Opsi
Vol. 18, No. 2, December 2025
p-ISSN 1693-2102
e-ISSN 2686-2352

Developing stakeholders in the circular supply chain of EV batteries: Initiate strategy

Iqbal Ramadhan *, Annie Purwani
Ahmad Dahlan University, Southern Ringroad, Kragilan, Tamanan, Bantul Regency, Yogyakarta Special Region 55191, Indonesia

***Corresponding Author**: iqbalramadhan081299@gmail.com

Article history:
Received: 4 October 2025
Revised: 10 December 2025
Accepted: 29 December 2025
Published: 30 December 2025

Keywords:
AHP
Battery recycling
Electric vehicles
Initiate recycling
PESTEL

ABSTRACT
The significant increase in the number of electric vehicles has led to the accumulation of used battery waste. This waste has the potential to pollute the environment, so a solution in the form of battery recycling (repair, refurbishment, reuse) is needed. However, this effort is hampered by the availability of workshops capable of recycling electric batteries. This study aims to identify and analyze the factors that influence repair shops' intentions to recycle electric batteries. These factors were collected through an open questionnaire classified based on the PESTEL framework, then the weight of each factor's importance was determined using the AHP method to formulate the initiation of electric vehicle battery recycling growth. The study prioritized the factors contributing to repair shops' intention to recycle batteries as follows: economic, technological, social, and environmental factors. The order of priority of these factors was then formulated as an initiation strategy: developing technological infrastructure and training, providing green certification, tax breaks and financial support, producer responsibility policies, and building partnerships. This research makes an important contribution to initiating strategies to address electric vehicle battery waste through a systematic approach in Indonesia.

DOI:
https://doi.org/10.31315/opsi.v18i2.15631

1. INTRODUCTION

Indonesia is currently committed to achieving Net Zero Emissions (NZE) by 2060 [1]. Fossil fuel vehicles are the largest contributors to emissions in Indonesia, as the number of vehicles has surged by 30% to 70% [2]. This requires a shift from the use of fossil fuels to the use of new and renewable energy sources.

The Indonesian government will continue to accelerate the electric battery vehicle program for transportation as an effort to promote transportation electrification [3]. This can be seen from January to April 2025, where sales of battery electric vehicles (BEVs) in Indonesia reached 23,900 units, an increase of 211% compared to the same period in the previous year [4]. This acceleration has led to an increase in demand for batteries in Indonesia, including Lithium Ion Batteries, commonly abbreviated as LIB. Lithium Ion Batteries are typically used in various industries, consumer electronics, and electric vehicles (EVs), as LIB batteries can store electrical energy for longer periods of time.

Interest in lithium-ion batteries is expected to continue to grow in line with the development of electric vehicles (EVs). The lithium-ion battery market is expected to grow by 25.45%, reaching a total installed capacity of 8.1 TWh or around 40,500,000 tons installed in electric vehicles by 2030. The increase in demand for lithium-ion batteries goes hand in hand with an increase in the amount of used battery waste, which is estimated to reach 250,000 tons in Indonesia by 2030 [5]. If not managed properly, battery waste can cause serious environmental pollution and endanger human health. One solution to this problem is through the practice of recycling electric batteries.

Recycling not only includes processing batteries that have reached the end of their useful life, but also includes efforts to repair components that can still be used, commonly referred to as repair [6]. Refurbished means returning a product to its original condition because it has suffered minimal or minor damage [7]. Reuse means the reuse of battery waste that can be used for the same or other purposes [8]. This can be an alternative to reducing battery waste. In addition, this process can create new jobs, extend the life of batteries as they enter a second phase of life, and increase the added value of products [9].

The Special Region of Yogyakarta still faces obstacles due to a lack of supporting infrastructure, such as workshops that are ready and capable of recycling electric battery waste. Initial survey results conducted in July 2024 found nine workshops or dealers in Yogyakarta. Based on the results of an open questionnaire, only three workshops were willing to recycle battery waste. The questionnaire also identified factors that influence repair shops' willingness to recycle battery waste, including cost, technology, waste, battery age, social factors, and labor. These factors are external elements that influence repair shops' decisions to recycle battery waste, and each can be categorized into the economic, social, technological, and environmental dimensions that form the core of PESTEL analysis.

This study adopts the PESTEL framework, which consists of six main factors: political, economic, social, technological, environmental, and legal. PESTEL analyzes the occurrence of an event and identifies its main driving factors [10]. PESTEL analysis has two main functions: to provide a comprehensive overview of a company's operating environment and to provide information that can be used to project future conditions [11]. This study focuses its analysis on four main factors that are considered to be drivers of repair shops' intentions to provide electric battery repair services. These factors are economic, technological, environmental, and social factors.

These factors were then analyzed by weighting each factor using the Analytic Hierarchy Process (AHP) method. AHP has a hierarchical structure as a consequence of the selected criteria and sub-criteria [12]. The rationale behind the AHP method is the process of assigning numerical scores to rank each decision alternative based on the decision maker's criteria. The AHP method was used to determine the weight or level of importance of each factor influencing the intentions of repair shops/dealers. The weighting results were then used to formulate the initiation of battery recycling acceleration. The integration of the AHP and PESTEL methods produced a comprehensive strategy that took these factors into account. This strategy can encourage repair shops/dealers to recycle electric batteries.

The anticipated increase in battery waste coupled with the limited availability of battery waste recycling facilities in the Yogyakarta region, Indonesia, highlights a significant research gap. This study focuses on identifying and prioritizing the key determinants influencing repair shops' decisions to offer Electric Vehicle (EV) battery repair services within Yogyakarta. The analysis of these determinants informs the development of targeted strategies aimed at accelerating the expansion of the EV battery supply chain support infrastructure. Ultimately, this approach seeks to enhance both the sustainability and economic viability of the electric vehicle battery recycling industry in the region. The novelty of this article lies in the identification and prioritization of these factors, as well as the formulation of an electric vehicle battery recycling initiation strategy based on the analysis results. This study provides actionable insights to promote a circular economy for EV batteries in Yogyakarta.

2. MATERIALS AND METHODS

PESTEL approach is a tool used to plan strategies by assessing the impact of political, economic, social, technological, environmental, and legal factors that may affect a project [13]. PESTEL analyzes the occurrence of an event and identifies its main driving factors. The PESTEL analysis focuses on four main factors, which are then weighted using AHP. Based on the classification results from the initial survey, this study limits its focus to four main factors, namely: Technological, Environmental, Economic, and Social. The justification for this is that these factors show the most dominant impact and the highest frequency of mention among respondents in Yogyakarta. This limitation is also important to maintain mathematical consistency in AHP processing, avoiding excessive complexity that can reduce the reliability of paired comparison results.

This article applies the AHP formulation as a structured method for assigning weights to criteria. Metode The AHP method was first introduced by Thomas Saaty in 1980. AHP is a method used to solve complex decision-making problems [14]. In addition, this method also helps in determining priorities and producing optimal decisions [15]. Through the AHP method, a hierarchical structure of selected criteria is compiled [16]. By combining decision-making techniques, AHP enables consistency evaluation in the decision-making process, thereby reducing potential bias.

The data collection techniques used in this study were observation, interviews, and questionnaires distributed to electric vehicle repair shops and dealers. The questionnaires were distributed to 15 respondents in the Special Region of Yogyakarta. Respondents in this study were determined using the purposive sampling technique. This method was chosen based on the rationale that the selected respondents must meet specific criteria related to expertise and location. The initial identification process of respondents was carried out systematically using an online search engine (Google Maps) with specific keywords ("electric vehicle repair shops/dealers") in the Special Region of Yogyakarta, resulting in 15 eligible entities.

The presentation of respondent profiles has a methodological purpose to improve the internal validity of the analysis results, particularly in the application of the AHP method. By presenting the respondents' backgrounds, it ensures that the input data and assessments used come from relevant and verified entities that have sufficient operational experience in the electric vehicle ecosystem in the Special Region of Yogyakarta.

The implementation of the AHP method using Microsoft Excel software is carried out through a series of systematic steps as follows :

1. Determine the criteria and sub-criteria to be used.
2. Develop a hierarchical structure for the criteria.
3. Calculate the geometric mean of the questionnaire results using the Excel syntax = GEOMEAN(C1,D2,..).
4. Create a criteria comparison matrix, where the geometric mean results are then used to create the comparison matrix.
5. Calculate the normalization criteria values, priority vectors, value weights, and eigen values [17].
   a. Calculate normalization by dividing the data by the sum of the results in each row of the matrix, then summing each column.
   b. Calculate the priority vector or sum by adding up all the criteria value matrices or normalized values
   c. Calculate the value weight or priority by dividing the priority value by the number of criteria.
   d. Calculate the eigen value or lambda max by multiplying the value weight by the total comparison matrix.
6. Calculate the CI (Consistency Index) to calculate the deviation from consistency using the Eq. (1) [18].

$$\mathrm{CI} = \frac{\lambda\,\mathrm{max} - \mathrm{n}}{\mathrm{n} - 1} \tag{1}$$

7. Determine the Random Index (RI) by referring to the RI table and considering the number of criteria used [19]. Table 1 is a list of indices.

Table 1. Random index

Matrix size	Value RI	Matrix size	Value RI
1,2	0.00	9	1.45
3	0.58	10	1.49
4	0.90	11	1.51
5	1.12	12	1.48
6	1.24	13	1.56
7	1.32	14	1.57
8	1.41	15	1.59

8. Calculate the overall consistency of the assessment using the Consistency Ratio (CR), where the Consistency Index (CI) is divided by the Random Index value. If the CR value is ≤ 0.01, then the

consistency value is acceptable. If not, then a re-assessment is required. The calculation uses the equation 2.

$$CR = \frac{CI}{RI} \tag{2}$$

The research framework structure and stages of achieving the study objectives are comprehensive presented in Figure 1.

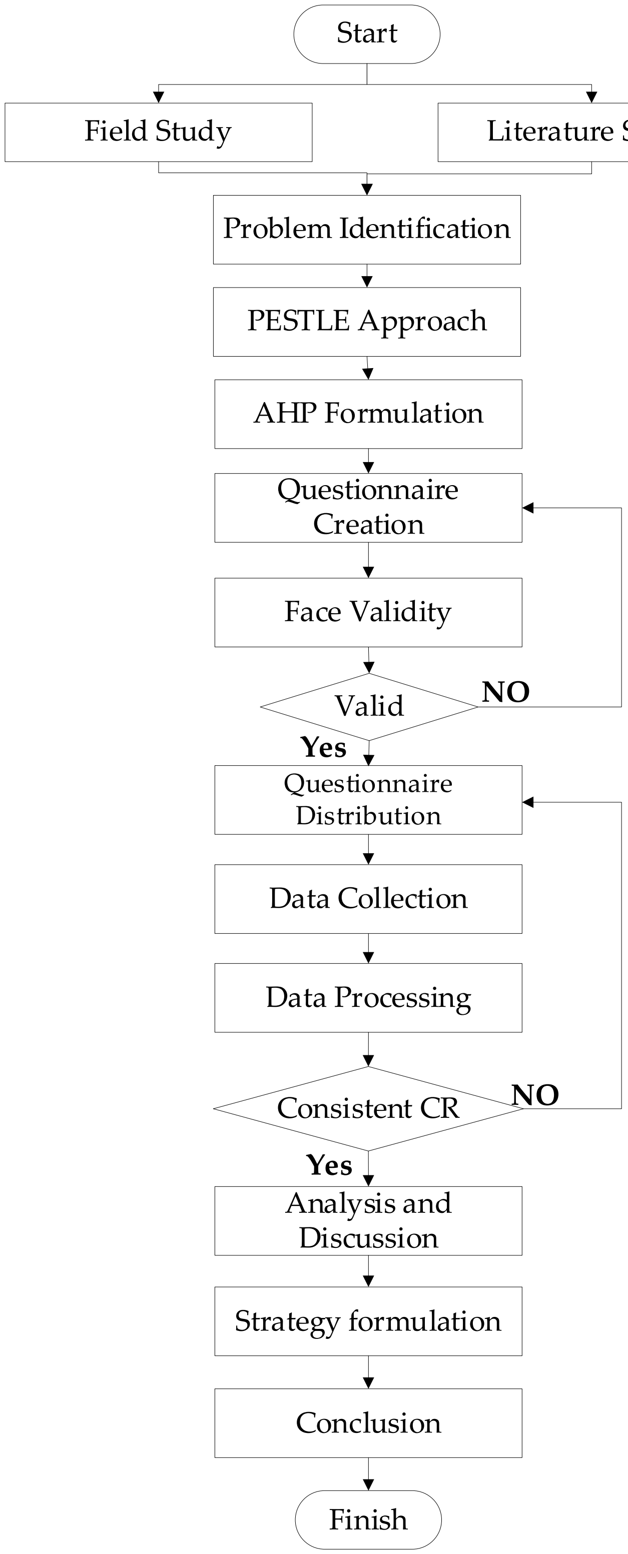

Figure 1. Research flowchart

3. RESULTS

The respondent profiles serve as validation within the framework of this research methodology. The presentation of the background of the 15 workshops and dealers involved, as detailed in Table 2, not merely a supplement, but an instrument to ensure the internal validity of the analysis results. The selection of respondents was based on two main criteria: verification of operational entities and adequate experience in the electric vehicle ecosystem in the Special Region of Yogyakarta, so that the assessments produced through the AHP come from authoritative sources. Details covering the type of entity (authorized repair shop, independent repair shop, sales dealer) and the size of the repair shop/dealer (reflecting operational capacity and service coverage) are crucial.

Table 2. Workshop/dealer data

Shop/Dealer Code	Type of Entity	Shop Size
B-01	Independent Workshop	Large
B-02	Authorized Dealer	Large
B-03	Authorized Dealer	Large
B-04	Authorized Dealer	Large
B-05	Authorized Dealer	Large
B-06	Independent Workshop	Small
B-07	Independent Workshop	Medium
B-08	Authorized Dealer	Large
B-09	Authorized Dealer	Medium
B-010	Authorized Dealer	Medium
B-011	Authorized Service Center	Large
B-012	Authorized Dealer	Large
B-013	Independent Workshop	Medium
B-014	Independent Workshop	Medium
B-015	Authorized Dealer	Medium

The first stage begins with determining the criteria and sub-criteria to be used, creating a hierarchical structure, calculating the geometric mean, and calculating the weight of each criterion and sub-criterion, followed by conducting a consistency check (Consistency Ratio, CR) to ensure the validity of the expert judgments before synthesizing the global weights to rank the available alternatives.

3.1. Criteria and sub-criteria

The formulation of criteria and subcriteria was based on the integration of empirical data from preliminary surveys with theoretical support obtained through a review of relevant previous literature. The resulting criteria and subcriteria are summarized in detail in Table 3.

Table 3. Criteria and sub criteria

Criteria	Sub Criteria	Description
Economy	Investment Costs.	Initial expenditures include equipment, facility construction, and labor training [20].
	Recycling Process Costs.	Operating costs include raw materials, energy, and worker wages during the recycling process [21].
	Economic Benefits of Recycling.	Potential revenue from the sale of recycled raw materials [20].
Technology	Availability of Recycling Technology	Access to tools and machinery required for the recycling process [22].
	Technician Expertise.	Skills and knowledge of the workforce in operating the recycling technology [21].
	Ease of Use.	Ease of operating the technology for efficiency and effectiveness of the recycling process [22].

Criteria	Sub Criteria	Description
Environmental	Awareness of Damage.	Public understanding of the negative impact of battery waste on the environment [23].
	Environmental Impact.	Reducing soil, water and air pollution and supporting environmental sustainability [24].
	Preservation of Natural Resources.	Reducing the need for mining of new raw materials and maintaining ecosystem balance [25].
Social	Support from the Community.	Community acceptance of battery recycling activities that influence success [20].
	Creating Business Opportunities.	Provides employment opportunities in the recycling sector and supports the local economy [20].
	Government Policy.	Regulations, incentives and educational programs on the importance of battery recycling [26] .

3.2. Hierarchical structure

The criteria and sub-criteria used were then arranged from the highest level, namely the objectives to be achieved, to the lowest hierarchy in the form of sub-criteria [27]. The hierarchical structure and sub-criteria can be seen in Figure 2.

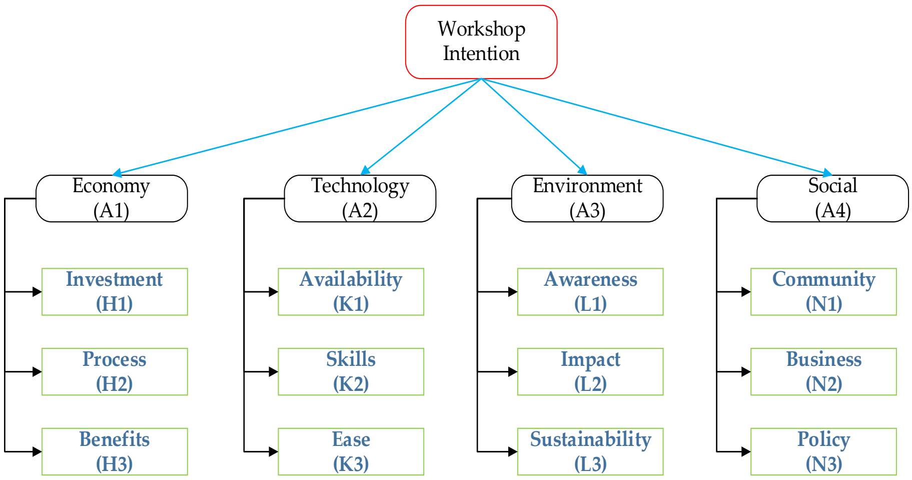

Figure 2. Hierarchical structure

3.3. Data Processing

Data management involves essential stages ranging from eliciting a pairwise comparison matrix based on subjective expert assessments to numerically verifying consistency indices and consistency ratios to ensure the validity of inputs before normalization and aggregation to obtain priority vectors.

3.3.1 Geometric Mean Result Criteria

Before processing data using AHP, it is necessary to calculate the geometric mean of the collected questionnaires. The geometric mean results of the criteria are shown in Table 4.

Table 4. Geomean result criteria.

	A1 vs A2	A1 vs A3	A1 vs A4	A2 vs A3	A2 vs A4	A3 vs A4
Geomean	1.542	0.869	0.922	1.677	2.267	2.376

Note: Description: Economy (A1), Technology (A2), Environment(A3), Social (A4)

3.3.2 Matrixs

The results of the geometric mean are used to compile a pairwise comparison matrix. This matrix serves as the basis for determining the priority weight of each element. The comparison matrix calculation is shown in Table 5.

Table 5. Geomean result criteria.

	A1	A2	A3	A4
A1	1	1.542	0.869	0.922
A2	0.648	1	1.677	2.267
A3	1.151	0.596	1	2.376
A4	1.084	0.441	0.421	1
Total	3.884	3.580	3.967	6.565

Note: Description: Economy (A1), Technology (A2), Environment (A3), Social (A4)

3.3.3 Normalization

The next step is to calculate the normalization value, vector priority, weight, and eigenvalue. The process begins by normalizing the matrix, where each value is divided by the number of columns. Next, vector priority is calculated by averaging the values in each row of the normalized matrix, which reflects the relative weight of the elements. In addition, the eigen value (λmax) is calculated to measure the consistency of the matrix. The results of these calculations are shown in Table 6.

Table 6. Normalization, P vector, weight, and eigen value

	Economy	Technology	Environmental	Social	P Vektor	Weight	Eigen
Economy	0.257	0.431	0.219	0.140	1.048	0.262	1.017
Technology	0.167	0.279	0.423	0.345	1.214	0.304	1.087
Environmental	0.296	0.167	0.252	0.362	1.077	0.269	1.068
Social	0.279	0.123	0.106	0.152	0.661	0.165	1.085
Total	1	1	1	1	4	1	4.257

The results of the AHP analysis need to be validated by evaluating the paired comparison matrix through three main indicators, namely the Consistency Index (CI), Random Index (RI), and Consistency Ratio (CR). The CI calculation result using equation (1) is 0.086, while the RI value was 0.9 because four criteria were used. The CR calculation result using equation (2) is 0.095

The same calculation as above is applied to the subcriteria, with the results presented in Table 7. These subcriteria are derived from the factors that make up the criteria. The complete calculations are presented in the appendix.

Table 7. Result sub criteria

Criteria	Sub Criteria	Normalization	Weight	Consistency Ratio
Economy	Investment	1	0.374	0.011
	Process	1	0.272	
	Benefits	1	0.354	
Technology	Availability	1	0.627	0.070
	Skills	1	0.185	
	Ease	1	0.188	
Environmental	Awareness	1	0.348	0.075
	Impact	1	0.264	
	Sustainability	1	0.389	
Social	Community	1	0.410	0.030
	Business	1	0.333	
	Policy	1	0.257	

4. DISCUSSION

Based on data processing, it is known that Table 6 shows the calculation of criteria by calculating normalization, vector priority, weight, and eigen value. The criterion with the largest weight is technology with a weight of 30.4%, followed by environment with 26.9%, economy with 26.2%, and finally social with 16.5%, as shown in Figure 3. In the normalization test, all criteria are declared normal, where the total normalization value is 1.

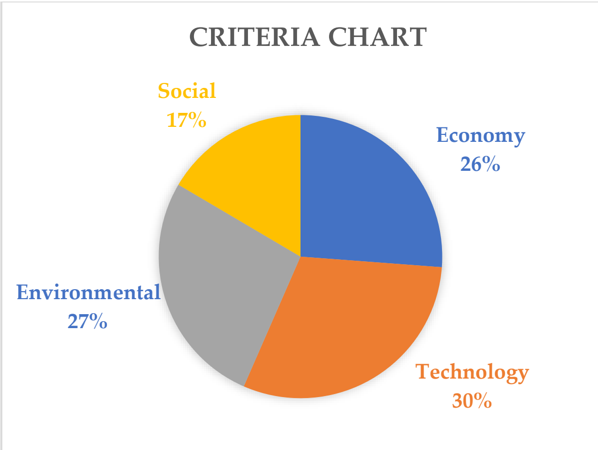

Figure 3. Criteria chart

Findings from the sub-criteria analysis show that technology availability is a dominant factor in repair shops' decisions to recycle electric vehicle batteries, with a weight of 63% (Figure 4. This is in line with previous research that emphasizes the importance of adequate technological infrastructure in supporting efficient and effective battery recycling processes [28]. The limitations of existing technology in the Yogyakarta region, as revealed in preliminary surveys and interviews with workshop owners, are a major obstacle to the development of the battery recycling industry. Therefore, investment in the development of battery recycling technology that is appropriate to local conditions is essential to encourage the active participation of workshops in this region. Furthermore, these findings also underscore the need for collaboration between the government, industry, and research institutions to accelerate the adoption of environmentally friendly and sustainable battery recycling technologies, as recommended by Toro et al. [29].

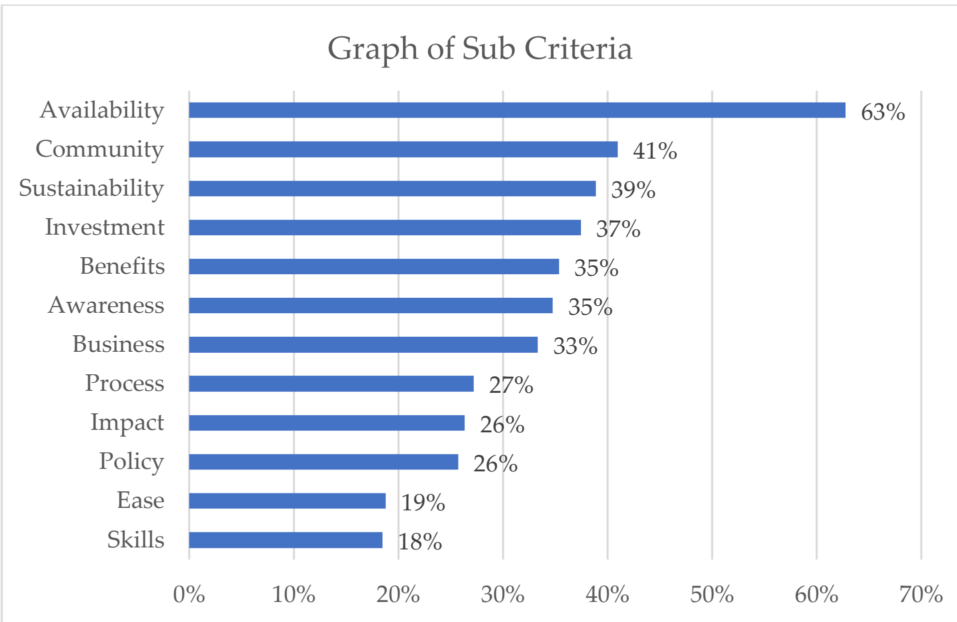

Figure 4. Graph of sub criteria

Strategy development using the PESTEL method prioritizes dominant factors that have a significant influence. This PESTEL analysis generally consists of six main factors: political, economic, social, technological, environmental, and legal [26]. However, in the context of this study, only four factors were used, namely economic, social, technological, and environmental. The use of these four factors was based on the results of an open questionnaire and reinforced by a literature study relevant to the real system in the Yogyakarta region. This more concise approach is also in line with other studies that focus on specific PESTEL factors that are most relevant to the research context [30], enabling more in-depth analysis focused on the most critical aspects of decision-making related to electric vehicle battery recycling.

From the results of the analysis using the AHP method, the technology factor emerged as the aspect with the highest weight, particularly in the sub-criterion of technology availability. This shows that technology availability is a major determinant in decision-making related to the development and application of battery recycling technology. However, conditions in Indonesia, particularly in the Special Region of Yogyakarta (DIY), still show significant limitations in terms of the availability of this technology. This finding is reinforced by preliminary surveys and interviews with workshop and dealer owners, which indicate that battery recycling technology is still very limited and is a major obstacle to the development of the battery recycling industry in the region.

These technological limitations have an impact on the efficiency and effectiveness of the battery recycling process, which ultimately affects the sustainability and economic potential of the industry. This is in line with the literature which states that battery recycling technology requires adequate infrastructure and technology to operate optimally.

4.1 Recommendation

This study presents strategic recommendations designed to address limitations and support the improvement of battery recycling technology capacity in DIY. Implementation of these findings requires synergistic collaboration between local government, repair shop associations, and the battery industry to form a sustainable recycling ecosystem in the region, promising positive economic and environmental impacts. Key recommendations include developing technological infrastructure, increasing human resource capacity through technical training, and strengthening partnerships between government, industry, and academia, all of which aim to accelerate the adoption of efficient and environmentally friendly battery recycling technologies. This overall strategy is expected to drive the acceleration of battery recycling in Indonesia, in line with environmental sustainability goals. The strategic recommendations formulated are presented in detail to facilitate in-depth review by stakeholders, the full details of which are elaborated in Table 8.

Table 8. Initiation recommendations

Criteria	Initiation
Technology	- Development of technological infrastructure and training to master electric battery recycling technology. - Implementation of information technology-based workshop management systems such as IOT to improve service and customer satisfaction [28]. - Development of information technology to track batteries in their second life [31]. - Involving universities in developing clean energy .
Environmental	- Establishing strategic partnerships with authorized environmental agencies to provide green certification to workshops that contribute significantly to the waste recycling process [32].
Economy	- Providing financing or technical assistance to workshops that want to recycle. Tax breaks and financial support for companies that invest in recycling technology [33].

Criteria	Initiation
	- Improving economics through economies of scale, automation, modularization, and revenue streams for recycling facilities [34].
Social	- The government establishes battery recycling standards, and automotive companies and battery manufacturers are required to take responsibility for recycling used batteries [35]. - Companies partner with recyclers for battery return logistics [34].

4.2 Future research

Although this study successfully identified key factors that influence repair shops' intentions to recycle electric vehicle batteries in Yogyakarta, there are several limitations that need to be acknowledged. First, the sample size of the study was limited, involving only 15 respondents from repair shops and dealers in the region. This may limit the generalizability of the findings to a larger population. Second, this study focused only on four PESTEL factors (economic, social, technological, and environmental), while political and legal factors may also play an important role in the context of battery recycling. Further research with a larger sample and broader coverage of factors could provide a more comprehensive understanding.

For further research, several areas of development can be explored. First, larger-scale quantitative research can be conducted to test the validity of the qualitative findings of this study. Surveys with more representative samples can provide stronger statistical evidence. Second, research can be expanded to include the perspectives of various stakeholders, such as local governments, battery manufacturers, and consumers. Comparative analysis between different regions in Indonesia could also provide additional insights into the factors that influence battery recycling. Finally, research on innovative and environmentally friendly battery recycling technologies could provide practical solutions to overcome existing technological limitations.

5. CONCLUSION

The key factors influencing repair shops' intentions to recycle electric vehicle batteries were determined through a preliminary survey supported by a literature review. These factors were then mapped into a PESTEL framework, covering economic (cost), technological (availability of equipment), environmental (battery waste), and social (awareness and society) aspects. Using the AHP method, these factors were prioritized based on their relative weight, with the technological aspect—with the subcriterion of technology availability—being the most dominant factor influencing repair shops' decisions. Based on the results of this analysis, a number of strategies developed from previous research findings were proposed. A company strategy of partnering with recyclers can accelerate the management of electric vehicle battery waste in Indonesia by creating synergies in technology, logistics, and sustainability, thereby supporting the formation of an efficient and environmentally responsible economy.

ACKNOWLEDGMENT

The author team would like to thank the Muhammadiyah Central Leadership Higher Education Research and Development Council for the Mu Research Program grant Wave VIII in 2024. This research was funded by the Funding and Implementation of the Muhammadiyah National Research Grant Batch VIII in 2024, Number: 0258.227/I.3/D/2025. I would like to thank Prof. Siti Mahsanah Budijati for her valuable suggestions and insightful feedback arranging the completion of this research. AI helps refine the framework of ideas or the structure of article writing.

REFERENCES

[1] N. P. Zahira and D. P. Fadillah, "Pemerintah Indonesia menuju target Net Zero Emission (NZE) tahun 1060 dengan Variable Renewable Energy (VRE) di Indonesia," *JIS J. Ilmu Sos.*, vol. 2, no. 2, pp. 2548–4893, 2022, doi: https://doi.org/10.21831/jis.v2i2.25.

[2] Z. G. T. Siregar *et al.*, "Potensi emisi co2 dari kendaraan bermotor di kawasan universitas negeri Semarang," *Kurvatek*, vol. 8, no. 1, pp. 55–62, 2023, doi: https://doi.org/10.33579/krvtk.v8i1.4017.

[3] M. I. Al Qodri and Widyastutik, “Emisi energi dan kebijakan kendaraan listrik: studi komparasi antara china dan indonesia,” *risal. kebijak. pertan. dan lingkung. rumusan kaji. strateg. bid. pertan. dan lingkung.*, vol. 10, no. 3, pp. 133–144, 2023, doi: 10.29244/jkebijakan.v10i3.48350.

[4] Gaikindo, “Whole sales mobil listrik di indonesia naik 211 persen pada 2025.” [online]. Available: https://www.gaikindo.or.id/whole-sales-mobil-listrik-di-indonesia-naik-211-persen-pada-2025/

[5] D. R. Rachmadhani and B. Priyono, “Techno-economic analysis of the business potential of recycling lithium-ion batteries using hydrometallurgical methods,” *Int. J. Eng. Bus. Soc. Sci.*, vol. 2, no. 02, pp. 938–948, 2024, doi: 10.58451/ijebss.v2i02.141.

[6] S. Jin *et al.*, “Structural evolution of layered oxide cathodes for spent li–ion batteries: degradation mechanism and repair strategy,” *SusMat*, vol. 3, no. 3, pp. 362–378, 2023, doi: 10.1002/sus2.126.

[7] M. R. Maarif, M. Taufik, and K. Rahayu, “Dampak perubahan status e-commerce menjadi importir berdasarkan permenkeu nomor 96 tahun atas pembelian barang elektronik,” *J. Bisnis Dan Manaj.*, vol. 2, no. 1, pp. 271–288, 2024, doi: https://doi.org/10.61930/jurbisman.v2i1.559.

[8] R. M. O. Lubis, Y. Pathuansyah, and Abdelina, “Pengelolaan wisata alam parsariran melalui implementasi green economydengan konsep 3r (reduse, reuse, recycle) terhadap pembangunan ekonomi masyarakat yang berkelanjutan,” *J. Ilm. Hosp.*, vol. 11, no. 2, pp. 655–662, 2022, doi: https://doi.org/10.47492/jih.v11i2.2273.

[9] A. Purwani, S. M. Budijati, and M. H. Asih, “Management of battery waste recycling by electric motorbike workshops : A literature review,” O*psi*, vol. 17, no. 1, pp. 216–233, 2024, [Online]. Available: https://doi.org/10.31315/opsi.v17i1.12173

[10] R. Aghlmand, M. Gheibi, A. Takhtravan, and Z. Kian, ″Implementation of green marketing frameworks based on conceptual system designing by integration of PESTLE, classical Delphi and MCDM modeling,″ vol. 2, no. 8. Springer International Publishing, 2022. doi: 10.1007/s43546-022-00273-8.

[11] S. Paramadita, A. Umar, and Y. J. Kurniawan, “Analisa pestel terhadap penetrasi gojek di indonesia,” *J. Pengabdi. dan Kewirausahaan*, vol. 4, no. 1, 2020, doi: 10.30813/jpk.v4i1.2079.

[12] Y. Y. Muanley, A. L. Son, G. S. Mada, and N. K. F. Dethan, “Analisis sensitivitas dalam metode analytic hierarchy process dan pengaruhnya terhadap urutan prioritas pada pemilihan smartphone android,” *Variansi J. Stat. Its Appl. Teach. Res.*, vol. 4, no. 3, pp. 173–190, 2022, doi: 10.35580/ variansiunm32.

[13] L. Bamatraf, A. Fasih, W. Vangesti, and N. L. P. Hariastuti, “Integrasi metode pestle dan tows untuk manajemen strategi industri manufacturing sawit (studi kasus: PT. Johan santosa),” *J. Nusant. Eng.*, vol. 7, pp. 130–139, 2024, doi: https://doi.org/10.29407/noe. v7i02.22934.

[14] F. A. Pratama, I. Soejanto, and E. Nursubiyantoro, “Performance measurement of organic tea supply chain with supply chain operation references (Case study of active Tegal Subur Farmer Group , Kulon Progo),” O*psi*, vol. 17, no. 1, pp. 204–215, 2024, [Online]. Available: https://doi.org/10.31315/opsi. v17i1.11036

[15] R. S. Wahyuni, M. Zaen, E. Nursubiyantoro, M. Raharja, and Y. Zulkarnain, “Selection of pilot and flight attendant uniform suppliers in a private airline holding company using the Analytic Hierarchy Process (AHP) method,” O*psi*, vol. 18, no. 1, pp. 22–33, 2025, [Online]. Available: https://doi.org/ 10.31315/opsi.v18i1.11505

[16] H. H. Purba, C. Jaqin, S. Aisyah, and M. Nabilla, “Analysis of lean-agile-resilient-green (LARG) implementation in the electric car industry in Indonesia,” *J. Sist. dan Manaj. Ind.*, vol. 8, no. 1, pp. 61–72, 2024, doi: 10.30656/jsmi.v8i1.7674.

[17] C. S. Sabhira, A. T. Wahyuni, W. Septianie, M. Luis, T. Industri, and U. Trisakti, “Decision making for the selection of vegetable suppliers for foods distributors uses AHP and TOPSIS,” O*psi*, vol. 17, no. 1, pp. 27–38, 2024, [Online]. Available: https://doi.org/10.31315/opsi.v17i1.9872

[18] W. S. Jatiningrum, S. Nastiti, A. Sesanti, R. Utami, and W. Sholihah, “Applying AHP-TOPSIS Approach for Selecting Marketplace based on Preferences of Generation Z in Yogyakarta , Indonesia,” O*psi*, vol. 15, no. 1, pp. 107–115, 2022, [Online]. Available: https://doi.org/10.31315/opsi.v15i1.6824

[19] D. S. Anggraini, S. Halim, and G. S. San, “Penerapan analytical hierarchy process dalam sistem penunjang keputusan untuk pemilihan telepon cerdas,” *Penerapan AHP dalam Sist. Penunjang Keputusan / J. Titra*, vol. 9, no. 1, pp. 113–120, 2021.

[20] M. T. Islam and U. Iyer-Raniga, "Lithium-ion battery recycling in the circular economy: a review," *recycling*, vol. 7, no. 3, 2022, doi: 10.3390/recycling7030033.

[21] L. Toro *et al.*, "A systematic review of battery recycling technologies: advances, challenges, and future prospects," *Energies*, vol. 16, no. 18, pp. 1–24, 2023, doi: 10.3390/en16186571.

[22] L. Zhang, W. Ran, S. Jiang, H. Wu, and Z. Yuan, "Understanding consumers' behavior intention of recycling mobile phone through formal channels in China: The effect of privacy concern," *Resour. Environ. Sustain.*, vol. 5, no. December 2020, p. 100027, 2021, doi: 10.1016/j.resenv.2021.100027.

[23] O. Velázquez-Martínez, J. Valio, A. Santasalo-Aarnio, M. Reuter, and R. Serna-Guerrero, "A critical review of lithium-ion battery recycling processes from a circular economy perspective," *Batteries*, vol. 5, no. 4, pp. 5–7, 2019, doi: 10.3390/batteries5040068.

[24] X. Ma, L. Azhari, and Y. Wang, "Li-ion battery recycling challenges," *Chem*, vol. 7, no. 11, pp. 2843–2847, 2021, doi: 10.1016/j.chempr.2021.09.013.

[25] A. Mondal, Y. Fu, W. Gao, and C. C. Mi, "Pretreatment of lithium ion batteries for safe recycling with high-temperature discharging approach," *Batteries*, vol. 10, no. 1, 2024, doi: 10.3390/batteries 10010037.

[26] M. Habiburrahman, A. Tri Setyoko, R. Nurcahyo, H. Daulay, and K. Natsuda, "Circular economy strategy for waste management companies of electric vehicle batteries in Indonesia," *Int. J. Product. Perform. Manag.*, vol. 74, no. 11, pp. 21–45, 2025, doi: 10.1108/IJPPM-01-2024-0015.

[27] A. Oktafiawan Nugroho and R. Budhiati Veronica, "Penerapan metode ahp sebagai sistem pendukung keputusan pemilihan tempat kerja," *UNNES J. Math.*, vol. 10, no. 1, pp. 48–48, 2021, [Online]. Available: http://journal.unnes.ac.id/sju/index.php/ujm

[28] R. Triaswinanti, R. Triastomo, A. N. G. Puspita, and A. Hapid, "Studi tekno-ekonomi proses pirometalurgi daur ulang baterai Lithium Manganese Oxide (Lmo) dan Lithium Iron Phosphate (Lfp)," *J@ti Undip J. Tek. Ind.*, vol. 18, no. 2, pp. 94–108, 2023, doi: 10.14710/jati.18.2.94-108.

[29] L. Toro *et al.*, "A Systematic review of battery recycling technologies : advances , challenges , and future prospects," *Batteries. vol. 16,* no. 18, pp. 1–24, 2023, doi: https://doi.org/10.3390/en16186571.

[30] I. C. Anggraini, D. A. Negoro, U. Kustiawan, R. Indradewa, M. Manajemen, and U. E. Unggul, "Analisa eksternal pada perencanaan bisnis dokter molis (solusi motor listrik anda)," vol. 6, no. 4, pp. 4839–4849, 2025, doi: http://doi.org/10.55338/jpkmn.v6i4.6739.

[31] M. Kurdve, M. Zackrisson, M. I. Johansson, B. Ebin, and U. Harlin, "Considerations when modelling ev battery circularity systems," *Batteries*, vol. 5, no. 2, pp. 1–20, 2019, doi: 10.3390/batteries5020040.

[32] S. Rehman, M. Al-greer, A. S. Burn, and M. Short, "High-volume battery recycling : technical review of challenges and future directions," *Batteries. vol. 11,* no. 3, pp. 1–30, 2025, doi: http://dx.doi.org/10.3390/batteries11030094.

[33] R. Pahrijal, "Mengubah sampah menjadi harta karun: inovasi daur ulang yang menguntungkan lingkungan dan ekonomi (studi literature)," *J. Multidisiplin West Sci.*, vol. 2, no. 06, pp. 483–492, 2023, doi: 10.58812/jmws.v2i6.430.

[34] A. Zanoletti, E. Carena, C. Ferrara, and E. Bontempi, "A review of lithium-ion battery recycling: technologies, sustainability, and open issues," *Batteries*, vol. 10, no. 1, 2024, doi: 10.3390/batteries 10010038.

[35] A. A. Putri, "Peluang dan tantangan daur ulang baterai EV," katadata green. [Online]. Available: https://green.katadata.co.id/infografik/66e3e62064990/peluang-dan-tantangan-daur-ulang-baterai-ev

Appendix

The relative weight values for each criterion and subcriterion are determined based on the results of data processing using the AHP method as follows :

1. Criteria

	Economy	Technology	Environmental	Social	P Vektor	Weight	Eigen Value	CI	RI	CR
Economy	0.257	0.431	0.219	0.140	1.048	0.262	1.017	0.086	0.9	0.095
Technology	0.167	0.279	0.423	0.345	1.214	0.304	1.087			
Environmental	0.296	0.167	0.252	0.362	1.077	0.269	1.068			
Social	0.279	0.123	0.106	0.152	0.661	0.165	1.085			
Total	**1**	**1**	**1**	**1**	**4**	**1**	**4.257**			

2. Sub-Criteria Economy

	Investment	Process	Benefits	P Vektor	Weight	Eigen Value	CI	RI	CR
Investment	0.370	0.417	0.337	1.123	0.374	1.013	0.007	0.58	0.011
Process	0.239	0.270	0.307	0.816	0.272	1.008			
Benefits	0.391	0.313	0.356	1.061	0.354	0.992			
Total	**1**	**1**	**1**	**3**	**1**	**3.013**			

3. Sub-Criteria Technology

	Availability	Skills	Ease	P Vektor	Weight	Eigen Value	CI	RI	CR
Availability	0.626	0.711	0.545	1.882	0.627	1.002	0.040	0.58	0.070
Skills	0.141	0.161	0.252	0.554	0.185	1.151			
Ease	0.232	0.129	0.202	0.563	0.188	0.928			
Total	**1**	**1**	**1**	**3**	**1**	**3.081**			

4. Sub-Criteria Environmental

	Awareness	Impact	Sustainability	P Vektor	Weight	Eigen Value	CI	RI	CR
Awareness	0.327	0.456	0.260	1.043	0.348	1.065	0.043	0.58	0.075
Impact	0.184	0.257	0.350	0.791	0.264	1.025			
Sustainability	0.489	0.287	0.390	1.166	0.389	0.997			
Total	**1**	**1**	**1**	**3**	**1**	**3.087**			

5. Sub-Criteria Social

	Community	Business	Policy	P Vektor	Weight	Eigen Value	CI	RI	CR
Community	0.412	0.474	0.343	1.229	0.410	0.994	0.017	0.58	0.030
Business	0.279	0.321	0.401	1.000	0.333	1.040			
Policy	0.309	0.205	0.257	0.771	0.257	1.001			
Total	**1**	**1**	**1**	**3**	**1**	**3.035**			