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CASE STUDY

# Conversion of motorcycles to electric vehicles towards sustainable mobility

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**ABSTRACT**

**BACKGROUND AND OBJECTIVES:** Developing Southeast Asian countries, including Indonesia, have significant hurdles in addressing the increasing usage of motorized vehicles and their detrimental impact on air quality, traffic, energy security, liability, and greenhouse gas emissions. is to assess the viability of transforming traditional internal combustion engine motorcycles into electric vehicles powered by batteries in Indonesia. The analysis will concentrate on the positive environmental outcomes, including decreased greenhouse gas emissions and energy usage, in addition to examining the economic and social consequences of this transition. The absence of exhaust emissions could create the impression that converting to battery-powered electric vehicles will consistently yield favorable environmental outcomes, such as reducing greenhouse gas emissions and energy consumption. Meanwhile, the economic and social impacts associated with electric vehicle conversion programs are also taken into account savings during post-conversion.
**METHODS:** Primary data was acquired through the distribution of questionnaires, conducting in-depth interviews with workshop managers, and obtaining scientific evaluations from participating experts. The Rapfish multidimensional scaling application was used to handle and evaluate the data. The analysis of the data involved the examination of five dimensions, namely social, economic, ecological, technological, and institutional, with each dimension comprising 37 variables.
**FINDINGS:** The sustainability index, which stands at 70.39 percent, indicating a fair level of sustainability, implies that there is significant development potential in the conversion process of internal combustion engine motorbikes to battery electric vehicles by strategically focusing on key leverage factors across various dimensions. The institutional dimension registers the lowest value at 48.92 percent, whereas the environmental, technological, social, and economic dimensions' exhibit values of 85.25 percent, 79.13 percent, 76.29 percent, and 62.37 percent, respectively. Achieving sustainability requires focused enhancements in various key areas: setting up waste conversion facilities in the environmental aspect, educating employees on environmental conservation and boosting business incentives in the social aspect, ensuring a stable supply of raw materials and maximizing market penetration in the economic aspect, and improving experience management and skill acquisition in the technological aspect. Additionally, the presence of funding, the involvement of marketing intermediaries, and the backing for initiatives aimed at converting vehicles to electric power within the institutional framework are key aspects that demand concentrated efforts.
**CONCLUSION:** The multidimensional assessment indicates that Indonesia's electric vehicle conversion program is progressing effectively, achieving an average sustainability index of 70.39 percent, categorized as fair. The results indicate that the initiative has effectively created a resilient, sustainable conversion framework that can be tailored to various environments and scenarios. To further enhance sustainability within these conversion initiatives, it is imperative to prioritize institutional dimensions, particularly financial and marketing support, as well as the critical role of the electric vehicle conversion itself. This model provides significant perspectives for policymakers and government entities when developing and executing forthcoming policies and initiatives.

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## INTRODUCTION

The primary contributor to carbon dioxide ($CO_2$) emissions is the transportation industry's reliance on fossil fuels, leading to significant implications for both global climate change and abnormal weather patterns at the local level (Rubino *et al.* 2017). The growing number of automobiles on the road is driving up the demand for fossil fuels, which is predicted to continue to rise next year. Conversely, energy consumption is positively correlated with economic growth (Oryani *et al.*, 2022). The anticipated figure for the total number of motorbikes in Indonesia by the end of 2022 is estimated to reach 125.3 million, showcasing a steady rise each year from 2012, with an additional 48.9 million units, equating to a growth of 64 percent (Ferlinda *et.al.*, 2024). The transportation sector contributes around 27 percent (%) of greenhouse gases (GHGs) emissions, of which around 90% is generated by the land transportation subsector (WRI, 2023). The present circumstances demand the promotion of innovation and the implementation of strategies to decrease carbon emissions in the land transportation sector, in order to hasten the attainment of targets for reducing greenhouse gas emissions. This innovation is consistent with and supports the Minister of Transportation's achievements in establishing climate change mitigation actions in the transportation sector to meet Indonesia's National Defined Contribution (NDC) target (Wahyono *et al.*, 2024). As part of the endeavor to diminish greenhouse gas emissions originating from the transportation sector, the government has set its sights on a program for converting 50,000 conventional motorbikes into electric motorbikes by 2023. Subsequently, the target has been raised to 150,000 units for the year 2024. To increase the acceleration of the conversion program, conversion subsidy funds of United States Dollar (USD) 340-620 have been distributed for each electric vehicle (EV) unit (Darmoyono, 2024). The significance of electric vehicles (EVs) lies in their role as pivotal technology for the future of automotive power systems, characterized by their silent operation, economical running costs, and lightweight construction (Zainol *et al.*, 2019). The lack of electric car infrastructure is a key issue in the Southeast Asian automobile market, particularly in Indonesia. With its status as the world's largest country, Indonesia showcases immense potential. The automotive industry has started to allocate resources towards research and development efforts for EV. The number of EV has risen considerably in recent years, owing to technology advancements and government attempts to lessen their environmental impact. Government rules on EV remain a key non-technical hurdle, although charging times and battery performance are technical difficulties. It is imperative to assess and scrutinize the initiatives aimed at converting EV to ascertain the trajectory of the program's overall effectiveness and its ability to sustain long-term growth or decline. One of the reliable tools for monitoring and reviewing sustainability is multidimensional scaling (MDS) method. The MDS method provides a valuable means of assessing the sustainability index of a process or product production, allowing for the determination of its level of sustainable status. The project system that occurred failed to keep the environment sustainable, so this urged policymakers to the solution development of sustainability (Alder *et al.*, 2000; Lloyd *et al.*, 2022). As the sustainability concept is growing more important, instruments are needed to evaluate it. he significance of the sustainability index is growing as it is utilized to evaluate the progress of sustainable development, encompassing not just the economic sector but also the environmental and social impacts concurrently. It contributes to making a management policy more efficient and effective. This research will promote realistic MDS approaches to assist workshop machinery entrepreneurs in making product management strategy decisions. MDS can assist entrepreneurs in obtaining quantitative assessments of item similarity across groups. MDS has the capability to transform customer evaluations of similarity or preference (such as a fondness for a narrative or product) into distances within a multidimensional space. MDS has two main advantages: it allows for individual analysis by creating a perception map of as many things or topics as possible, which a multivariate approach does not allow for, and without the requirement to strictly measure product attributes, researchers can add dimensions. (Hout *et al.*, 2013). Originally, Multidimensional Scaling (MDS) was employed for the purpose of suggesting fisheries policies. Nevertheless, it has also expanded into various fields, including ecology (Kenkel and Orloci, 1986), political science, sociology (Amato, 1990), and the

management of natural resources (Sulaiman *et al*., 2021). Research on determining sustainability index using MDS related to others topic has been widely reported by several authors, such as algae biomass production (Santoso *et al*., 2023), duck farming (Rohaeni *et al*., 2021; Bakrie *et al*., 2023), garlic (Paczka *et al*., 2021), chocolate (Fairuzia *et al*., 2020), compost (Santoso *et al*., 2023a), beef (Rohaeni *et al*., 2024), dairy (Lovarelli *et al*., 2020), buffalo (Rohaeni *et al*., 2023), shrimp (Sivaraman *et al*., 2019), rice (Rachman *et al*., 2022), coffee (Yusuf *et al*., 2022), black soldier fly (Santoso *et al*., 2023b), integrated farming (Widjaja *et al*., 2023), and sago (Allaily *et al*., 2024). Although research on sustainability has been conducted independently across various agricultural products. However, there remains a gap in the exploration of applying sustainability principles to evaluate machinery, particularly in the context of enhancing electric machine conversion efficiency. Efforts to make conversion program become a superior program for the future require some efforts to find out factors influence the sustainability of electric machinery industry. The study regarding the comprehension of the wider consequences and obstacles encountered in the conversion of electric vehicles has been documented. For instance, certain studies underscore the importance of solid infrastructure and policy reinforcement in guaranteeing the enduring feasibility of electric bicycles (Kumar and Alok, 2020). The adoption of electric bicycles is significantly influenced by consumer acceptance and behavior change, with incentives and awareness campaigns serving as crucial factors, as highlighted by Garg *et al*. (2023). This underscores the importance of conducting a thorough. Also important is the development of technologies such as battery management systems (Gabbar *et al*., 2019), battery charging (Collin *et al*., 2019), and battery recycling (Amusa *et al*., 2019). The evaluation of the sustainability of electric conversion holds significant importance in analyzing trade-offs in sustainability, establishing the extent of regulatory constraints within the automotive sector, engaging a wider range of stakeholders, and enabling enhancements in areas like planning and strategic initiatives to meet the future objectives of the automotive industry. Therefore, this study hypothesizes that the electric vehicle conversion program will support climate change mitigation program in addition to reducing GHGs emission also improves the environment quality. The practical approach of MDS provides information that can assist management decision-makers in electric vehicle conversion program. In this study, the MDS analysis is expected to assist the workshop entrepreneurs in making decisions about several alternative product machinery managements. The main goal of this study is to evaluate the sustainability index pertaining to the transformation of motorbikes from internal combustion engines to electric vehicle motorbikes within the context of Indonesia. Specifically, this research aims to assess the sustainability index for each dimension (social, economic, ecological, technological and institutional), and does not assess engine performance characteristics. Specifically, this research purposes to 1) Assess the sustainability index of each dimension (social, economic, ecological, technological, and Institutional); 2) Identify the factors that have a sensitive effect on the engine conversion system; and 3) Determine the most dominant factor in the engine conversion system. The present research project was carried out at the Research Centre for Behavioural and Circular Economy, National Research and Innovation Agency, Indonesia in 2024.

## MATERIALS AND METHODS

*Research materials and procedure*

This study was carried out by examining data that centered on the transformation of a traditional internal combustion engine (ICE) motorcycle into a converted battery-powered electric vehicle (CBEV). The method of obtaining secondary data involves collecting data from research journals, and other literature related to the sustainability of machinery conversion program. Moreover, data was collected by conducting a Focus Group Discussion (FGD) and administering questionnaires to thirteen experts who have significant involvement, skill, and understanding of the electric conversion program. The qualifications of the experts involved in filling out the questionnaire are those who have at least 3 years' experience in electric conversion experiences. Based on the specified respondent criteria, several respondents were determined, including individuals from, the industrial department agency, members of automotive groups, and various experts associated with machine conversion program. Extensive literature

Table 1: Parameter values of the leverage factor

| No. | Factor value | Category | Description |
|---|---|---|---|
| 1 | <2.0% | Neutral | Not influential |
| 2 | 2-8% | Influential | Moderate to good impact |
| 3 | >8.0% | Significant | Dominant |

review and expert consultations were utilized to select the attributes, ensuring their relevance to the sustainability of the electric conversion program. Each attribute was then assigned a weight reflecting its importance, determined through a FGD method. The normalization of weights was carried out to guarantee that the total sum of weights equated to one, thereby improving the transparency and precision of the MDS analysis. In-depth interviews were carried out with management and conversion workshop operators to gather primary data, alongside scientific assessments provided by experts who participated as respondents. The data is then processed and analyzed with the MDS method. The Rapfish program was used to do MDS analysis program (Pitcher and Preikshot, 2001).

*Data analysis*

The sustainability of the electrical conversion program was assessed utilizing a multidimensional scaling (MDS) approach and the Rapid Appraisal (Rap) conversion machine conversion analysis tool. The identified attributes demonstrate the degree of sustainability across various dimensions, with adjustments made based on the information accessibility pertaining to the specific resource (Kavanagh and Pitcher, 2004). There are five dimensions: environmental, economic, social, technological, and institutional, with 37 attributes in all (Table 2). A questionnaire with likert-scale response options is used to describe the dimensions and attributes. The questionnaire response sheet allows expert participants to rate items as either low, moderate, or high by assigning numerical values of 0, 1, or 2 respectively. In the realm of MDS, two distinct points or objects are graphically represented by points that are closely situated. Widely separated points were employed to denote items or points that differed from each other (Alder *et al*., 2000). In MDS, ordination or distance determination approaches were based on the Euclidian distance in n-space using Eq. 1 (Lloyd *et al*., 2022):

$$d = \sqrt{\left(\left|x_1 - x_2\right|^2 + \left|y_1 - y_2\right|^2 + \left|z_1 - x_2\right|^2 + \ldots\right)} \quad (1)$$

In MDS, configurations of objects or points were estimated by regressing Euclidian distance (dij) from point i to point j with point of origin (oij) using Eq. 2 (Lloyd *et al*., 2022):

$$d_{ij} = \alpha + \beta\delta\beta_{ij} + \varepsilon \quad (2)$$

The ALSCAL algorithm was employed for the regression analysis of Eq. 2. The ALSCAL method optimizes squared distance (squared distance = $d_{ijk}$) against squared data (point of origin = $o_{ijk}$), which in three dimensions (i, j, k) is called S-Stress using Eq. 3 (Lloyd *et al*., 2022):

$$s = \sqrt{\frac{1}{m}\sum_{k=1}^{m}\left[\frac{\sum_i\sum_j\left(d_{ijk}^2 - o_{ijk}^2\right)^2}{\sum_i\sum_j o_{ijk}^4}\right]} \quad (3)$$

Where, the squared distance is Euclidian distance assigned a value using Eq. 4 (Lloyd *et al*., 2022):

$$d_{ijk} = \sum_{a=1}^{r} w_{ka}\left(x_{ia} - x_{ja}\right)^2 \quad (4)$$

*EV conversion sustainability analysis*

The levels of sustainability performance of EV conversion are divided into 4 levels, resulting in intervals of 0, 25%, 50%, 75%, and 100%. The assessment categories are as follows: 0.00 - 25, poor category and unsustainable; 25.01 - 50, less category, less sustainable; 50.01 - 75, adequate category, fairly sustainable; 75.01 - 100.00, good category sustainable (Arofi *et al*., 2015). Employing analysis techniques can also assist in pinpointing characteristics that are attuned to sustainability considerations. The indicator with the highest root mean square (RMS) value is the most sensitive (Pitcher and Preikshot, 2001). The values of the leverage factors fall within the range of 2%-8%, indicating a moderate to good impact. If < 2%, the factor is considered not influential, while if > 8%, the factor is considered dominant (sustainable) according to Pitcher and Preikshot, (2001). Table 1 presents the factors that have an impact and are dominant.

Table 2: List of dimensions and their attributes

| Environment | Economy | Social | Technology | Institution |
|---|---|---|---|---|
| 1. Electrical energy efficiency | 8. Productivity | 15. Education level of manager | 23. Adoption of conversion system | 29. Existence of corporation |
| 2. Noisy pollution | 9. Management level | 16. Business motivation | 24. Specialization or skills required | 30. Existence role of conversion program |
| 3. Water efficiency | 10. Business success rate | 17. Public unrest potential | 25. Facilities and infrastructure | 31. stakeholder s supporting |
| 4. Water pollution | 11. Welfare of managers/workers | 18. Job losses potential | 26. Increasing technology conversion | 32. Procedures for receiving government assistance |
| 5. Air pollution | 12. Availability of raw materials | 19. Workers' knowledge of environmental preservation | 27. Level of method sensitivity | 33. Existence of entrepreneurs' community |
| 6. Machines and parts waste | 13. Market absorption of conversion services | 20. Work accidents potential | 28. Worker capacity building program | 34. Existence of finance agency |
| 7. Treatment facilities for waste parts | 14. Salary | 21. Potential job creation for local residents | | 35. Marketing agency supporting |
| | | 22. Salary gaps between workers | | 36. Supporting from research agency |
| | | | | 37. Existence of waste management unit |

Monte Carlo analysis helps in determining the error, assessing the uncertainty in MDS. If the discrepancy between the MDS value and Monte Carlo value is small, it indicates that the MDS analysis for determining sustainability is sufficiently accurate with a 95% confidence level.

## RESULTS AND DISCUSSION

The MDS technique was implemented to generate the sustainability index value for the ICE to CBEV conversion process and to identify variable features. The MDS dimensions measured include the five dimensions and all of their attributes. Utilizing a scientific assessment questionnaire, the input data for this calculation was obtained. Furthermore, this analysis will uncover sensitive attributes and influential variables that play a role in the sustainability of the process.

*Index of sustainability*

Scientific evaluation of the attributes within each dimension of sustainability is crucial for accurately estimating the sustainability index level. The consideration of specific and temporal characteristics is crucial in the determination of an attribute. (Pitcher and Preikshot, 2001). The attribute of all dimensions consists of environmental, economy, social, technology, and institutional that presented in Table 2.

Attribute of environmental dimension was consisting of noisy, water, and air pollution; water efficiency; waste of machinery part treatment. Meanwhile, social dimension attributes are determined by education level, corporate motivation, the possibility of public unrest, understanding of environmental conservation, and job loss. The economic dimension of a business includes factors such as the salary and welfare of workers, productivity levels, and the ability of the service market to absorb goods and services. Technology attributes include conversion system adoption, technological improvement possibilities, worker capacity building programmes, facilities and infrastructure, and management experience and skills. The ultimate institutional feature includes the presence of a corporation or agency that offers support for the program, along with the function of conversion program. To establish the level of sustainability in each process of converting an ICE motorcycle into a CBEV, the attributes in every dimension were created in a sheet questionnaire and submitted to the relevant scientific judgment. Additionally, the MDS approach and the Rapfish program were utilized to assess the

Table 3: The results of sustainability index for the five dimensions and its associated data quality statues

| Dimension | Index (%) | Status | Stress | $R^2$ (Structured query reporter: SQR) |
|---|---|---|---|---|
| Environmental | 85.24 | good | 0.1397 | 0.9429 |
| Social | 76.29 | good | 0.1385 | 0.9484 |
| Economical | 62.37 | fairly | 0.1442 | 0.9416 |
| Technological | 79.13 | good | 0.1469 | 0.9439 |
| Institutional | 48.92 | unsustainable | 0.1351 | 0.9498 |
| Average | 70.39 | fairly | | |

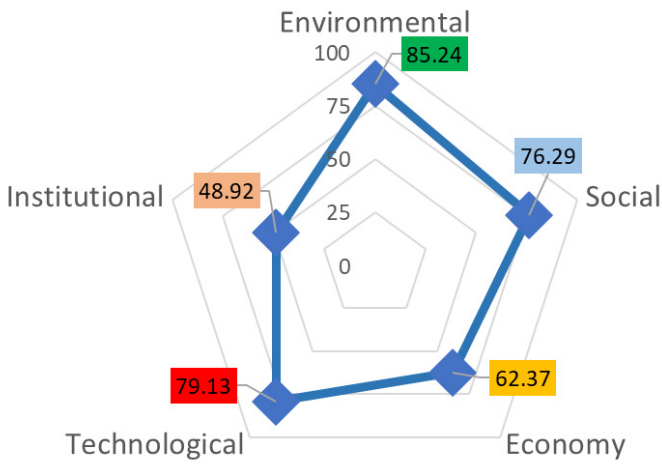


Fig. 1: Sustainability status of CBEV conversion program

expert's evaluation results. The sustainability index calculation results were outlined in Table 3.

MDS analysis findings for the performance of CBEV program are 70.37% on a sustainability scale of 0-100, with $R^2$ (SQR) > 0.94, indicating that it is quite category and fairly sustainable. This value represents the culmination of appraising 37 attributes across five distinct dimensions. The environmental dimension has an index value of 85.24%, the social dimension has 76.29%, the economic dimension has 62.37%, the technological dimension has 79.13%, and the institutional dimension has 48.92%. The results of the sustainability analysis can be seen in Fig. 1 and Table 3.

*Environmental dimension*

Among the various aspects, the environmental dimension stands out by providing the greatest value, as evidenced by a sustainability index score of 85.24%. The attribute that has the highest impact, at 4.65%, is the accessibility of treatment facilities for waste materials that can be utilized by others. On the other hand, the most impactful environmental attribute was generated of air and water pollution (3.16-3.44%) (Fig. 2). The increase in the number of workshops, both small and large scale workshops, as a result of this conversion program will increase the potential for workshop waste which can cause serious problems for the environment. The process of electric vehicle conversion entails the transformation of traditional fossil fuel-based vehicles into electric vehicles through the replacement of internal combustion engines and fuel delivery systems with electric motors and rechargeable batteries (Zaenuri *et al*., 2023). The waste produced by the workshop is divided into two, namely: metal solid waste (pieces of metal nuts/screws, used welding waste) and non-metal (used tires/rubber, foam, synthetic leather, used rags or fabrics that have been contaminated by oil/ solvent, dry paint, etc.) (Tchobanoglous *et al*., 2014). Waste generated during the conversion process includes engine and fuel system components extracted from the motor body, as well as supplementary part kits that enhance fuel engine functionality (Matasova and Tupov, 2020). In order to mitigate the impact of this waste, workshop

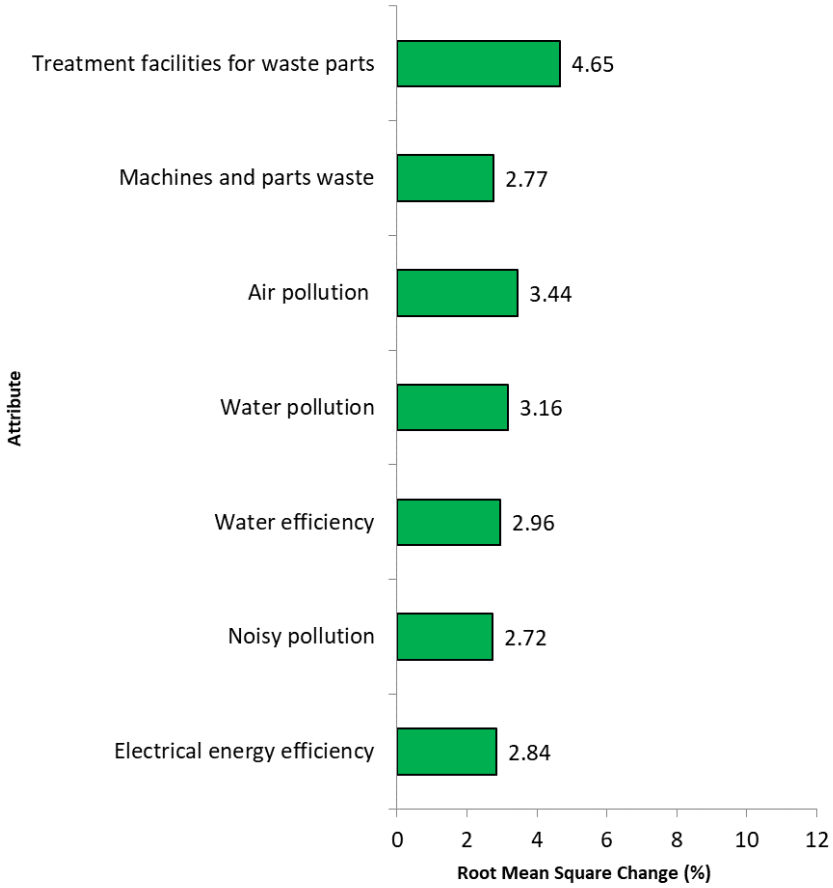


Fig. 2: Leverage of environment attributes

owners should prioritize a number of waste handling initiatives. Waste fuel engine systems can be utilized and modified to become motors that drive several agricultural machines or small industrial machines, such as grass cutters, corn harvesting machines, food chopping machines, etc. (Bouchiat *et al*., 2023). Utilization and modification of motors into various new machines necessitates the modification of their transmission systems. This is due to the fact that motorcycle engines, known for their high torque, need to be adjusted to suit the specific torque power requirements of the new machines, which may call for medium or low torque power (Lomonova *et al*., 2002).

It is important to anticipate the disposal of other motorbike parts, such as exhaust systems, cables, and fuel systems, in order to minimize their environmental impact. Therefore, it is recommended that every conversion workshop have a waste treatment facility unit (Salem *et al*., 2023). For small workshops that still do not have waste facilities, the workshop is expected to have a standard operation procedure (SOP) for waste management that regulates the management of conversion part waste for processing to other parties (Andriyani *et al*., 2024). It is crucial to consider the possibility of water and air pollution during the conversion process. Electric vehicles have the potential to decrease greenhouse gas emissions by 4.5% in countries like Indonesia through the implementation of recycling within a closed-loop cycle (Sakunai *et al*., 2021). The hybrid electric vehicles (HEV) confirmed an excellent alternative to battery electric vehicles (ICEV), showing good compromise between global warming (GW) impact (85% with respect to the ICEV), terrestrial acidification, and particulate formation, similar to the ICEV (Pipitone *et al*., 2021). Water

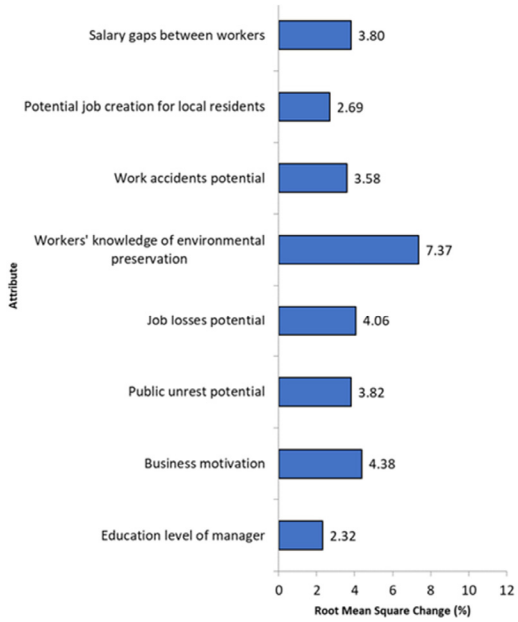


Fig. 3: Leverage of social attributes

pollution may come from waste motor oil and other motorbike waste that flows into the water drain. In order to prevent water wastage, it is essential to establish workshops with a more precise layout and conversion area to avoid the contamination of public drains with oil and other waste materials. The collected waste oil can be distributed to other parties to be reused (Tchobanoglous *et al*., 2014).

*Social dimension*

Based on the MDS Sustainability Index analysis of the converted electrical motorcycle program, the sustainability index value of the dimension was 76.29%, indicating a fairly sustainable state. This implied that the societal involvement in the sustainability of the converted electric motorcycle project was quite favorable. The leverage analysis results for the social dimension showed that workers' knowledge of environmental preservation, business motivation, and job loss potential were the attributes with a dominant influence on the sustainability index value. According to Habibie *et al*. (2022), the shift from conventional motorcycles to electric motorcycles could result in possible job displacement, suggesting that those who make the switch will enjoy additional. Using an ICE motorcycle requires queuing at gas stations for refueling. In addition, they need to allocate time to maintain the engine and other parts at a motorcycle workshop, while electric motorcycle owners do not need to maintain the electric motor engine at a workshop. Meanwhile, the job loss potential attribute, as discussed in Heylen *et al.* (2020), shows that training provides significant and measurable benefits for welfare and economic growth without causing significant negative impacts on the environment. This approach has the capability to target additional influential factors (characteristics) within the societal realm, including the risk of unemployment resulting from the shift from motorcycles to electric vehicles. The leverage analysis results for the social dimension (Fig. 3) showed that out of the eight attributes analyzed, three sensitive attributes significantly influenced the sustainability of the activity, workers' knowledge of environmental preservation, business motivation, and job loss potential.

The close connection between the social and economic dimensions is further highlighted by the correlation between business incentives, the market adoption of conversion services, and the rate of business success. Huang *et al.* (2021), revealed that technological knowledge is positively related to someone's intention to adopt EV. The manager's level of education and the potential for job creation among




Fig. 4: Leverage of economic attributes

local residents are two social dimension attributes that exhibit minimal impact on the sustainability of the activity. This indicates that electric motorcycle conversion activities do not require managers with a high education level, as some industries have developed plug-in conversion kits. Therefore, workshop managers with a Bachelor's degree or even a Vocational High School education level and at least 2 to 5 years of experience in motorcycle workshops are sufficient, as stated by Sari *et al*. (2020) that the most important factors are coaching and training. Job opportunities for local residents are primarily available during the early phase of motorcycle conversion to electric vehicles. However, these opportunities are expected to diminish considerably as the demand for converting fossil fuel motorcycles decreases over time.

*Economic dimension*

The MDS analysis has shown that the sustainability index for the economic dimension is 62.37%, a bit below the overall average of 70.39% (Table 4). This indicates that the economic dimension is in the adequate category (Arofi *et al*., 2015), contributing to the total average of 88.61% for all dimensions. With a stress value of 0.1385 and an R2 of 0.9484, the sustainability index demonstrates strong validity (Table 3). The attribute of market absorption of conversion services has shown the highest RMS change of 7.20% among the other six attributes in the leverage of economic dimension (Fig. 4). This indicates that market absorption of conversion services intends to be riskier due to the CBEV program being considered a new product and not widely known by the public. The disparity in supply and demand for BEV necessitates the enhancement of pricing and commercialization strategies to address market uncertainty. Proof and Focjik (2016) stated that information acceleration can improve traditional linear customer information acquisition approaches. This resulted in the calculation of appropriate pricing and marketing strategies during the initial stages of decision-making, thereby enhancing decision-making processes in the face of market unpredictability. In addition, the complexities surrounding BEV diffusion emphasize the importance of assessing

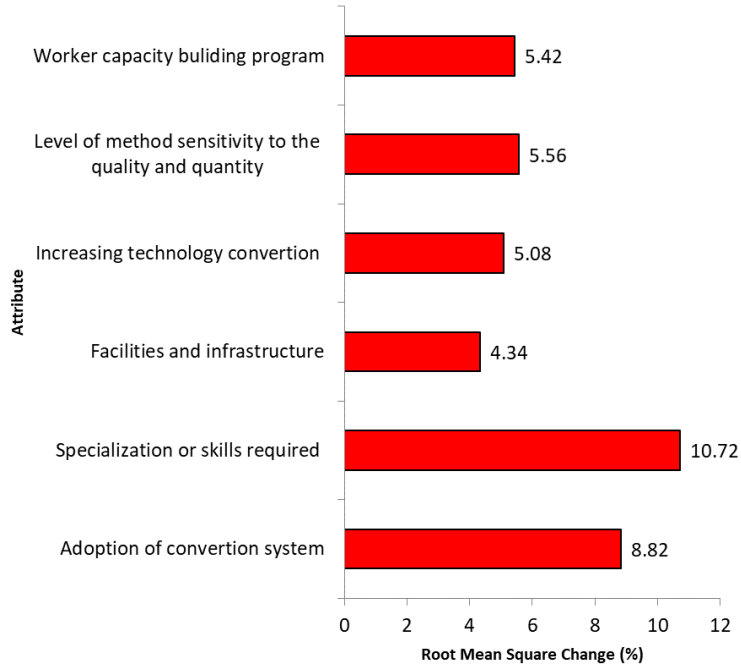


Fig. 5: Leverage of technology attributes

market penetration from an integrated perspective, considering the interaction between technology and behaviour (Martino *et al*., 2012). Neubauer and Pesaran (2013) have previously demonstrated that the elevated expenses associated with battery replacement and apprehensions regarding costs can dissuade prospective purchasers. This, in turn, could exacerbate the ambiguity surrounding the market acceptance of BEV conversion services. The importance of raw materials availability in production ranked second in the leverage of economic dimension with the RMS change of 6.03. This is very crucial due to the emerging nature of BEVs. Despite the accessibility of batteries and various components in the market, their prices remain relatively high, underscoring the obstacles confronting the industry. Karabelli *et al*. (2020) pointed out that the demand for critical materials for BEV's components underscores the necessity to ensure a stable supply chain to support the growth of sustainable mobility solutions. Furthermore, the strategic importance of sourcing raw materials goes beyond the production of battery BEV, presenting a wider obstacle for the technology industry in developed countries (Helmers, 2014). Efforts to address these challenges require collaboration among stakeholders along the entire supply chain, including processing industries, raw material suppliers, recycling companies, policymakers, and the public. Another element to consider is the characteristic of business success rate, which demonstrates an RMS fluctuation of 5.81%. This indicates that business success in BEV conversion services is a relatively new business in Indonesia requiring special attention. Several factors influence this, including public awareness campaigns (Sabyasachi *et al*., 2024). It is essential to implement these campaigns in order to efficiently expand BEV conversion services and accommodate the growing demand. Despite the readiness of workshops to serve customers based on field results, the current low demand is leading to a decreased rate of business success. Additionally, simplifying business processes involving government collaboration is essential, as the conversion process requires official vehicle documentation changes, which can be time-consuming. Therefore, as Ma and Yang (2024) explained, collaboration between the government and the private sector is vital for fostering innovations, ultimately enhancing the success rate of BEV conversions.

The study is primarily concerned with evaluating the sustainability of transitioning motorcycles to electric vehicles in Indonesia. The three attributes that are considered critical to achieve economic sustainability are market absorption of conversion services, availability of raw material, and may affect the success of the conversion motorcycles services business. Hence, the study has not yet examined the economic consequences concerning the expenses linked to costs and the possible reductions in fuel and maintenance expenditures. A previous study by Suwignyo *et al*. (2022) has found that converting to electric vehicles may save up to 68% of their income. In addition, the research conducted by Imansuri *et al.* (2023) revealed that the production cost per unit for electric conversion motorcycles in Indonesia is estimated to be USD 645.

*Technological dimension*

The findings from the sustainability analysis of the five attributes indicate that the technology aspect demonstrates sustainability, as evidenced by a sustainability index score of 79.13%. This has shown and supports the results of research conducted by Vacchi *et al*. (2021) that technology can be seen as a key dimension of sustainability along with the environment, society, and economy. In the technology dimension, the attributes that have the greatest influence is the specialization of skills required with a value of 10.72%, and adoption of conversion system with a value of 8.82%. Many scholars have explored the process of converting ICE vehicles into EVs through their research efforts (Ubaid *et al*., 2023; Gunawan *et al*., 2022). In line with this, the components needed to convert a conventional motorbike into an electric motorbike have been made in the form of a component package, making the conversion work easier. However, it is very necessary to have adequate worker skills in the mechanical and electrical fields. It is evident that specialized knowledge and skills, particularly in the areas of mechanics and electricity, are crucial for the successful transition of traditional motorcycles to electric motorcycles within the technological aspect of sustainability. Apart from that, it can be seen in the technology dimension table that adoption of the conversion system attribute has a high value, namely 8.82%. The attribute of method sensitivity to quality and quantity has showed an RMS score of 5.56%. It is imperative to establish regulations for this conversion program in order to address both technical and safety considerations, thereby safeguarding the well-being of users.

The relevant regulations are outlined in the Ministry of Transportation Regulation No. 39 of 2023. Every motorcycle that has undergone conversion and is intended for road use must meet technical and roadworthiness requirements to ensure safety. Type A workshops are responsible for conducting testing on converted motorcycles that possess a type test certificate derived from per-type testing, ensuring quality control measures are met. Several components are examined, including the battery pack, direct current (DC) to DC converter, electric motor, controller/inverter/electronic control unit, charger port, and other supporting equipment. The battery pack should undergo testing by a recognized institution to ensure compliance with either Indonesian national or international standards. Additionally, it should be securely mounted on the motorcycle using appropriate locking mechanisms. These type A workshops play a crucial role in maintaining standardization to support safety aspects of converted electric motorcycles. The demonstration illustrates the significant influence of this characteristic on the sustainability of technology. The simplicity of integrating the conversion system within local communities is expected to stimulate the proliferation of conversion workshops operating as micro, small and medium enterprises (MSMEs). This is in line with the research results presented by Osatis and Asavanirandorn (2022), that with the growth of conversion workshops, the need for skilled engineering-based personnel, especially Mechanical Engineering and Electrical Engineering, who come from automotive and electrical vocational schools, will increase.

*Institutional dimension*

The sustainability of the program to convert ICE motorcycles to CBEV motorcycles in Indonesia faces several challenges due to existing institutional arrangements. The obstacles encompass regulatory disintegration, collaboration among governmental bodies, enhancement of capabilities, and financial structures. It is imperative for the government of Indonesia to create a comprehensive electric vehicle ecosystem, with a strong emphasis on the

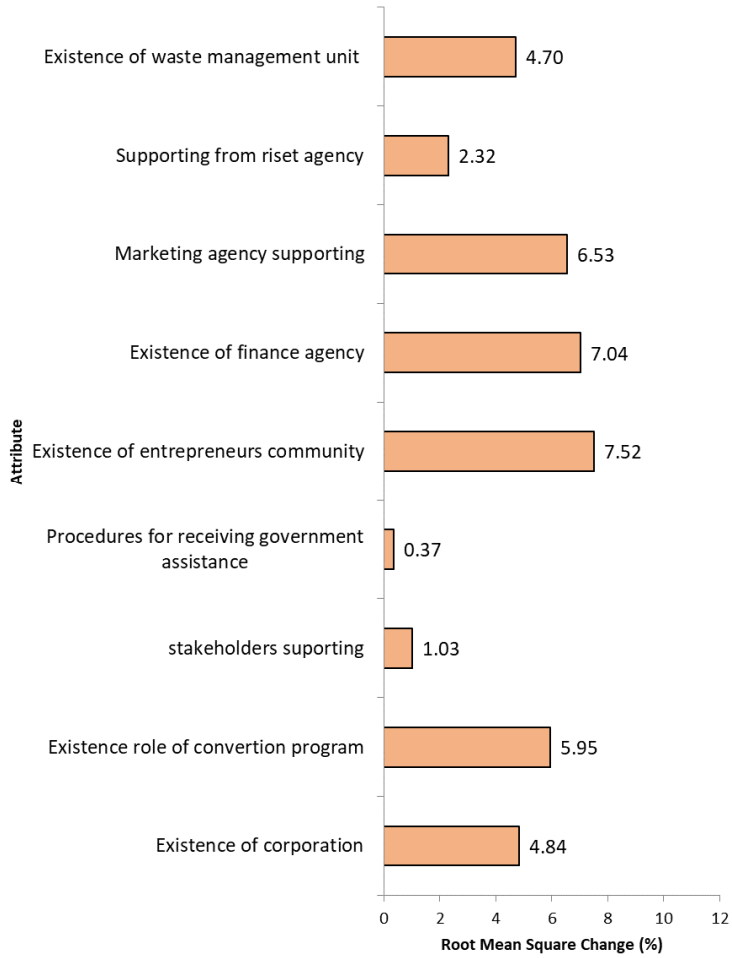


Fig. 6: Leverage of institutional attributes

implementation of integrated policies, infrastructure enhancement, and engagement with stakeholders (Hasudungan *et al*., 2023). Based on the MDS analysis using a Rapfish program, the sustainability index for the institutional dimension stands at 48.92%, with a stress value of 0.1351 and an R square of 0.9498, indicating a high degree of model fit and reliability in the data quality. Institutional sustainability index contributes to the lowest value between the other dimensions. The entrepreneurial community, financial agencies, and marketing agencies are identified as the three most significant attributes, with percentages of 7.52%, 7.04%, and 6.53% respectively. A waste management unit is critical in handling the disposal and recycling of old motorcycle parts and batteries, ensuring environmental sustainability. The significant contribution (4.70) emphasizes the importance of environmental management in facilitating the conversion program. This analysis suggest that every conversion workshop should have a waste treatment facility unit (Salem *et al*., 2023). Research agencies provide essential data, technological advancements, and innovation necessary for the successful implementation of the conversion program. The modest contribution (2.32) suggests potential for greater engagement and backing from research organizations. Marketing agencies play a crucial role in promoting the conversion program, raising public awareness, and driving consumer adoption. This significant

contribution (6.53) underscores the importance of effective marketing strategies in program success. The high contribution score (7.04) for financial institutions in supporting the conversion of ICE motorcycles to CBEV motorcycles in Indonesia highlights the critical role of financial support in facilitating this transition. The significance of loans, subsidies, and financial incentives is evident in addressing the economic obstacles linked to the initial substantial expenses of conversion and adoption. In Indonesia, integrating financial institutions into the conversion program could provide the much-needed push for widespread adoption. Robust financial support mechanisms will be essential in ensuring the program's success and long-term viability. However, funding mechanism is identified too complicated and takes too long. Governments around the world are taking a leading role in hastening this transition through the provision of incentives and subsidies aimed at boosting the uptake of electric vehicles. One significant effect of government incentives is the lowering of the upfront expenses associated with electric vehicles. This makes EVs more competitive with ICE vehicles, especially in terms of total cost of ownership. Consumers are more likely to consider an electric vehicle when they see it as an economically attractive option. It is crucial to have streamlined and easily accessible processes in place for individuals to obtain government aid in order to promote engagement in the conversion initiative at Rp 10 million per unit. This incentive value has increased from the previous Rp 7 million per unit. The increase in the electric motorcycle conversion incentive is stipulated in the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 13 of 2023. The presence of entrepreneurial communities is pivotal in stimulating innovation and opening up avenues for business development, particularly in the sphere of transforming combustion engine motorcycles to electric motorcycles. This influence is reflected in the highest contribution score (7.52) in the sustainability index. The presence of a vibrant entrepreneurial community can drive the innovations and adoption of new technologies (Zhang *et al*., 2024), such as electric motorcycles, by providing a supportive ecosystem for start-ups and established businesses alike. It is crucial to have streamlined and easily accessible processes in place for individuals to obtain government aid in order to promote engagement in the conversion initiative. The minimal contribution (0.37) indicates a need for improving the efficiency and accessibility of government assistance programs. Support from various stakeholders, including industry players, government agencies, and non-profits, is crucial for a cohesive and coordinated effort. The minimal level of contribution (1.03) indicates the necessity to enhance stakeholder engagement and support. The conversion program itself must be well-defined, managed, and integrated into broader sustainability initiatives. The significant contribution (5.95) demonstrates the program's central role in achieving sustainability goals. Corporate engagement, by means of financial backing and active involvement, has the potential to propel significant advancements and creativity in the process of conversion on a massive scale. The moderate contribution (4.84) indicates that while corporations play a crucial role, there is potential for increased corporate engagement. Corporate engagement, by means of financial backing and active involvement, has the potential to propel significant advancements and creativity in the process of conversion on a massive scale.

With an overall sustainability index of 48.92%, the analysis highlights the substantial contributions of financial support, marketing, and entrepreneurial communities. Nevertheless, it also highlights areas that require enhancement, including government aid processes and involvement of stakeholders. The high R square value (0.9498) confirms the reliability of these findings, providing a robust framework for policymakers and stakeholders to enhance the sustainability of the conversion program.

*Future and prospect for engine conversion program*

The shift from traditional combustion engine vehicles to electric vehicles, such as electric motorcycles, has garnered significant attention from countries globally as they strive to transition their transportation energy towards meeting the net zero emission goals established by numerous nations. By using electric vehicles, dependence on fossil fuels will be reduced, as will fuel imports, contributing to energy stability and security in the future. Especially for oil-importing countries, fluctuations in oil prices significantly impact the economy. A potential method to incentivize the transition of vehicles to electric models involves a program focused on converting ICE motorcycles to CBEV motorcycles. From the results

of various sustainable dimensions, we can see that various efforts are needed to push this conversion program. Considering the number of motorcycles, 125.3 million units in 2022, this conversion program is indeed very attractive and necessary to reduce various issues such as fuel imports, fuel subsidies, and air pollution. The apprehensions regarding waste generated by the motorcycle conversion process have unveiled potential business prospects in the form of reusing or recycling components to create fresh raw materials. Additionally, by converting to CBEV motorcycles, users gain various benefits, including having more free time since they do not need to queue at gas stations for refueling, and not needing to maintain electric motors at workshops due to minimal maintenance requirements. From an economic standpoint, utilizing electric motorcycles is far more cost-effective than using ICE motorcycles, given that the operational and maintenance expenses of CBEV motorcycles are notably reduced in comparison to ICE motorcycles. Moreover, converting millions or tens of millions of motorcycles will build ecosystems such as the lithium battery industry, electric motors, and controllers that require tens of millions of components for conversion. Additionally, the implementation of the program will require many conversion workshops with skilled technicians to carry out the conversions. The skill in converting motorcycles can be elevated to further the development and construction of CBEV motorcycles. Currently, the government provides a subsidy of 10 million rupiahs per converted motorcycle unit to cover the high initial costs of conversion and adoption. In the event that this conversion program achieves economic feasibility, the costs associated with the conversion will decrease, thereby presenting an appealing prospect for financial institutions to offer loans for the execution of this conversion.

## CONCLUSION

The sustainability of transitioning ICE motorcycles to CBEVs in Indonesia is noteworthy, especially when evaluated from five critical perspectives: environmental, social, economic, technological, and institutional. However, the institutional dimension lags in terms of environmental friendliness. The development of a conversion program necessitates careful consideration of 37 critical characteristics, with certain attributes requiring targeted enhancement due to their substantial influence on the overall sustainability of the program. The conversion of electric vehicles in Indonesia presents a notable sustainability potential in terms of the environmental aspect, as evidenced by a substantia sustainability index score of 85.24%. Effective waste management, particularly in workshops, is crucial to mitigate the environmental impact of increased workshop waste, which includes both metal and non-metal waste from the conversion process. The adaptation and utilization of waste fuel engine systems in agricultural and industrial equipment can help mitigate environmental impacts. Workshops should establish waste treatment facilities or standard operating procedures for waste management to prevent air and water pollution, thus ensuring that the environmental benefits of electric vehicle conversion are maximized. The electric motorcycle conversion program in Indonesia exhibits a relatively sustainable social dimension, boasting a sustainability index value of 76.29%. Key factors influencing this sustainability include workers' knowledge of environmental preservation, business motivation, and potential job loss. While electric motorcycles reduce time spent on refuelling and maintenance, job losses in traditional motorcycle services can be mitigated through training programs that support economic growth without harming the environment. The correlation between social and economic aspects highlights the significance of market penetration and the rates of business achievement. Workshop managers are not required to possess extensive educational credentials; practical experience and training are deemed satisfactory for the role. However, job creation from the conversion process is mainly limited to the initial stages, decreasing as the number of internal combustion engine motorcycles diminishes. The economic dimension of the electric motorcycle conversion program in Indonesia has a sustainability index of 62.37%, indicating it is adequate but below the overall average of 70.39%. The market absorption of conversion services is the most influential factor, with significant risks due to the novelty of BEV and market uncertainties. Improved pricing and commercialization strategies are essential to address this. The availability and cost of raw materials, especially batteries, present further challenges, requiring a stable supply chain and stakeholder collaboration. Business success rates are currently low due to limited demand, underscoring the need for public awareness campaigns and

streamlined government collaboration for vehicle documentation changes. Overall, the key to improving the sustainability and prosperity of BEV conversion services lies in addressing these economic challenges. conversion services. The technological dimension of the electric motorcycle conversion program in Indonesia is sustainable, with a high sustainability index value of 79.13%. The specialization of skills and the adoption of the conversion system are the most influential attributes, emphasizing the need for workers skilled in mechanical and electrical fields. The ease of implementing the conversion system fosters the growth of conversion workshops, increasing demand for skilled personnel from vocational schools. Continuous capacity building for employees is essential to keep pace with technological advancements and improve workshop innovations. Overall, developing competencies via formal and informal education is essential for maintaining the technological aspect of the transformation initiative. The institutional dimension of the electric motorcycle conversion program in Indonesia faces significant challenges, reflected in a sustainability index value of 48.92%. Key issues include regulatory fragmentation, coordination between government agencies, and complex funding mechanisms. Vital components for enhancement include the backing from entrepreneurial networks, financial establishments, and marketing firms, all of which have pivotal functions in encouraging acceptance and easing the shift. Overall, the electric motorcycle conversion program in Indonesia exhibits strong potential in environmental and technological sustainability, driven by effective waste management and the need for skilled labor. However, significant challenges remain in the economic and institutional dimensions. Addressing these challenges through better market strategies, financial support, and regulatory coordination is crucial for enhancing the program's overall sustainability and success. Quantitative metrics, such as sustainability index ratings and enhancements to specific attributes, offer a precise guide for focused enhancements and emphasize the significance of a comprehensive strategy in attaining sustainable conversion to electric vehicles.

## AUTHOR CONTRIBUTIONS

A.D. Santoso conducted the literature review, designed the experiments, oversaw the work, and wrote the manuscript; H. Daulay conducted a literature study, experimented, and authored and edited the manuscript; A. Priyanti assisted with experimental and administrative tasks, as well as providing technical and material support; U.K. Yaumidin conducted a thorough analysis of the manuscript's substantial worth. N. Irawati assisted with experimentation and data collection; H. Sumartono analyzed and interpreted the data; The statistical analysis was performed by V.M.M. Silalahi; P. Astuti prepared and revised the manuscript; A.R. Farandy edited and supervised written works; A. Parikesit was in charge of overseeing all experimental and textual works; M.F. Manti is responsible for the manuscript's validation and generation; W. Joelijani was responsible for the manuscript's creation, validation, and generation; E. Indriasari connects literature evaluation and data recognition; S. Wahyuni assisted with experimentation and data collection.

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## CONFLICT OF INTEREST

The authors declare that there are no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were observed by the authors.

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## ABBREVIATIONS

| | |
|---|---|
| *%* | Percent |
| *ASCAL* | Multidimensional scaling, other name biside MDS |
| *BEV* | Battery-powered electric vehicle |
| *BPS* | Badan pusat statistik (Central Bureau of Statistics) |
| $CO_2$ | Carbon dioxide |
| *CBEV* | Converted battery-powered electric vehicle |
| *d* | Euclidian distance |
| $d_{ij}$ | Euclidian distance from point i to point j |
| $d_{ijk}$ | Squared distance |
| *Eq* | Equation |
| *EV* | Electric vehicle |
| *Fe* | Iron |
| *FGD* | Focus group discussion |
| *GHGs* | Greenhouse gases |
| *I, J, K* | Dimension |
| *ICE* | Internal combustion engine |
| *MDS* | Multidimensional scaling |
| *MSMEs* | Micro, small and medium enterprises |
| *NDC* | National determined contribution |
| $O_{ijk}$ | Point of origin |
| *Rapfish* | Rapid appraisal for fisheries |
| *S* | Stress |
| *SOP* | standart operation prosedure |
| *SQR* | Structured query reporter |
| *USD* | United state dolar |
| *Rap* | Rapid appraisal |
| *RMS* | Root mean square |
| $R^2$ | Root mean square |
| *y* | Year |

## REFERENCES

Allaily A.; Santoso, A.D.; Rofiq, M.N.; Sasongko, N.A.; Daulay, H.; Wiloso, E.I.; Widjaja, E.; Utomo, B.N.; Yanuar, A.I.; Suryani, S., Erlambang, Y.; Thiyas, U.; Iskandar, D.; Anhar, A.; Rahmawati, M.; Simamora, T.; Yusriani, Y.; Maghfirah, G.; Ammar, M., (2024). Sustainability assessment of animal feed production from by-products of Sago palm smallholder industry. Global J. Environ. Sci. Manage., 10(3): 1275-1296 (**22 pages**).

Alder, J.; Pitcher, T.J.; Preikshot, D.; Kristin, K.; Ferriss, B., (2000). How good is good? A rapid appraisal technique for evaluation of the sustainability status of fisheries of the North Atlantic. Fisheries Centre, University of British Columbia, Canada **(47 pages)**.

Amato, P.R., (1990). Dimensions of the family environment as perceived by children: A multidimensional scaling analysis. J. Marriage Fam., 52(3):613–620 (**7 pages**).

Amusa, H.K.; Sadiq, M.; Alam, G.; Alam, R.; Siefan, A.; Ibrahim, H.; Raza, A.; Yildiz, B., (2024). Electric vehicle batteries waste management and recycling challenges: A comprehensive review of green technologies and future prospects. J. Mater. Cycles Waste Manage., 26:1959–1978 (**20 pages**).

Andriyani, N.; Suprobo, P.; Adi, T.J.W.; Aspar, W.A.N.; , Jatmiko, A.D.; Santoso, A.D., (2024). Integrating urban building information modeling and circular economy framework for green sustainablility. Global J. Environ. Sci. Manage., 10(3): 1313-1332 (**20 pages**).

Arofi, F.; Rukmana, D.; Ibrahim, B., (2015). The analysis of integration sustainability of coffee plantation and goat husbandry: A case study in Ampelgading subdistrict, Malang Regency, East Java, Indonesia. J. Economics Sustainable Dev., 6(10): 1-8 (**8 pages**).

Bakrie, B.; Sirnawati, E.; Rohaeni, E.S.; Hutahaean, L.; Santoso, A.D.; Wasito, W.; Indrawanto, C., (2023). Sustainability analysis of intensive duck farming system in Sliyeg District, Indonesia: MDS and MICMAC analysis approach. Intl. J. Sustainable Dev. Plan., 18(10): 3181-3193 (**13 pages**).

Bouchiat, R.; Veignie, E.; Kaczmarek, F.; Dorchy, J.; Fortunato, A.D.; Rafin, C.A., (2023). A comprehensive review of risk assessments of organic effluents in car workshops. Environments. 10(12): 220 (**15 pages**).

Collin, R.; Miao, Y.; Yokochi, A.; Enjeti, P.; Von Jouanne, A., (2019). Advanced electric vehicle fast-charging technologies. Energies. 12(10): 1839 (**26 pages**).

Darmoyono, I., (2024). Study on challenges and opportunities for electric vehicle development for land-based public transport sector in cities of Indonesia. The Economic and Social Commission for Asia and the Pacific (ESCAP). Jakarta.

Fairuzia, N.; Krisnamurthi, B.; Rifin, A., (2020). Analysis of sustainability status of cocoa plantation smallholders. IOP Conference Series: Earth Environ. Sci., 486: 012001 **(8 pages).**

Ferlinda, I.; Pujiyanto, E.; Hisjam, M., (2024). Analysis of sustainable business models in electric motorcycle rental. E3S Web of Conference. 517: 05012 **(6 pages)**.

Gabbar, H.A.; Othman, A.M.; Abdussami, M.R., (2021). Review of

battery management systems (BMS) development and industrial standards. Technologies. 9(2): 28 (**23 pages**).

Garg, P.; Kumar, A.; Mittal, R.K., (2023). What drives consumers' sustainable mobility behavior? An empirical investigation. Vis. Sustainable. 19: 289-319 (**11 pages**).

Gunawan, Y.; Supriatna, N.K.; Firmansyah, A.I.; Slamet, S.; Wicaksono, N.A.; Ahadi, K.; Fadhilah, N.R., (2022). Endurance testing of the electric vehicle that converted from the internal combustion engine vehicle. Intl. J. Sustainable Transp. Technol., *5*(2): 61-69 (**9 pages**).

Habibie, A.; Hisjam, M.; Sutopo, W.; Nizam, M., (2021). Sustainability evaluation of internal combustion engine motorcycle to electric motorcycle conversion. Evergreen. 8(2): 469-476 (**8 pages**).

Hasudungan, A.; Waskito, A.S.; Banjaransari, A.; Sanjaya, A.; Ferlito, C.; Pramudya, E.P.; Gracelle, F.; Matthew, J.A.; Widjaja, N.; Casadio, P.; Ismail, R., (2023). Indonesia economic and business outlook 2023. Prasetiya Mulya Publishing, Jakarta.

Helmers, E. (2015). Possible Resource Restrictions for the Future Large-Scale Production of Electric Cars. In: Hartard, S., Liebert, W. (eds) Competition and Conflicts on Resource Use. Nat. Resour. Manage. Policy. 46. Springer.

Heylen, C.; Meunier, F.; Peeters, A.; Ek, S.; Neang, M.; Hean, S.; Peanh, S., (2020). Multidimensional benefits of sustainable agriculture practices of Cambodian smallholder farmers. Sustainable Agric. Res., 9(1):10-25 (**16 pages**).

Hout, M.C.; Papesh, M.H.; Goldinger, S.D., (2013). Multidimensional scaling, WIREs Cogn. Sci., (4): 93-103 **(11 pages)**.

Huang, X.; Lin, Y.; Lim, M.K.; Tseng, M.L.; Zhou, F., (2021). The influence of knowledge management on adoption intention of electric vehicles: perspective on technological knowledge. Industrial Manage. Data Syst., 121(7): 1481-1495 (**15 pages**).

Imansuri, F.; Wirandi, M.; Sumasto, F.; Aisyah, S.; Permana, A.K., (2023). Investment feasibility study of implementing electric conversion motorcycle in Indonesia: A sustainable development perspective. J. Ind. Services. 9(2): 81-86 (**6 pages**).

Karabelli, D.; Kiemel, S.; Singh, S.; Koller, J.; Ehrenberger, S.; Miehe, R.; Weeber, M.; Birke, K.P., (2020). Tackling xEV battery chemistry in view of raw material supply shortfalls. Frontiers in Energy Res., 8: 594857 (**13 pages**).

Kavanagh, P.; Pitcher, T.J., (2004). Implementing microsoft excel software for rapfish: A technique for the rapid appraisal of fisheries status. Fish. Center Res. Rep., 12(2): 1-75 **(75 pages)**.

Kenkel, N.C. and Orloci. L., (1986). Applying metric and nonmetric multidimensional scaling to ecological studies: some new results. Ecology. 67: 919–928 **(10 pages)**.

Kumar, R.R.; Alok, K., (2020). Adoption of electric vehicle: A literature review and prospects for sustainability, J. Cleaner Prod., 253: 119911 (**21 pages**).

Lomonova, E.A.; Vandenput, A.J.A.; Rubacek, J.; d'Herripon, B.; Roovers, G., (2002). Development of an improved electrically assisted bicycle. IEEE Industry Applications Conference. 37: 384-389 (**6 pages**).

Lovarelli, D.; Bacenetti, J.; Guarino, M., (2020). A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production?. J. Cleaner Prod., 262: 121409 ( **13 pages**).

Lloyd, C.; Ananthan, P.S.; Ramasubramanian, V.; Sugunan, V.V.; Panikkar, P.; Landge, A.T., (2022). Rapid reservoir fisheries appraisal (r-RAPFISH): Indicator based framework for sustainable fish production in Indian reservoirs. J. Cleaner Prod., 379: 134435 **(17 pages).**

Ma, J.; Yang, D., (2024). Research on the mechanism of government-industry-university-research collaboration for cultivating innovative talent based on game theory. Heliyon. 10(3): 25335 (**20 pages**).

Martino, T.; Banister, D.; Bishop, J.D.K.; McCulloch, M., (2012). Realizing the Electric Vehicle Revolution. Nature Publishing Group, 2(5): 328-333 **(6 pages).**

Matasova, O.; Tupov, V., (2020). Calculation of the required noise reduction of a engine exhaust system. MATEC Web of Conferences. 320: 00017 (**9 pages**).

Neubauer, J.S.; Pesaran, A., (2013). A Techno-Economic Analysis of BEV Service Providers Offering Battery Swapping Services. National Renewable Energy Laboratory, Detroit, Michigan.

Novotny, A.; Szeberin, I.; Kovács, S.; Máté, D., (2022). National culture and the market development of battery electric vehicles in 21 countries. Energies. 15:1539 (**16 pages**).

Oryani, B.; Kamyab, H.; Moridian, A.; Azizi, Z.; Rezania, S.; Chelliapan, S., (2022). Does structural change boost the energy demand in a fossil fuel-driven economy? New evidence from Iran. Energy. 254: 124391 (**12 pages**).

Osatis, C.; Asavanirandorn, C., (2022). An exploring Human resource development in small and medium enterprises in response to electric vehicle industry development. World Electr. Veh. J., 13(6): 98 (**13 pages**).

Oyelaran-Oyeyinka, B.; Lal, K., (2006). Learning new technologies by small and medium enterprises in developing countries. Technovation. 26(2): 220-231 (**12 pages**).

Paczka, G.; Mazur-Pączka, A.; Garczyńska, M.; Kostecka, J.; Butt, K.R., (2021). Garlic (Allium sativum L.) Cultivation using vermicompost-amended soil as an aspect of sustainable plant product ion. Sustainability. 13(24): 13557 (**11 pages**).

Pipitone, E.; Caltabellotta, S.; Occhipinti, L., (2021). A life cycles environmental impact comparison between traditional, hybrid, and electric vehicles in the European context. Sustainability. 13(19): 10992 (**32 pages**).

Pitcher, T.J.; Preikshot, D., (2001). RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fish. Res., 49(3): 255-270 **(16 pages).**

Proof, H.; Focjik, T., (2016). Pricing and commercialisation of electric mobility-dealing with high market uncertainty. Intl. J. Technol. Manage. 16(1): 30-54 **(25 pages).**

Rachman, B.; Ariningsih, E.; Sudaryanto, T.; Ariani, M.; Septanti, K.S.; Adawiyah, C.R.; Ashari; Agustian, A.; Saliem, H.P.; Tarigan, H.; Syahyuti; Yuniarti, E., (2022). Sustainability status, sensitive and key factors for increasing rice production: A case study in West Java, Indonesia. PLOS ONE. 17(12): 1-19 (**19 pages**).

Rohaeni, E.S.; Santoso, A.D.; Ariningsih, E.; Widaningsih, N.; Hutahaean, L.; Priyanto, D.; Ilham, N.; Suharyon, S.; Herdis, H.; Widiawati, Y.; Hadiatry, M.C.; Ermuna, S.S.; Mardiharini, M.; Sugandi, D.; Bakrie, B.; Wasito, W., (2023). Analysing the sustainability of swamp buffalo (*Bubalus bubalis carabauesis*) farming as a protein source and germplasm. Open Agric., 8(1): 20220224 (**23 pages**).

Rohaeni, E.S.; Mailena, E.; Lesmayati, S.; Ermuna, S.S., (2021). Sustainability analysis for rice and duck farming in swampy land, Hulu Sungai Utara Regency, South Kalimantan. IOP Conf. Ser.: Earth Environ. Sci., 648: 012134 (**16 pages**).

Rohaeni, E.S.; Ilham, N.; Saptati, R.A.; Rahayu, H.S.P.; Priyono, P.; Anggraeny, Y.N.; Qomariah, R.; Pamungkas, D.; Ermuna, S.S.; Mahendri, I.G.A.P.; Mariyono, M.; Darsani, Y.R.; Hutahaean, L.; Praptana, R.H.; Lesmayati, S.; Ahmad, S.N.; Bahar, S.; Suhartini, S.H.; Santoso, A.D.; Rakhmani, S.I.W., (2024). Developing a sustainable beef cattle business model for smallholder farms in South Kalimantan's drylands. Intl. J. Sustainable Dev. Plann., 19(2): 481-500 (**20 pages**).

Rubino, L.; Capasso, C.; Veneri, O., (2017). Review on plug-in electric vehicle charging architectures integrated with distributed energy sources for sustainable mobility. Appl. Energy. 207: 438– 464 (**27 pages**).

Sabyasachi, S.; Singh, A.R.; Godse, R.; Jaiswal, S.; Bajaj, M.; Srivastava, I.; Blazek, V.; Prokop, L.; Misak, S. (2024). Reimagining E-mobility: A holistic business model for the electric vehicle charging ecosystem. Alexandria Eng. J., 93: 236–258 (**23 pages**).

Sakunai, T.; Ito, L.; Tokai, A., (2021). Environmental impact assessment on production and material supply stages of lithium-ion batteries with increasing demands for electric vehicles. J. Material Cycles Waste Manage., 23: 470-479 (**10 pages**).

Salem, K.S.; Clayson, K.; Salas, M.; Haque, N.; Rao, R.; Agate, S.; Singh, A.; Levis, J.W.; Mittal, A.; Yarbrough, J.M.; Venditti, R.A., (2023). Critical review of existing and emerging technologies and systems to optimize solid waste management for feed-stocks and energy conversion. Matter. 6(10): 3348-3377 (**30 pages**).

Santoso, A.D.; Hariyanti, J.; Pinardi, D.; Kusretuwardani; Widyastuti, N.; Djarot, I.N.; Handayani, T.; Sitomurni, I.; Apriyanto, H., (2023). Sustainability index analysis of microalgae cultivation from biorefinery palm oil mill effluent. Global J. Environ. Sci. Manage., 9(3): 559-576 (**18 pages**).

Santoso, A.D.; Arianti, F.D.; Rohaeni, E.S.; Haryanto, B.; Pertiwi, M.; Panggabean, L.P.; Prabowo, A.; Sundari, S.; Wijayanti, S.P.; Djarot, I.N.; Kurniawati, F.; Sahwan, F.L.; Prasetyo, T.; Barkah, A.; Adibroto, T.A.; Ridlo, R.; Febijanto, I.; Wasil, A.A.; Lusiana, S.; Rosmeika, R., Heryanto, R. B., (2023a). Sustainability index analysis of organic fertilizer production from paunch manure and rice straw waste. Global J. Environ. Sci. Manage., 9(SI): 193-218 (**26 pages**).

Santoso, A.D.; Handayani, T.; Nugroho, R.A.; Yanuar, A.I.; Nadirah, N.; Widjaja, E.; Rohaeni, E.S.; Oktaufik, M.A.M.; Ayuningtyas, U.; Erlambang, Y.P.; Herdioso, R.; Rofiq, M.N.; Hutapea, R.; Sihombing, A.L.; Rustianto, B.; Susila, I.M.A.D.; Irawan, D.; Iskandar, D.; Indrijarso, S.; Widiarta, G.D., (2023b). Sustainability index analysis of the black soldier flies *(Hermetia illucens)* cultivation from food waste substrate. Global J. Environ. Sci. Manage., 9(4): 851-870 **(20 pages).**

Sari, D.A.A.; Suryanto; Sudarwanto, A.S.; Nugraha, S.; Utomowati, R., (2021). Reduce marine debris policy in Indonesia. Earth Environ. Sci., 724(1): 012118 (**7 pages**).

Sivaraman, I.; Krishnan, M.; Radhakrishnan, K., (2019). Better management practices for sustainable small-scale shrimp farming. J. Cleaner Prod., 214: 559-572 (**14 pages**).

Sulaiman, I.A.; Nasution, Z.; Rauf, A.; Kusuma, M.S.B., (2021). Multidimensional scaling approach to evaluate sustainability status of belawan watershed management. IOP Conference Series: Earth and Environ. Sci., 912: 012064 (**8 pages**).

Suwignjo, P.; Yuniarto, M.N.; Nugraha, Y.U.; Desanti, A.F.; Sidharta, I.; Wiratno, S.E.; Yuwono, T., (2023). Benefits of electric motorcycle in improving personal sustainable economy: A view from Indonesia online ride-hailing rider. Intl. J. Technol., 14(1): 38-53 (**6 pages**).

Tchobanoglous, G.; Burton, F.L.; Stendel, H.D., (2014). Wastewater Engineering Treatment and Resource Recovery. 5 th Edition. New York: McGraw-Hill Education.

Ubaid, A.; Mazhar, A.R.; Riaz, Y.; Aziz, S.; Bhandari, K.S.; Jung, D.W., (2023). Development of an electric powertrain for the conversion of an ICE vehicle. International Conference on Metal Material Processes and Manufacturing. 44: 73-79 (**7 pages**).

Vacchi, M.; Siligardi, C.; Demaria, F.; Cedillo-González, E. I.; González-Sánchez, R.; Settembre-Blundo, D., (2021). Technological sustainability or sustainable technology? A multidimensional vision of sustainability in manufacturing. Sustainability. 13(17): 9942 (**18 pages**).

Veza, I.; Abas, M.A.; Djamari, D.W.; Tamaldin, N.; Endrasari, F.; Budiman, B.A.; Idris, M.; Opia, A.C.; Juangsa, F.B.; Aziz, M., (2022) Electric vehicles in Malaysia and Indonesia: Opportunities Challenges. Energies. 15(7):2564 (**24 pages**).

Wahyono, Y.; Irviandi, R.; Gilbran, A.; Panggabean, L.P.; Ridlo, R.; Sundari, S.; Suryaningtyas, A.D.; Prihatin, A.L.; Novianti, E.D.; Lestari, M.C.; Anisah, A. (2024). Study of carbon emissions in the use of fossil and renewable energy to Respond ro the urgency of a sustainable energy transition in Indonesia's group of twenty (G20) presidency: A short communication. In E3S Web of Conferences. 519: 03007 (**6 pages**).

World Resources Institute (WRI) Indonesia, 2023. Supporting Indonesia's achievement of net zero emissions target 2060, WRI Indonesia and the Ministry of Transportation Encourage Implementation of Land Transportation Climate Change Mitigation Action Strategy.

Widjaja, E., Utomo, B.N.; Santoso, A.D.; Erlambang, Y.P; Surono; Firmansyah, M.A.; Handoko, S.; Erythrina, E.; Rofiq, M.N.; Iskandar, D.; Sasongko, N.A.; Rochmadi, T.; Abbas, N.; Hanif, M.; Garno, Y.S.; Arianti, F.D.; Suretno, N.D.; Askinatin, M.; Hastuti, C.O.I.; Fahrodji, F., (2023). Sustainability index analysis for environmentally low-input integrated farming. Global J. Environ. Sci. Manage. 10(2): 1-20 (**20 pages**).

Yusuf, E.S.; Ariningsih, E.; Ashari, Gunawan, E.; Purba, H.J.; Suhartini, S.H.; Tarigan, H.; Syahyuti; Hestina, J.; Saputra, Y.H.; Wulandari, S.; Ilham, N.; Ariani, M., (2022). Sustainability of arabica coffee business in West Java, Indonesia: A multidimensional scaling approach. Open Agric., 7: 820–836 (**17 pages**).

Zainol, Z.; Toha, S.F.; Kamisan, N.A.; Bukhari, W.M.S.W., (2019). Design and development of a retrofit electric motorbike. Intl. J. Recent Technol. Eng., 7(6):71–75 (**5 pages**).

Zhang, Y.; Ding, C., (2023). Using MDS preference plot as visual analytics of data: A machine learning approach. Methodol. Innovations. 16(1): 205979912211445 (**11 pages**).

Zainuri, F.; Tullah, F.H.; Prasetya, M.; Susanto, S.; Purnama, I.; Subarkah, D.; Ramiati, R.; Widiyatmoko, T.; Noval, R., (2023). Electric vehicle conversion study for sustainable transport. Recent in Eng. Sci. Technol., 1(02): 18–24 (**7 pages**).

Zhang, Q.; Zhu, X.; Lee, M.J., (2024). Exploring institutional pressures, green innovation, and sustainable performance: Examining the mediated moderation role of entrepreneurial orientation. Sustainability. 16(5): 2058 (**20 pages**).

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