Sustainable supply chain planning for swap battery system: Case study electric motorcycle applications in Indonesia

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Abstract. Indonesia is a country that has a high level of increase motorcycles. Consequently, the large numbers of motorcycles contribute to toxic gas emissions. This has leads to the substitution of technology from fossil-powered motorcycles to electric motorcycles, especially electric motorcycles that use the battery swap method as a way of charging electricity. Currently, there is not much progress related to the electric motorcycles in Indonesia. The opportunity to plan sustainable supply chains by considering the triple bottom line, such as economic, social and environmental. This study uses literature study as the method to assess the supply chain of swap battery system. This study aims to create a sustainable supply chain plan for electric motorbikes to help accelerate the circulation of electric motors in Indonesia.

Keywords: supply chain, sustainable, swap battery

1. Introduction
Global warming has made governments around the world act to reduce greenhouse gas emissions in the transportation sector [1]. One of them is the Indonesian government [2]. The Indonesian government through decree president No 61/2011 has planned a national action to reduce greenhouse gas emissions during 2010-2020 with a target to reduce CO$_2$ gas by 0.038 gigatons to 0.056 gigatons in the transportation sector [3]. Road transport in the passenger sector has long been a significant source of greenhouse gas (GHG) emissions [4]. This sector is growing rapidly in developing countries like Indonesia [5].

There is a growing consensus that moving to a low carbon future within the transport sector will require a significant shift from its current state, whereby conventional fossil fueled internal combustion engines (ICE) dominate the market, to sustainable means of transportation [6]. Private transport, which constitutes 42% of global well-to-wheel (WTW) transport related emissions [7]. One type of private transportation is motorcycle. Motorcycles as means of private transportation have the highest percentage in intra-city transport in Indonesia [5]. Motorcycles become one of the top transportation planned to replace the petroleum-fuelled motors into electric motorcycles that do not produce emissions and environmentally friendly. A major drawback of all electric motorcycles is the charging time. One of the most time efficient and hassle-free charging method is the battery swapping technique [8]. Compared to the plug-in charging system, battery swap offers a variety of attractive features such as faster charging time and lower switching rates [9]-[12].

Indonesian researchers have been developed an electric motorcycle with a battery swap charging method, but these electric motorcycles have not widely circulated in the market and policies that regulate electric vehicles have not published in Indonesia yet. While electric motorcycles have not been widely circulated, it would be better if the supply chain was designed sequentially considering economic, social and environmental conditions. This study aims to plan a sustainable supply chain plan for battery swaps in electric motorcycles application in Indonesia in order to smooth the flow of supply chains and pay attention to its sustainability.
2. Research Method

In this research, we use study literature to collect data of problems in global sustainable supply chain swap battery. Problems are collected by type such as economic, social and environment. Analyse the data and make sustainable supply chain plan.

2.1 Study Literature

At this stage, the literature study was obtained from various scientific articles on the problem of sustainable supply chain on battery swap products that can be found in Table 1.

2.2 Analyse Data

After collecting sustainable supply chain problems on battery swap products, then search for solutions to these problems based on scientific articles or sustainable strategies of a company. The following list of sustainable supply chain battery swap solutions can be found in Table 2.

| Table 1. Sustainable Supply Chain Swap Battery Problem |
|-----------------------------------------------|-----------------------------------------------|
| Aspect | Main problem | Explanation of the problem | The caused problem |
| Economy | Worker's experience and knowledge [13] | Workers who lack experience and knowledge in the battery cell production process | Lithium technology is a new technology and is not yet familiar |
| Economy | Distribution of electricity stations [14] [15] [16] [17] | Estimates of the distribution of the number of electric stations and electricity charging schemes in the framework of economic concern are needed. | Each type of electric vehicle has different electrical power and travel routes |
| Economy | Price of electric vehicles [18] | Competition between electric vehicle companies to reduce the price of electric vehicles that use the battery swap method | The distributed swap stations could also provide a facility for energy grid storage that could be used to mitigate the intermittency of generation from renewable energy sources such as solar, wind, and geothermal energy. A question arises about whether consumers of electric vehicles can be more economical than conventional vehicle consumers |
| Economy | The number of batteries that are ready to be used for drivers of electric vehicles at the charging station [19] [20] [21] [22] | There is no estimate of the number of filling stations and the number of swap batteries available in each station by considering the service quality of the charging stations | There is no certainty between the arrival of the electric vehicle to the charging station and the number of battery swaps that must be ready to use. Availability of batteries that are ready to use can affect the quality of charging station services |
| Social | Collaboration between departments [14] | Problems arise when the production process has taken place | Lack of collaboration in production planning in each department in a battery company, for example production departments, marketing |
| Social  | Technology barrier [18] [23] | Various battery swap brands are not compatible to be exchanged. | Each brand swap battery has different swap stations, charging stations, and different battery exchange infrastructure |
|---|---|---|---|
| Social  | Political problem [24] | Battery series products are not assembled in one place | For battery series products that are not produced in one place, but involve various places. Then it will be vulnerable to political problems |
| Social  | Infrastructure [25] [26] | Charging infrastructure can affect EV infrastructure | The combination of electric vehicle policies with an increase of electric charging stations can affect the growth of using of electric vehicles |
| Social  | Policy [27] [28] [29] | There are no policies or standards that regulate the minimum security, test methods and performance of electric vehicle components | Electric vehicle technology is still in the laboratory testing phase |
| Environment  | Electric vehicle route [14] | There is no clarity between charging time and vehicle mileage | There has been no analysis of the impact of time filling in EVs with vehicle mileage problems |
| Environment  | Battery recycling [18] [30] [31] | Batteries can be a source of danger for the environment | If a large number of expired EV batteries cannot be processed and recycled properly, this battery will be a source of environmental hazards |
| Environment  | Environment sustainable supply chain [32] | Remanufacture battery to support large scale of adoption electric vehicle | No research has investigated remanufacturing of Lithium-ion batteries on a company scale, so far only laboratory scale remanufacturing |
| Environment  | Reduction of natural resources [33] [34] [35] [36] | The need for battery material as an electric vehicle energy is greater than the availability of battery material in nature | Battery materials such as Nickel and Copper are depleted due to the use of other applications, while graphite and Cobalt materials are needed a lot in the battery manufacturing process. |
| Environment  | Emmision [33] | Various types of Lithium batteries provide different amounts of gas emissions. | Greenhouse gas emissions due to the use of Lithium batteries during the process of assembling electric vehicles and when using electric vehicles |
| Aspect       | Main problem                                      | Explanation of the problem                                                                                                                                                                                                 | Alternative solutions                                                                                                                                                                                                                                                                                                                                 | Repair results                                                                                                                                                                                                                     |
|--------------|--------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Economy      | Worker’s experience and knowledge [13]           | Workers who lack experience and knowledge in the battery cell production process                                                                                                                                                                                                         | Cooperation between battery companies (A123 System) and universities (MIT in Massachusetts) to produce graduates who can become engineering talent, supply chain expertise, and operators that run the lines for lithium technology                                                                                                           | Over the next ten years it grew to over 3,000 employees and had received near $250 million in grants from the government to build a 550 MW lithium-ion cell plant in Michigan. Speaking with current and past employees                                                                                               |
| Economy      | Distribution of electricity stations [14] [15] [16] [17] | Estimates of the distribution of the number of electric stations and electricity charging schemes in the framework of economic concern are needed.                                                                                                                                 | Conduct a calculation and algorithm analysis of the electricity needs of EV with the need for an the number of electric charging station                                                                                                                                                           | Plan the amount and distance between electric charging stations                                                                                                                                                                                                                                                                                               |
| Economy      | Price of electric vehicles [18]                  | Competition between electric vehicle companies to reduce the price of electric vehicles that use the battery swap method                                                                                                                                                               | Assisted by the law to standardize swapping technology and management, drive patterns, infrastructure development, swap stations will eliminate the need for expensive, resource-intensive and uncontrolled public costs, and will play a more important role in national energy storage.                                                                                     | Calculation and analysis of algorithms can be applied for battery swapping model                                                                                                                                                                                                                                                                               |
| Economy      | The number of batteries that are ready to be used for drivers of electric vehicles at the charging station [19] [20] [21] [22] | There is no estimate of the number of charging stations and the number of swap batteries available in each station by considering the service quality of the charging stations                                                                 | Arrival, departure and swapping services of electric vehicles at the swap battery station are modeled with the network calculus theory. The amount of battery that is used up and the charged battery is modeled in Stackelberg game optimization                                                                                     | Simulation results have shown the effectiveness of the proposed method, guaranteeing the quality of services offered by the swap battery charging station, balancing the benefits between swap battery charging stations and battery supply chains while maximizing economy welfare                                                                                           |
| Category       | Issue                                                                 | Solution                                                                 | Impact                                                                 |
|----------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------|
| Social         | Lack of collaboration in production planning in each department in a battery company, for example production departments, marketing departments, suppliers, and distributors | Collaborate with each other to exchange information and capabilities before the production process takes place | Reducing the risk of miss-production                                      |
| Social         | Various battery swap brands are not compatible to be exchanged.        | Standardization of swap battery is needed                                 | Standardization of battery services is a major problem regarding compatible EV battery interoperability, which will enable technology-free battery exchange between various EV brands, different swap stations, different energy exchange infrastructure and different charging stations |
| Social         | Battery series products are not assembled in one place                | Carried out joint ventures and strategic alliances between companies, suppliers, distributors in each battery brand | The battery supply chain becomes smooth and the battery price is reduced |
| Social         | Charging infrastructure can affect EV infrastructure                  | Increase in the number of electric charging stations                      | The location of easily accessible electric charging stations can increase the number of using electric vehicles. |
| Social         | There are no policies or standards that regulate the minimum security, test methods and performance of electric vehicle components | Designing a standard test framework or policy framework for electric vehicles and their components based on laboratory capabilities that are aligned with global regulations | The proposed standard framework and policy framework can reduce global trade barriers even though they are only applied nationally |
| Environment    | There is no clarity between charging time and vehicle mileage          | Conduct research between charging time and vehicle mileage                | There are plans to calculate it. It can save electricity resources battery life as well |


| Environment | Battery Recycling [18][30][31] | Batteries can be a source of danger for the environment | Required the development of battery recycling technology that requires collaboration and supervision between battery manufacturers, vendors and consultants |
| --- | --- | --- | --- |
| Environment | Environment Sustainable Supply Chain [32] | Remanufacture battery to support large scale adoption electric vehicle | Create and analyze battery recycling network models, then develop value chain configuration scenarios to optimize the function of battery recycling for green mobility |
| Environment | Reduction of Natural Resources [33][34][35][36] | The need for battery material as an electric vehicle energy is greater than the availability of battery material in nature | Develop several recycling options and make economic comparisons if replacing the battery cathode material |
| Environment | Emission [33] | Various types of Lithium batteries provide different amounts of gas emissions. | Li-NMC produces less gas emissions than LiFeP |

Lithium battery technology provides environmentally friendly technology and recycling network model. Increasing the company's profits by 30.93% if remanufacturing infrastructure is integrated into a standalone electric vehicle Lithium-ion battery manufacturing supply chain. Materials that are widely used to assemble batteries are Graphite and Cobalt. Although graphite cannot be recycled, Cobalt material can be recycled.
2.3 Sustainable Supply Chain Plan

Based on the results of the problem collection and the solution to a scientific article on sustainable supply chain swap battery, it can be seen that there are various types of problems that have been investigated by previous researchers. The problem in the category of economy is based on the effect of the problem on the economic conditions of stakeholders from the battery swap. The problem of social categories is based on the existence of social interaction between battery swap stakeholders and the effect of consequences if there is no interaction between stakeholders. Problems in the environmental category are based on the effect of the problem on the environment. So that based on the collection of problems can be planned for sustainable supply chain swap battery for electric motor applications in Indonesia.

2.3.1 Sustainably Plan For Economic Problems

There are four types of problems relating to the economy.

2.3.1.1 Worker’s Experience And Knowledge [13]

The solution is to collaborate between the Government of Indonesia and battery companies to provide knowledge and teaching about lithium battery technology in various universities. This is to encourage the growth of the number of workers who are battery technology experts. Until now Indonesia has had several battery technology researchers, to increase the number of battery technology researchers needed, the role of the government to provide educational scholarships and subsidize the development of the battery laboratory. While the battery company must be more open to provide opportunities for students to learn battery technology in their company.

2.3.1.2 Distribution Problems Of Charging Stations [14] [15] [16] [17]

The calculation and algorithm analysis of the distribution of charging stations that consider the distance of the electric vehicle for a single charge can be used as a reference when designing sustainable supply chain swap batteries for electric motorcycle applications.

2.3.1.3 Price of Electric Vehicle [18]

The implementation of technology standards and battery swap management can reduce the price of electric motorcycles. Because the existence of standards can reduce technological barriers caused by different minimum specifications between brand battery swap products and equalize the minimum quality of battery charging rack. Reducing the price of electric motorcycles can potentially make consumers of fossil-fuel motorcycles interested in using electric motors. Planning drive patterns can make electric vehicles more economical than conventional vehicles. In addition, sales of electric motors will also increase along with standards or policies that protect consumers.

2.3.1.4 The Number of Batteries That Are Ready To Be Used For Drivers of Electric Vehicles at The Charging Station [19] [20][21] [22]

The number of battery swap products that are ready to be used at each charging station can provide benefits to consumers of electric motorcycles as well as to entrepreneurs charging stations. Calculation of the estimated number of batteries that are ready to be used will prevent the occurrence of stock out, the image of the charging station service will be good and consumers will be fulfilled the need to swap the product battery.

2.3.2 Sustainably Plan For Social Problems

There are four types of problems relating to the social.

2.3.2.1 Collaboration Between Department [14]

Inter-departmental collaboration before the battery swap production process will minimize production errors. The involvement of suppliers in designing products before carrying out the production process can make a common perception between the supply demand from the company and the ability of the supplier.
The involvement of the distributor with the company will accelerate product turnover from the warehouse to the market. Cooperation in exchanging information from the marketing department with the production department will facilitate production scheduling.

2.3.2.2 Technology Barrier [18] [23]

The problem of different technology specification barriers between swap battery brands can be reduced if the minimum standard compatible battery swap applies. This is the same as in the economic aspect, where social aspects are also affected due to differences in technology specifications and battery swap infrastructure. Different technology and battery swap infrastructure can harm consumers and disrupt the supply chain flow.

2.3.2.3 Political Problem [24]

Joint ventures and strategic alliances can reduce political barriers. Because the existence of such cooperation can benefit various parties with the existence of agreements that regulate the obligations and rights of each stakeholder in the battery swap.

2.3.2.4 Infrastructure [25] [26]

The problem of infrastructure can be addressed by implementing a policy of increasing the number of electric charging stations that indirectly affect the increase in the use of electric vehicles.

2.3.2.5 Policy [27] [28] [29]

The existence of a standard test framework or policy framework can be a reference in maintaining the quality of electric vehicle products and their components in order to meet consumer needs.

2.3.3 Sustainably Plan For Environment Problems

There are five types of problems relating to the environment.

2.3.3.1 Electric Vehicle Route [14]

With the research on charging time with the distance of an electric motor can help save battery life, save electricity and reduce the environmental impact if there are a lot of expired batteries that are discarded due to the small battery capacity.

2.3.3.2 Battery Recycling [18] [30] [31]

The possibility of an increase in demand for lithium batteries can make a bad impact on the environment if it is not planned to recycle lithium batteries that have expired or are reduced by a lot of state of healty (SOH) batteries. One solution that can be planned is to develop lithium battery recycling technology so that it can be used after being used as an electric motor battery swap.

2.3.3.3 Environment Sustainable Supply Chain [32]

Remanufacturing swaps of batteries that have expired can provide potential benefits. Because in the lithium battery swap there is a material that can still be used.

2.3.3.4 Reduction of Natural Resource [33] [34] [35] [36]

Recycling battery materials such as Cobalt can reduce the taking of Cobalt from nature. In addition, it can also conduct research using new stamps to be used as battery material.

2.3.3.5 Emissions [33]

Select battery materials based on consideration of the usefulness and amount of gas emissions.
3. Conclusion

Based on the results of data processing, it can be concluded that there are at least three types of problems and solutions for sustainable swap supply chain batteries for electric motorcycle applications. The problem is divided into three types such as economic, social and environmental problems. There are four types of problems relating to the economy, including: the worker's experience and knowledge, the distribution of electricity stations, the price of electric vehicles and the batteries that are ready to be used for drivers of electric vehicles at the charging station. For types of problems related to social, there are four problems, including collaboration between departments, technology barriers, political problems and infrastructure. There are five types of problems related to the environment, including: electric vehicle route, battery recycling, environment sustainable supply chain, reduction of natural resources and emission.

It can be expected from the results of this study can be taken into consideration when planning a sustainable supply chain from battery swap products in Indonesia and can help accelerate the circulation of electric motors in Indonesia.

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References
[1] Bonilla O and Merino D 2010 Engineering Management Journal 22 pp 34-44
[2] Anggraini S, Boer R, Dewi R, Hidayat A and Suharto A 2011 Study on carbon governace at sub-national level in Indonesia Institute for Global Environment Strategies
[3] Republic of Indonesia Presidential Regulation No. 61 of 2011, concerning National Action Plan for the Reduction of Greenhouse Gas Emissions
[4] Zubaryeva A, Thiel C, Barbone E and Mercier A 2012 Technological Forecasting and Social Change 79 pp 1622-37
[5] Anonim, “Jumlah Kendaraan Bermotor (Unit)”, Retrieved online: https://data.go.id/dataset/jumlah-kendaraan-bermotor-unit/resource/f9c24882-8de4-481e-9c66-400ed8fb0df, 3 June 2018
[6] Edenhofer O, Pichs R, Sokona Y, et al 2014 Intergovernmental Panel on Climate Change
[7] Energy Technology Perspectives 2017 OECD Publishing/IEA.
[8] Ahmad A, Khan Z, Alam M and Khatee B 2018 Smart Science 6 pp 36-53
[9] Mushfique S, Hvojo P, Miguel A 2015 IEEE Transactions on Power Systems 30 pp 901-10
[10] Zheng Y, Dong Z, Xu Y et al 2014 IEEE Transactions on Power Systems 29 pp 221-29
[11] Liu N, Chen Z, Liu J, et al 2014 Energy 64 pp 779-92
[12] Liu N, Lin X, Chen Q et al 2017 Journal of Energy Engineering 143
[13] Johnson T 2018 Breaking down the lithium-ion cell manufacturing supply chaon in the U.S. to identify key barriers to growth
[14] Alejandra A, Mendez C, Faulin J, Armas J, Grasman S 2016 Energies 9
[15] Wu T and Pang G 2015 IEEE Transportation Electrification Conference and Expo
[16] Li W, Li Y, Deng H and Bao L 2018 Sustainability
[17] Pengcheng P, Zhang I and Giannakis G 2018 IEEE Transactions on control of network system
[18] Wang H, Xu H, Jones A 2010 International Conference on Optoelectronics and Image Processing pp 362-66
[19] Zhao T, Zhang J, Liu W, Wang P 2017 Chinese Society for Electrical Engineering
[20] Xu Q, Wang P and Tianyang Z, 2017 IEEE Power & Energy Society General Meeting
[21] Grau I, Papadopoulos P, Skarvelis S, Cipcigan L and Jenkis N 2017 USCUDAR
[22] Ginigene O and Fabregas O 2018 SysCon
[23] Suen S, Lin B and Jang I 2013 EVS27 International Battery Hybrid and Fuel Cell Electric Vehicle Symsposium
[24] Jussani A, Wright J, Ibusui U 2017 Innovation Management Review 14 pp 333-38
[25] Sukla P, Dhar S, Pathak M and Bhaskar K 2014 Electric vehicles scenario and a roadmap for India UNEP DTU Partnership Centre on Energy Climate and Sustainable Development Technical: University of Denmark
[26] Mak H, Rong Y and Max Z 2013 Management science 59
[27] Sutopo W and Kadir E.A 2017 Telkomnika 5 pp 584-89
[28] Sutopo W and Kadir E.A 2018 IJECE 8 pp 220-26
[29] Sutopo W and Kadir E.A 2018 Telkomnika 16 pp 544-49
[30] Idjis H, Attias D, Bocquet J and Sophie R 2013 IFIP Advances in Information and Communication Technology pp 609-18
[31] Gaines L 2018 Sustainable materials and technologies 68
[32] Li L, Dababneh F, Zhao J 2018 Applied Energy 226 pp 277-86
[33] Benjamin R 2016 Int J Interact Des Manuf 10 pp 217-27
[34] Olivetti E, Gerbrand C, Gaustad G and Fu X 2017 Joule 1 pp 229-43
[35] Drabik E and Rizos V 2018 The Centre for European Policy Studies Research Report
[36] Sun X, Hao H, Zhao F and Liu Z. 2017 Resources Conservation & Recycling 124 pp 50 -61