A Literature Review: Commercialization Study of Electric Motorcycle Conversion in Indonesia

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Abstract. The number of motorcycles in Indonesia increased very significantly in Indonesia at the last 10 years, reaching 300%. Automatically, its will make carbon pollution in Indonesia increasing. Electric motorcycle is one that can be used to remove carbon pollution. Indonesian government very concern about this by issuing Presidential Regulation Number 55 of 2019 for push and accelerate the electrification all vehicle in Indonesia including motorcycle. The goal of this study is to see the development of research on converting Internal Combustion Engine (ICE) motorcycles into electric motorcycle, both in the world and in Indonesia. The method used is quantitative descriptive statistics through Scopus web. The results of this research are expected to be a reference for research in Indonesia that want to be immediately prepare for electric motorcycle conversion. In this research also give taxonomy and classification based on Goldsmith Model as a technology commercialization model and SWOT analysis for implementation electric motorcycle conversion program in Indonesia.

1. Introduction

The number of motorcycles in Indonesia increased from 2007 to 2017 significantly. In 2007 the number of motorcycles in Indonesia is 41 million units. In 2017 the number of motorcycles in Indonesia become more than 113 million units. Based on this trend, it is not impossible that the number will continuously increase in years forward.

With the increasing number of motorcycles, automatically carbon emissions will also increase. Whereas at present the governments in all countries are reducing gas emissions from transportation in their respective countries [1]. As a national action, the government of Indonesia plans to suppress carbon gas emissions. It is stated in Presidential Regulation Number 61 of 2011 [2]. The action is designed from transportation sector and targets a reduction of CO2 by 0.038 up to 0.056 gigatons during 2010-2020. In 2019, through Presidential Regulation Number 55 Indonesia’s government push for accelerate the electrification all vehicle in Indonesia [3]. Transportation sector is the one of the most pollution source in the world [4]. One of the contributors of carbon gas emissions from the transportation sector is Internal Combustion Engine (ICE) motorcycles. The usage of electrical technology is one that can be used on ICE motorcycles to reduce carbon emissions. This study will discuss the conversion ICE motorcycle into an electric motorcycle in Indonesia.
It is called electric motorcycle because electricity used as a replacement of fuel in ICE motorcycle [5]. Electric vehicles have low noise level and high energy saving [6]. The implementation of electric vehicles will reduce gas emissions from transportation and also will support the development of electricity establishment [5]. Electric motorcycle conversion is a new technology for Indonesia. Goldsmith commercialization model is one of the most effective models to identified technology commercialization. The Goldsmith commercialization model is a model that integrates technical aspects, markets and business process elements for commercialization into a sequential concurrent activity matrix [7].

2. Method
The methodology in this research is study of literature through the page www.scopus.com. Scopus is the largest abstract database, citations and literature for tracking and analyzing research [8].

The flow of research as follows:
- Search at the Scopus for the keywords "electric motorcycle" from first paper at 1989 until August of 2019.
- Scopus data analysis.
- Paper taxonomy and classification based on goldsmith model.
- SWOT analysis for implementation electric motorcycle conversion in Indonesia.

3. Results and Discussion

3.1. Data of Scopus
From searching for data through the Scopus web, there are 286 studies about electric motorcycles. The following is the result of the searching:

Figure 1. Number of Papers Based on Years

Figure 1 shows that research on electric motorbikes began in 1989. The research was conducted in Japan with the title "The concept of a future electric vehicle and the development of an electric motorcycle". This paper studied about comparation between electric vehicle performance and ICE vehicle performance [9]. After 2004, research on electric motorcycles began to be consistently studied and after 2010 research about electric motorcycle increased. It is showed by the number of studies presented in more than ten papers each year. In early 2019, there are already 27 papers presented.
From the figure 2, it shows that Asia has the biggest courage in studying about electric motorcycle. Asia has presented 183 papers about it. Europe becomes runner up by presenting 61 papers and America has presented 37 papers. Australia become the lowest continent that studied about it. Australia has presented only 5 papers.

Asia is the greatest continent in doing study about electrical motorcycle. About 183 studies have been released in Scopus. Based on Figure 3, the country that release the greatest amount is Taiwan with 52 papers. Recently, Taiwan becomes model country that is already implementing electric vehicle as on their mass transportation. China becomes runner up with 50 papers released and the third is Japan with 27 papers. In South East Asia, Thailand becomes the greatest country that release 12 papers. Indonesia has released 10 papers about electric motorcycle. Malaysia has released 6 papers, Singapore has released 3 papers, and the last Vietnam has released 2 papers.

3.2. Research Classification
There are 286 studies about electric motorcycle. It will be classified to 6 topics. The following result of classification shown in the table below:
Based on the Table 1, the biggest topic is Product Design and Simulation Study. The number of papers in this topic is 144 papers or more than 50% from all topic. The second topic is Feasibility and Market Study, the papers released is 56 papers or 20%. Environmental Issue Study about electric motorcycle has released 38 papers or 13%, Implementation Impact Study has released 34 papers or 12%, and Supply Chain Study has released 9 papers or 3%. The smallest topic is Ergonomic Issue Study, the papers in this topic only 5 papers or 2%.

There are some previous papers in each topic. The following papers shown in the table below:

| Title and Author | Topic of Paper | Content of Paper |
|------------------|---------------|------------------|
| *A study of electric motorcycle* (Matsuda, 2014) | Product Design and Simulation Study | In this research, developed the prototypes of electric motorcycle about technical design and parts suppliers. The developed electric motorcycle has the equivalent with ICE motorcycle 250cc and can travel distances of up to 100km. The result of this paper is prototype and simulation with environmental loads such as water problem, cold and heat situation, shock problem, and impact of an accident [10]. |
| *A Study of Function Control in the Electric Motorcycle* (Kawai et al., 2015) | Product Design and Simulation Study | This paper shows that control in electric motorcycle simpler than ICE motorcycle. This study develops the prototype electric motorcycle having manual transmission. The problem points of electric motorcycle which put electric propulsion motor and manual transmission together at first tested [11]. |
| *Design and Analysis of Chassis for an Electric Motorcycle* (Jeyapandiarajan et al., 2018) | Product Design and Simulation Study | This paper designs an electric motorcycle chassis with structurally stable. This chassis simulation with frame forces and geometries suspension. This paper also makes other material comparation to find the best suitable component for electric motorcycle chassis (strength, cost, and weight) [12]. |
| Title                                                                 | Type                           | Summary                                                                                                                                                                                                 |
|-----------------------------------------------------------------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| To produce or convert: A case for large scale electric motorcycle     | Feasibility and Market Study  | This paper discusses about the electric motorcycle economic feasibility and viability. In this research, simulated by producing per year of 2500 motorcycles and produced by 20 people. The result is electric motorcycles more economical than ICE motorcycles. In a short period, this cost savings can offset the motorcycle price [13]. |
| conversion in Singapore (Teo et al., 2014)                           |                                |                                                                                                                                                                                                       |
| Techno-economic analysis of lithium-ion battery for motorcycle         | Feasibility and Market Study  | This paper explores about development lithium-ion battery technology for motorcycles in Indonesia. This technology development is conducted by reviewing the technical aspects, market aspects, and aspects of the business. The financial analysis that used in this paper are the analysis of NPV, PP, and IRR [14]. |
| development (Kurniyati, et al., 2016)                                 |                                |                                                                                                                                                                                                       |
| Electric vehicles, air pollution, and the motorcycle city: A stated   | Feasibility and Market Study  | This paper discusses the replacement for ICE motorcycle. Five scenarios given to respondents what they selected between electric motorcycle, ICE motorcycle, and no motorcycle based on speed, price, charge time, and range. The results is a convincing market in Solo for electric motorcycle. However, the motorcycle must be low price and powerful [15]. |
| preference survey of consumers’ willingness to adopt electric         |                                |                                                                                                                                                                                                       |
| motorcycles in Solo, Indonesia (Guerra, 2019)                        |                                |                                                                                                                                                                                                       |
| Exploring the determinants of consumers’ WTB and WTP for electric     | Feasibility and Market Study  | This study discussed the willingness to pay (WTP) factors and willingness to buy (WTB) factors consumers for electric motorcycle. The results indicate the respondents don't quite understand about electric motorcycle. When interesting electric motorcycle, the respondents more concern about actual cost of electric motorcycle (repair fee, tax incentives, sale price, charging fee, etc.). The load capacity and driving speed have just a little attention [16]. |
| motorcycles using CVM method in Macau (Zhu et al., 2019)             |                                |                                                                                                                                                                                                       |
| Environmental impact of converted electrical motorcycle               | Environmental Issue Study      | This study discusses the environmental impact ICE sports motorcycle conversion to electric sports motorcycle. This conversion will reduce gas emissions. However, impacts and energy sources during post-conversion usage must be considered. The result of conversion will reduce gas emissions and life cycle energy used [17]. |
| (Xuan et al., 2014)                                                   |                                |                                                                                                                                                                                                       |
ICE Motorcycle and Electric Motorcycle: Environmental and Economic Analysis (Tuayharn et al., 2015)

This research studies the comparison using electric motorcycle and ICE motorcycle in Thailand. The fuel consumption of ICE motorcycle's is $1.94 \text{ Lge/100km}$ with CO2 released equivalent to $43.59 \text{ g/km}$. On the other side, the electric motorcycle consumed $0.27 \text{ Lge/100km}$ with CO2 released is at $20.67 \text{ g/km}$ if use coal generated electricity, and $10.7 \text{ g/km}$ if use natural gas generated electricity. Total cost of electric motorcycle save up to $20\%$ over 10 years [18].

Environmental impact of electric motorcycles: Evidence from traffic noise assessment by a building-based data mining technique (Sheng et al., 2016)

ICE motorcycles make a high noise because its traffic at the city. The result of this study indicated that electric motorcycle can reduce the human risk to high traffic noise in the city until $22.7\%$ than before [19].

Study of the Energy Efficiency and Greenhouse Emissions from Motorcycles Powered by Electric and Internal Combustion Engines (Daemme et al., 2017)

This paper discusses about comparison ICE motorcycle and electric motorcycle in Brazil. The result indicated the difference of gas emissions significantly between both of them. The efficiencies of ICE motorcycles are $13\%-17\%$ and for electric motorcycle showed $47\%$ [20].

Energy and emission impacts of liquid fueled engines compared to electric motors for small size motorcycles based on the Brazilian scenario (de Assis et al., 2019)

This paper considers environmental impact for evaluation of greenhouse gases in Brazil. The result shows that electric motorcycles have more energy saving than ICE motorcycle. Gas emissions from electric motorcycle are not dangerous for nature, but the impact from battery must be considered further [21].

Failure safety method according to battery's state-of charge condition in electric motorcycle (Lee and Kim, 2014)

This paper explores about electric motorcycle battery safety based on the status of battery. This study simulated by Automotive Simulation Models (ASM) program and used Model Based Design (MBD). The result is if Li-ion battery discharges until $10\%$ will have a significant problem [22].

Mobile phone use among motorcyclists and electric bike riders: A case study of Hanoi, Vietnam (Truong et al., 2016)

This paper explores the factors related to mobile phone used by motorcycle rider and electric bike riders. This paper also studies their prevalence. The method of this research is observation survey at 12 cross sectional sites. The result of prevalence when riding
and using a mobile phone was 8.4% (95% CI: 8.06-8.74%) [23].

This paper describes that general qualities of electric motorcycles are lower than the qualities of ICE motorcycle. The motors and batteries technology are the main reason in this problem. The method of this study is TOPSIS method, fuzzy theory, analytic hierarchy process, and Borda method. The results show that the best of seven alternative is Lithium battery, and the second one is the Nickel-Zinc battery [24].

This paper explores an electric vehicle charging strategy given the Renewable Energy Sources (RES) high penetration. The result proposes take CO2 emissions tax. If mostly used by fossil fuel, it will be high taxed. And if mostly used RES power source, it will be low taxed [25].

This time, electric motorcycle in Indonesia have a low progress. The chance for accelerate is planning sustainable supply chains by regarding the triple bottom line, such as environmental, social, and economic. This literature study used as the method to measure the swap battery system supply chain and create a sustainable supply chain scheme for electric motorcycle [26].

This paper shows the comparation of charging pattern between electric motorcycle and electric car because of their charging time difference. And automatically the collective power profile will be different. The ability of slow and fast charging on electric motorcycle are showed in this paper [27].

This paper shows the electric scooter design has 23 factors and has its own priorities. Furthermore, while riding the electric scooter, its postures have been evaluated. The result indicates the significant factors are comfort and convenience, the design of vehicle control, dimensions of vehicle space and performance, and the design of dashboard [28].
Work-related road safety: The impact of the low noise levels produced by electric vehicles according to experienced drivers (Pardo et al., 2019)

This paper shows that the low noise levels of electric vehicle could take a new safety risk even though it seen as positiveness previously. This study explores the experience of electric vehicle drivers and hybrid vehicle drivers. The total of respondents in Malaga, Spain is 95 drivers. The result indicates “medium” risk situations at low speeds with pedestrians because of the low noise [29].

3.3. Taxonomy and classification based on Goldsmith Model

Goldsmith model can describe well about technology commercialization [7]. Goldsmith commercialization model consists of three phases consisting of the concept phase, the development phase and the growth phase. In each phase of the commercialization model analyses the technical, market and business aspects so that the commercialization process can be carried out effectively. The combination of these three phases and aspects forms a matrix model that described by Figure 4. There are 6 papers described in Step 1-Technology Analysis, 12 papers explored Step 2-Market Needs Assessment, 38 papers studied in Step 3-Venture Assessment. Step 4-Technical Feasibility at the most paper by 86 papers. There are still no paper at Step 17-Market Diversification and Step 18-Business Maturity.

| Stage          | Technical | Market | Business |
|----------------|-----------|--------|----------|
| Concept Phase  |           |        |          |
| Stage 1        | Step 1    | Step 2 | Step 3   |
| Investigation  | Technology | Market Needs | Venture |
|                | Analysis  | Assessment | Assessment |
|                | 9 papers  | 12 papers | 38 papers |
| Development Phase |         |        |          |
| Stage 2        | Step 4    | Step 5 | Step 6   |
| Feasibility    | Technical Feasibility | Market Study | Economic Feasibility |
|                | 39 papers  | 19 papers | 23 papers |
| Stage 3        | Step 7    | Step 8 | Step 9   |
| Development    | Engineering Prototype | Strategic Market Plan | Strategic Business Plan |
|                | 51 papers  | 10 papers | 3 papers |
| Stage 4        | Step 10   | Step 11 | Step 12  |
| Introduction   | Business Start Up | Pre Production Prototype | Market Validation |
|                | 5 papers   | 3 papers | 3 papers |
| Growth Phase   |           |        |          |
| Stage 5        | Step 13   | Step 14 | Step 15  |
| Growth         | Production | Sales and Distribution | Business Growth |
|                | 5 papers   | 2 papers | 3 papers |
| Stage 6        | Step 16   | Step 17 | Step 18  |
| Maturity       | Production Support | Market Diversification | Business Maturity |
|                | 14 papers  | 0 papers | 0 papers |

Figure 4. Taxonomy Based on Goldsmith Model
3.4. SWOT Analysis for Implementation Electric Motorcycle Conversion in Indonesia

Electric motorcycle conversion is creating electric motorcycle by change the power source of ICE motorcycle. ICE motorcycle can be converted to electric motorcycle by adding Conversion Kit. The conversion kit consists of Brushless Direct Current Motor (BLDC), controller, and battery. The function of BLDC is generating the power for motorcycle. BLDC converts supplied electrical energy into mechanical energy. BLDC usually installed at rear wheel of motorcycle. The controller function as set the power from BLDC to motorcycle power. The last part of conversion kit is battery. Battery is the power source of electric motorcycle, if it installed greater battery capacity, automatically it will be produced greater power for electric motorcycle. The main part of conversion kit is battery because battery is the most expensive than the other. The diagram of electric motorcycle conversion showed by Figure 5. The differentiation between electric motorcycle conversion, ICE motorcycle, and electric motorcycle showed by Table 3.

![Electric Motorcycle Conversion Diagram](image)

**Figure 5. Electric Motorcycle Conversion Diagram**

| Description       | ICE Motorcycle                  | Electric Motorcycle Conversion                 | Electric Motorcycle                  |
|-------------------|---------------------------------|-----------------------------------------------|--------------------------------------|
| Power source      | Gasoline                        | Gasoline converted to electric                | Electric                             |
| Classification    | Engine capacity                 | Battery capacity                              | Battery capacity                     |
| Motorcycle drive  | Engine                          | Engine converted to BLDC                      | BLDC                                 |
| Expense           | Less efficient                  | More efficient                                | More efficient                       |
| Environment       | Less green friendly             | Greener friendly                              | Greener friendly                     |
| Maintenance       | More maintenance                | Less maintenance                              | Less maintenance                     |

Table 3. Motorcycle Difference
Many consumers in Indonesia not have attention yet about green product such as electric motorcycle. Even though, electric motorcycle is more environmentally friendly than ICE motorcycle. Electric motorcycle is 53% more green friendly than ICE motorcycle [18]. Moreover, implementation of electric motorcycle can reduce traffic noise. Electric motorcycle can reduce high traffic noise until 22.7% at the city [19]. In Indonesia, ICE motorcycle consumers have very attention about economic value. The following result of economic comparison shown in the figure below:

![Cost Comparison ICE Motorcycle VS Electric Motorcycle](Figure 6)

Based on Figure 6, could be seen that electric motorcycle more efficient than ICE motorcycle. The power source of motorcycle comparison between gasoline and electrical shown on Figure 5. In the end of the 10th month, electric motorcycle can save until 84% compared with ICE motorcycle.

![SWOT Analysis of Electric Motorcycle Conversion](Figure 7)

Figure 7 above shows the SWOT analysis of implementation of electric motorcycle conversion in Indonesia. The explanation of each showed below:

### 3.4.1 Strength
- This conversion program will have an impact in environmental, economic, and social. As explained above electric motorcycle can reduce gas emission pollution until 53%. This electric motorcycle also can reduce 22.7% of high traffic noise. This conversion program is expected reduce energy dependence from non-renewable resources.
• From economic perspective, electric motorcycle is more efficient than ICE motorcycle. Consumers can save their budget for gasoline at ICE motorcycle until 84% by using electric motorcycle at the end of the 10th month. This conversion program can grow the new industry such as BLDC industry, controller for electric motorcycle industry, and battery industry as the main part of electric motorcycle. Based on Figure 4, private workshop as people’s economy can grow by converting ICE motorcycle to electric motorcycle.

• There is some local product that can be used in electric motorcycle conversion such as battery. Battery is the main part of electric motorcycle conversion because battery is the most expensive than the other parts. By developing electric motorcycle conversion, automatically it will be increasing battery production as the main part from local product.

• Electric motorcycle conversion has a different maintenance with ICE motorcycle. In ICE motorcycle, it must take periodic maintenance and service such as oil change, engine cleaning, etc. But in electric motorcycle conversion, it doesn’t need to do that because there is no engine. So electric motorcycle conversion is less maintenance than ICE motorcycle.

3.4.2. Weakness
• Fast charging technology is not ready in Indonesia. It will be a weakness of electric motorcycle conversion. Now, the charging time of battery is 5-6 hours. But if fast charging used, it just only takes 2-3 hours. Fast charging technology must be faster developed in Indonesia for supporting electric motorcycle conversion program.

• Socialization is one of the most important in this conversion program. Good socialization to the community will make this program succeed quickly. The socialization for example gas emissions awareness, government regulation, safety awareness of electric motorcycle, gas emissions awareness, etc. Generally, Indonesia’s people confused trying new technology and by this socialization expected to receive it more quickly.

• As a new product and new technology, electric motorcycle conversion will take great initial development cost. But it will be paid off with healthier environment. Indonesia’s government has also prepared a great budget for researching and developing it.

• Indonesia doesn’t yet have a standard about electric motorcycle. International regulation standard of electric motorcycle is UN R136 “about uniform provisions concerning the approval of vehicles of category L with regard to specific requirements for the electric power train”. This regulation standard consists of Electrical Safety and Rechargeable Electrical Energy Storage System (REESS) Safety. The others international standard related to electric motorcycle shown in the table below:

| Topic                      | International Standard |
|----------------------------|------------------------|
| Electrification safety     | ISO 13063              |
| (vehicle)                  |                        |
| Charging systems           | IEC 60335-2-29(Rev.), ISO 61851-3, ISO 18246 |
| DC charging connectors     | IEC 62196-4            |
| Cell testing & safety      | IEC 62660-1,-2         |
| Cell safety                | IEC 62660-3            |
| Battery testing & safety   | ISO 18243              |
| Electricity consumption    | ISO 13064-1            |
| Vehicle performance        | ISO 13064-2            |

3.4.3. Opportunity
• Environment public awareness is increasing recently. Carbon emissions has disrupted public health. Around the world is also actively promoting about this environmental issue. Electric motorcycle conversion will be faster accepted because this awareness.
Public needs for motorcycle transportation are increasing. It showed by motorcycle sales are increasing every year. From this, it will be advantageous for electric motorcycle conversion as an option motorcycle that more environmentally friendly.

With the growth of new industries and private workshop, automatically will require labor and will open new job vacancies. This is one of the social impacts from this conversion program. It will reduce the number of unemployed people in Indonesia.

Indonesia’s government at least has released 7 regulation related to electric vehicle, such as Regulation Number 30 of 2007 about Energy [30], Presidential Regulation Number 61 of 2011 about National Action Plan for Reducing Greenhouse Gas Emissions [2], Government Regulation Number 79 of 2014 about National Energy Policy [31], Government Regulation Number 14 of 2015 about National Industrial Development Master Plan 2015-2035 [32], Regulation Number 16 of 2016 about Ratification of the Paris Agreement to The United Nations Framework Convention on Climate Change [33], Presidential Regulation Number 22 of 2017 about National Energy General Plan [34], and the last is Presidential Regulation Number 55 of 2019 about Acceleration of Electric Vehicle Program Based on Battery for Road Transportation [3]. Based on those regulation, Indonesia’s government is very focus about conversion of electric vehicle in Indonesia. Government’s expectation at 2035, at least 30% of road transportation use electric energy.

3.4.4. Threats

- Electric motorcycle had already been developed in the other country. Electric motorcycle product from other country automatically will become a competitor electric motorcycle conversion in Indonesia. The advantages of electric motorcycle conversion are public don’t need purchase a new motorcycle but they can convert their old ICE motorcycle to electric motorcycle.

- The main problem before implementation electric motorcycle conversion is infrastructure. The infrastructure of electric motorcycle such as fast charging technology, public electric charging station, battery swap technology, etc. Indonesia’s government must be serious and fast in infrastructure development so the people can trust more and faster too in making decision for electric motorcycle conversion.

- Public perception about electric motorcycle conversion is still low. Generally, public will think more before decide use a new product and new technology. But it can be prevented with socialization and advertisement about electric motorcycle conversion.

- If electric motorcycle conversion increasing automatically electricity demand will increase too. Government must be prepared and forecast the electricity demand so problem in electricity will not happen in the future.

4. Conclusion

From this study, it was found that electric motorcycle conversion includes new technology and is still highly developed. This literature review expected provide benefits in adding references to all parties involved in this conversion program. The future research about electric motorcycle conversion still very open such as feasibility and market study for each city in Indonesia, infrastructure study for supporting electric motorcycle conversion, implementation impact study, environmental study by using electric motorcycle in Indonesia, etc. For the government must be serious for electric motorcycle conversion so as not to lag behind other countries. Socialization to the public about electric motorcycle conversion should be intensive so that the public understands about this product. Indonesian government also should accelerate infrastructure development such as fast charging technology, public electric charging station, battery swap technology. Tax deduction for companies involved can also accelerate its growth. Indonesian National Standards (SNI) for electric motorcycle conversion must be formalized immediately.
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