysia, and Taiwan; the Mediterranean, Turkey, Nairobi, Kenya, Ethiopia, South Africa, and Nigeria. Some of the waste discussed in the screened record is SME construction waste, which is very diverse since it is related to construction waste, more specifically concrete, metal from industry, electric vehicles, electronic waste, including copper from electrical equipment, copper from pickling electronic component circuit boards, waste pens, clothing industry, fluorescent lamp mercury, horticulture, household waste, HDPE plastic, stale bread, and even human feces or feces. The management carried out on this waste also varies, such as implementing reduce, reuse, and recycle practices as well as improving management methods, yet more practices recycle them into basic materials again. Forty-four articles do not focus on waste management but rather on minimizing waste during the production process, evaluating potential environmental impacts, using recycled materials, evaluating circular economy practices, or evaluating the implementation of waste management.

According to several researchers, waste management is management that first analyzes the product life cycle. The product life cycle will consider starting with the material, the process of converting the material into a product, and then the distribution of the product to users. Once declared unusable, an end-of-life product collection process will be carried out. Management will be carried out after EoL is collected. The possible management treatment is recycling, which is then developed from 3R, 6R, and finally 9R [12-13]. Several researchers realize that, waste can become a potential resource and have economic value if managed well.

Several researchers started from the concepts of several researchers, such as Strasser et al. [14] who questioned where the goods we consume should be thrown away. Human recycling has been around since ancient times. Although the first recorded paper recycling occurred in 1031 in Japan, ancient cultures commonly reused everyday items long before this – mainly due to a lack of resources and long production processes [15]. This concept is the forerunner to the emergence of the circular economy (CE) to sustainable supply chain (CSC). CE is increasingly recognized as an alternative to linear economic models, prioritizing "take-make-dispose" activities. By integrating CE principles into the supply chain, the concept of CSC has emerged, which can increase organizational sustainability and reduce the potential for disruption in the supply chain [16-17].

Departing from an open supply chain that will involve many SMEs, several studies from screened records explore the understanding and intentions of SME managers towards CE [18-21] to make SMEs successful in implementing the CE concept [18, 22, 23]. In general, the factors potential to be successful are internal and external. Internal factors include management awareness, waste management capabilities, employee skills, and technological capabilities. In contrast, external factors include support for laws related to recycling, government policies, the availability of infrastructure and standards, and support for IoT applications.

### *3.4. Synthesis and analyzing the research*

The synthesis results of the 39 articles that can be downloaded are shown in Table 2. It presents that waste management research after 2020 is 72%. This strengthens the results of the VoS viewer mapping (Figure 7), that the development of discussions on waste management has developed rapidly since 2020. There are at least 18 waste subjects in Table 2. The articles not specifically discussing certain waste are as much as 49% and only around 15% discussing electronic waste. Recycling methods used by these researchers are 6R treatment (redesigning, reusing, remanufacturing, recovering, recycling, and reducing), in which recycle treatment using pyrometallurgy and hydrometallurgy, remanufacture treatment, and reuse treatment. From Table 2, there are several models as a framework for sustainable SME recycling management. We present five management models involving SMEs.

Figure 9 is a grouping of 18 waste subjects into five groups, namely e-waste, plastic waste, industrial waste, household waste, and not specifically. We did not find battery waste, which will be the object of our research, in the five groups, but we will include it as an e-waste group. Research on the e-waste group began to be carried out in 2019. Meanwhile, other waste groups are more intensively researched because articles

are published almost every year. Referring to the amount of research that specifically mentions waste objects, research related to e-waste carried out by SMEs is 25%.

**Table 2**. Literature review articles

| No | Authors | Year | Waste | Recycling Method | SME | Resarch goals |
|---|---|---|---|---|---|---|
| 1 | Li et al [28] | 2024 | Not discussing waste specifically | Not specifically discussed | SME | Establishing a complex network evolution game model of cross-regional cooperation of construction waste recycling companies |
| 2 | Berkemeier et al. [29] | 2024 | Not discussing waste specifically | Not specifically discussed | Cosmetic SME | Overcoming the technology gap in the digital technology industry for cosmetic SMEs using the twin transition |
| 3 | Sukri et al. [30] | 2023 | Not discussing waste specifically | Not specifically discussed | SME in Malaysia | Evaluating Malaysian small and medium enterprises (SMEs) implementing green innovation capabilities to maintain their business performance, especially environmentally friendly innovation capabilities for products, processes, organization, marketing and innovation. |
| 4 | Rumambi et al. [12] | 2023 | Construction waste | Recycle | SME | Describing construction waste management activities and their relevance to financial reporting elements from a green accounting perspective |
| 5 | Giridhar & Panicker [13] | 2023 | Pen | Recycle using pyro-hydrometallurgy | SME in India | Investigating the influence of cognitive aspects, namely the presentation of information and materials, on the performance of workers in assembly lines and proposes an economical worker allocation approach based on the findings of the first study considering pen recycling units using NASA-TLX method |
| 6 | Rodrigues & Franco [31] | 2023 | Not discussing waste specifically | Not specifically discussed | 424 SME in South Korea | Empirically testing the influence of entrepreneurial orientation on new product creativity, competitive advantage, and new product performance |
| 7 | Ren & Albrecht [22] | 2023 | Not discussing waste specifically | Not specifically discussed | SME CEI in Europe | Exploring the role of demand-pull and technology-push policy instruments in shaping CEI in Europe |
| 8 | Feil et al. [32] | 2022 | Not discussing waste specifically | Not specifically discussed | 29 SME furniture in Taquari Valley, Brazil | Measuring and analyzing a qualitative-quantitative way sustainability at the organizational level in order to assist management and decision-making processes in micro and small furniture companies in Brazil |
| 9 | Chaudhuri et al. [33] | 2022 | Plastic waste | Recycle into creative products | SME recycling plastics business | Identifying specific resources and capabilities required to deliver value to customers through in-depth interviews |
| 10 | Badraddin et al [34] | 2022 | Concrete | Recycle | SME in Malaysia | Exploring success factors for concrete recycling in construction projects, using Malaysia as a case study |
| 11 | Xie et al [35] | 2022 | Not discussing waste specifically | Not specifically discussed | SME | Building an evolutionary game model to investigate cooperation between manufacturers and e-commerce platforms with government intervention or not |

**Table 2**. Literature review articles (Continued)

| No | Authors | Year | Waste | Recycling Method | SME | Resarch goals |
|---|---|---|---|---|---|---|
| 12 | Benabdallah & Boudour [36] | 2022 | Stale bread waste | Not specifically discussed | SME | Presenting an Internet of Things (IoT) based framework for monitoring and collecting bread waste from recycling bins |
| 13 | Abdullah [37] | 2021 | Material from EoL EVs | Remanufacture and Recycle | SME with recycling business | Carrying out measurements and evaluations of remanufacturing of waste steel sheet (WSS) from ELVs into useful mesh steel sheet (MSS) |
| 14 | Dany H. et al. [38] | 2021 | Plastic HDPE | Recycle HDPE | SME | Looking for an economical alternative way to reduce odors in the recycling process using an experimental design regarding the effect of selected washing temperatures, namely 65°, 75°, 85°, and 95° by which on odor removal from recycled HDPE was further studied |
| 15 | Guevara-Rivera et al. [39] | 2021 | Not discussing waste specifically | Not specifically discussed | SME candy in Mexico | Designing a methodology to build a simulation model of implementing CE strategies in each SME to prove the policy before implemented in the real world, using Netlogo |
| 16 | Ouma et al. [40] | 2021 | Solid and liquid waste from horticultural processing | Not specifically discussed | 31 SME in Nairobi | Finding out the latest knowledge, attitudes, and practices regarding waste management among horticultural processing MSMEs in Kenya |
| 17 | Badraddin et al. [23] | 2021 | Concrete | Recycle concrete | Construction SMEs | Evaluating concrete recycling aimed to highlight the challenges of concrete recycling, which are hampered by the challenges of personal competency, technology, and law |
| 18 | Wu et al [20] | 2021 | Plastic waste | Recycle plastic waste into bricolage collected on a network basis | SME in Taiwan | Investigating the industrialization process Taiwanese SMEs that have succeeded in developing their plastic waste industry into an industrial-level circular economy by utilizing bricolage network-based collectives and adaptive institutional governance frameworks |
| 19 | Sharma et al. [18] | 2021 | Not discussing waste specifically | Not specifically discussed | SMEs are in the process of transitioning from LE to CE | Collecting information on the prospects, barriers, and prerequisites for the LE to CE transition from recent studies |
| 20 | Bagire et al [41] | 2021 | Fecal waste | Recycle feces into bricks | SME | Identifying companies and providing business development support to them while testing the potential to become sustainable desludging companies |
| 21 | Woodard [42] | 2021 | Household waste | Not specifically discussed | 100 SME in England | Identifying the level of waste from SMEs that enters the household stream illegally and measuring waste generated by SMEs and households as a policy maker to force SMEs to be responsible for the waste |
| 22 | Peña-Montoya et al [43] | 2020 | Not discussing waste specifically | Not specifically discussed | SME in Colombia | Building an adapted maturity model to measure the level of maturity of reverse logistics aspects in small and medium enterprises in the Colombian region |

**Table 2**. Literature review articles (Continued)

| No | Authors | Year | Waste | Recycling Method | SME | Resarch goals |
|---|---|---|---|---|---|---|
| 23 | Foschi & Bonoli [44] | 2020 | Not discussing waste specifically | Not specifically discussed | SME in China | Presenting the case of a small-to-medium enterprise applying a decision-making process to rethink frozen food packaging design in line with systemic and life cycle thinking using Eco-design and Life Cycle Assessment (LCA) |
| 24 | Ceptureanu et al [45] | 2020 | Not discussing waste specifically | Not specifically discussed | 397 SME in Rumania | Testing the influence of eco-innovation capabilities on sustainability-driven innovation practices in SMEs using PLS-SEM and SmartPLS software |
| 25 | Tedesco & Montacchini E. [46] | 2020 | Textile waste | Not specifically discussed | SME in Torino | Describing the potential of a life cycle approach for the development of new building products from textile waste |
| 26 | Šebestová & Sroka [47] | 2020 | Not discussing waste specifically | Not specifically discussed | SME in Ceko and Poland | Comparing the concept of sustainable development goals, at Czech and Polish SMEs |
| 27 | Aricat &. and Ling [24] | 2020 | EoL Phoncell | Not specifically discussed | Management of used goods by scavengers in 4 Myanmar cities | Examining the used goods handling/recycling system in Myanmar which has adopted mobile phones in its daily operations |
| 28 | Mandić et al. [48] | 2019 | Electronic waste | Recycle using pyro-hydrometallurgy | SME in Serbia | Finding pyro-hydrometallurgical treatment for metals with low investment thereby making the market competitive regarding the development of innovative, efficient, and selective recycling processes in which continuous growth of e-waste is unavoidable |
| 29 | D'Adamo et al. [49] | 2019 | Waste electrical and electronic equipment | Recycle using hydrometallurgy | SME | Analysis was carried out on three categories of WPCB (low, medium and high level) and 15 categories of electronic waste. |
| 30 | Balakrishnan et al [50] | 2018 | Metals | Reuse becomes diffusion dialysis, acid inhibition, and nanofiltration | SME in Europe | Evaluating acid recovery SME, in which local manufacturing, plant customization, and centralized treatment are likely to encourage the uptake of such technologies in the Indian metal finishing sector |
| 31 | Favi et al [51] | 2018 | Not discussing waste specifically | Not specifically discussed | SME | Exploring the application of green design methodology and the associated software platform (G.EN.ESI–Green ENgineering dESIgn) in the technical department of a manufacturing company |
| 32 | Cuc & Tripa. [26] | 2018 | Waste from the clothing industry | Not specifically discussed | Clothing industry SME | Describing how small and medium enterprises (SMEs) in the clothing industry can achieve competitive advantage by using a sustainable approach |

**Table 2**. Literature review articles (Continued)

| No | Authors | Year | Waste | Recycling Method | SME | Resarch goals |
|---|---|---|---|---|---|---|
| 33 | Abiye et al [52] | 2016 | Scrap iron | Not specifically discussed | SME in Nigeria | Conducting model-based estimates of the atmospheric dispersion of gaseous pollutants (SO2 and NOx) released from a scrap metal recycling plant located in Nigeria |
| 34 | Orthodoxou et.al. [53] | 2015 | Not discussing waste specifically | Not specifically discussed | SME | Anticipating the consequences of acidogenic reactions and low process temperatures through decentralized processing of food waste (FW) with composting in containers by small to medium scale companies by conducted using physical and chemical parameters in the FW composting reactor in operational vessels monitored for 8 weeks |
| 35 | Bi et al. [19] | 2015 | Not discussing waste specifically | 6R | SME | Illustrating the importance of redesign, reuse, remanufacture, recover, recycle, and reduce (6R) towards sustainable manufacturing |
| 36 | Top [54] | 2015 | Not discussing waste specifically | Not specifically discussed | 31 Furniture SME in Gumushane Turkey | Investigating the types of waste and recycling methods applied in micro-scale companies engaged in furniture manufacturing |
| 37 | Redmond et al. [55] | 2014 | Not discussing waste specifically | Not specifically discussed | 404 SME in Australia | Measuring the collective waste volume of 404 SMEs, reconceptualizing SME waste into subcategories, and by measuring landfill volume. |
| 38 | Peng et al. [56] | 2014 | Mercury waste from fluorescent lamps | Not specifically discussed | SME in China | Proposing expansion of funding responsibilities to finance and support SFL recycling systems and discussing in detail the various recycling network systems and funding flows of the two take-back modes |

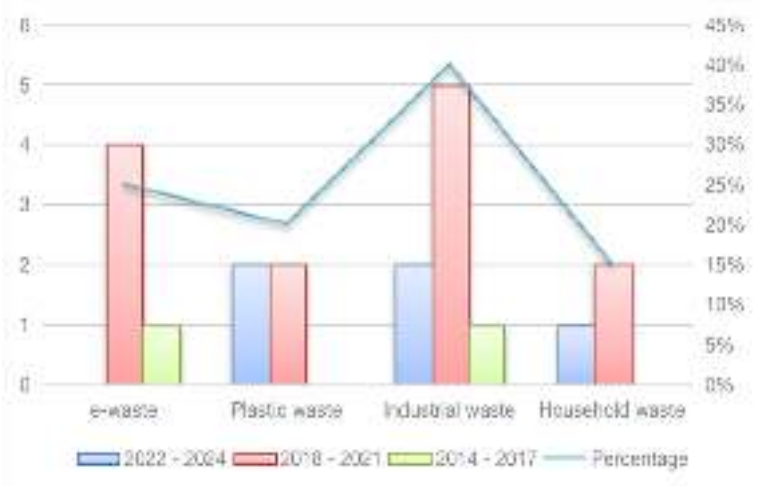


**Figure 9**. Articles based on waste type

Based on the recycling method, we tried to divide it into four groups, as shown in Figure 10. By focusing on articles that carry out recycling, it was found that the recycling method for basic materials ranks highest compared to other recycling methods. The second order is recycling by carrying out reuse treatment,

which is 33%. Meanwhile, the recycling method with remanufacturing for SMEs only found 2 articles. Publications related to recycling methods only started in 2018.

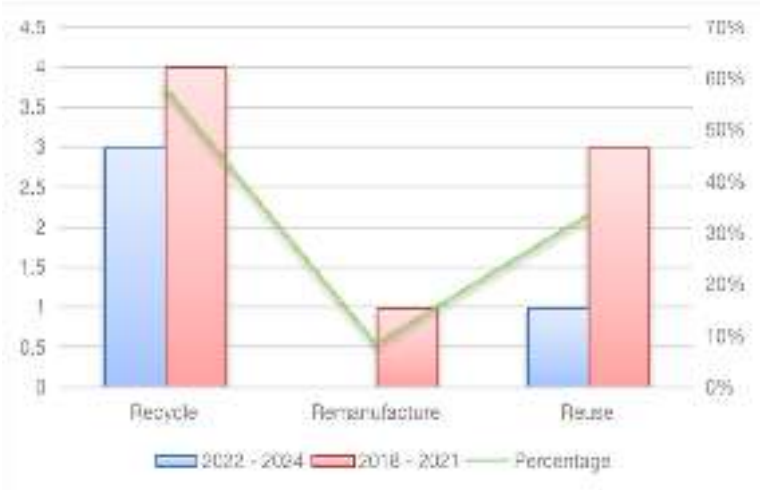


**Figure 10**. Articles based on recycling type

3.4.1 Used goods management in Myanmar [24]

The supply chain of goods used in Myanmar heavily depends on a chain of scavengers and integrators. Several large integrators collaborate with scavengers. Researchers noted that supply chains need clarity on work processes, information, pricing, risk, efficiency, and coordination. Researchers found that the presence of cell phones greatly helped scavengers with work efficiency and large profits. This cellphone will be very helpful for information needs, pricing, and coordination. Nevertheless, the obstacle for scavengers is that not all have and can use cell phones.

3.4.2 Plastic management in Colombia [25]

Researchers propose a maturity model as a framework for SMEs to manage plastic waste in Colombia. This model will accelerate SMEs globally to support sustainable solid waste management in Colombia and ultimately can significantly increase the competitiveness of SMEs in Colombia. This framework uses three aspects (business strategy, strategy and objectives of RL, and sustainability) and eight dimensions (integration of RL in SC strategy, RL management, holistic approach, objectives of RL, alignment with the business objectives, employees and shareholders, infrastructure and equipment, and environmental management).

3.4.3 Fashion management [26]

This research is an effort to reduce waste, and creating new products can be a manageable amount of effort and expenditure in Romania. Then, the researchers proposed the fact that SMEs need to have modern technology by using appropriate software. SMEs need to be encouraged in creative activities by employing fashion designers who can create new and imaginative models with the courage to create different combinations of materials from the recycled ones.

3.4.3 Printed Circuit Board management [27]

Valuable metals from printed circuit boards (PCBs) of electronic devices are gold (Au) and palladium (Pd). However, this PCB also contains dangerous metals, namely lead and copper (Cu). The model proposed by the researchers is an economic model (break-even point, BEP) with parameters to produce maximum gold and palladium and minimize lead and copper. Additionally, BEP analysis provides insight into the minimum content of valuable metals required to achieve a positive net present value (NPV), taking into account three variables: (i) Au price, (ii) Pd price, and (iii) PCB cost. In this case, BEP shows that the content of valuable metals is lower than that of Au and Pd if presenting in amounts of 35–115 ppm.

3.4.4 Management of manufacturing robots [19]

Researchers stated that SMEs are highly motivated to increase the utilization rate of industrial robots through redesign, reuse, recovery, reduction, remanufacture, and recycle (6R) processes. Efficient utilization will potentially impact the sustainability of the SME. Researchers adopted a modular architecture in which industrial robots are treated as core modular components. They used low-cost, specialized parts that can be integrated with the robot to expand its capabilities for various tasks. In such a way, industrial robots can be reused for multiple missions across production lines; utilization rates can be significantly increased to provide economic benefits for SMEs.

## 4. DISCUSSION

Based on the results of a literature review of 66 articles, there are no specific articles as a framework for managing waste or electric vehicle battery waste. Based on the results of a literature review of 66 articles, there is no specific article as a framework for managing waste or electric vehicle battery waste. After searching 39 articles discussing waste management frameworks, only 15% explicitly discussed electronic waste. Based on Figure 9, we believe that research related to battery waste that will be managed by workshops (SME) is new. We also believe that the recycling method which recycles it into basic materials, although very important and has been carried out by many SMEs, has not yet been implemented by SMEs for battery waste (Figure 10).

Some approaches to managing battery waste recycling include battery configuration management models for manufacturing [19]. Meanwhile, several models can be adopted to manage recycling into a business model [21, 24, 30-31, 45]. In general, the five researchers stated that adopting the concept of green, eco, or environmentally friendly is a necessity where the hope of a business is sustainability. Sebastian Ion [45] stated that for a company to produce green performance, SMEs need to increase eco-innovation capability in an effort to achieve sustainability in processes, organizations, and products. Eco-innovation capability is carried out by innovating eco products, eco processes, and eco-organizations; apart from that, it needs to be supported by eco marketing and eco-technology [30]. Margarida [31] reinforces this concept, stating that this eco-business needs care and knowledge from SME managers and needs funding support, skills, networks, and bureaucracy.

Imran Mahmud [21] approached electronics end-of-life phenomena from the perspective of managers of small and medium electronics stores in Bangladesh, using a stimulus-organism-response perspective. The response studied was "recycling intention-RI." The organism factors are "recycling attitude-RA," "subjective norm-SN," "personal norm-PN," and "perceived behavior control-PBC." The stimuli studied were "information publicity" as input for RA and SN, "ascription of responsibility" as input for PN, and "convenience of recycling" as input for PBC. Interestingly, all relationships are significantly positive, except that personal norms and perceived behavior are not significant to RI. Meanwhile, according to [57-58] self-norms and behaviors strongly influence intention, which will then influence recycling behavior [59].

The significance of personal norms and behaviors in the context of waste management for end-of-life electric vehicle batteries within SMEs, particularly repair shops, is an area of inquiry that requires further investigation. Our forthcoming research will explore this subject to determine its relevance and impact on recycling practices. The study aims to create a framework for managing the recycling of end-of-life batteries by workshops as part of an open supply chain. It will focus on the workshops as integral components of the supply chain. Moreover, this exploratory research will attempt to investigate whether personnel attitudes and actions significantly influence waste management practices in these settings, thereby contributing to the industry's environmental sustainability.

## 5. CONCLUSION

Research related to the sustainability of supply chains, particularly in the context of end-of-life products, is an area that requires further exploration. This gap in the literature strongly supports the recommendation for further scholarly investigation, especially concerning the end-of-life management of electric vehicle batteries. Studies are essential to prevent hazardous waste and battery refuse from overwhelming our environment and society. These pose significant risks to ecological stability, natural resources, and public health. Urgent research efforts are necessary to develop effective management strategies that can mitigate these environmental and societal threats.

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