# A Manufacturer Opening Decision of Electric Motorcycle Conversion Kit Using The Mixed Integer Linear Programming Method

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## Abstract

Most people are now concerned about environmental issues. As the number of motorized vehicles grows, so does the consumption of fossil fuels. As a result, CO2 levels in the atmosphere rise. Starting to use alternate energy sources, such as electric automobiles, is one approach that can be implemented. By replacing the engine parts with a conversion kit, conventional motorcycles can be converted to electric motorcycles. In this study, the model is being developed by adding parameters. The cost of ordering raw supplies, storage expenses, transportation costs, and tax benefits are all factored into data processing. By using a mixed integer linear programming (MILP) model, this research offers a mathematical model for deciding which electric motorcycle conversion kit business to open. The results demonstrate that the model can be used as a decision-making tool for starting an electric motorbike conversion kit manufacturer due to tax reductions, and then starting as a manufacturer is more effective than becoming a trader.

## Keywords
Supply Chain Network Design, Electric Vehicle, Facility Location, Mixed Integer Linear Programming

## 1. Introduction
The use of fossil fuels causes an increase in carbon dioxide (CO2) levels in the atmosphere. According to Woo et al (2017), the transportation sector is a major contributor to fossil fuel consumption and greenhouse gas emissions. The CO2 emissions produced by the transportation sector are about 22.9% of the total CO2 emissions in the world. Therefore, to reduce the use of fossil fuels and slow down climate change, it is necessary to transition to renewable energy and use alternative energy sources.

Based on BPS data in 2019, the number of motorcycles in Indonesia reached 113 million units. This certainly affects the environmental problems caused, namely the increase in carbon emissions. Therefore, the Government through Presidential Regulation no. 55 of 2019 issued a regulation regarding the Acceleration of the Battery Electric Vehicle Program for road transportation which also encourages the vehicle electrification process. In addition, with the innovation of electric vehicle technology, it can be a solution for transportation modes that are environmentally friendly, energy efficient, and low maintenance and operational costs (Sutopo et al 2013).

There are 2 types of motorcycles, namely the new design of electric motorcycle, where the company designs vehicles that use electric technology in their operations. The second type is a convertible electric motorcycle, which is a conventional motorcycle that is converted into an electric motorcycle by replacing several components with a conversion kit. The conversion kit consists of a BLDC motor, BMS, controller and battery.

Sebelas Maret University is a pioneer in the manufacture of CEM and is technically proven by the use of Lithium-Ion batteries that can replace fossil fuel energy sources in conventional motorcycles. CEM uses LFP technology, so there is no risk of explosion in the event of a short circuit. In addition, LFP batteries have a lifespan of up to 3000 usage cycles and longer than current commercial EM batteries (such as Lithium-Ion Batteries and LiPo Batteries). CEM is capable of traveling a distance of 55 km/charge and has a maximum speed of up to 70 km/hour (Nizam, 2019). Jodinesa, et al. (2020) explained that the market share of convertible electric motorcycles in Surakarta, Indonesia resulted in a positive response from the people of Surakarta. Based on the previous explanation, it appears that the opportunity for electric motorcycles is very large. Several studies on standards related to electric vehicles and batteries have been developed, such as the Lithium Ion battery standard by Sutopo and Kadir (2017), battery management system standard by Rahmawatie et al. (2017), and electric vehicle charging standards by Sutopo et al. (2018).

The difference in the supply chain network of convertible electric motorcycles with new electric motorcycles is that the conversion process is carried out by conversion workshops instead of ATPM (Brand Holder Sole Agent), consumers of converted electric motorcycles already have conventional motorcycles, and conversion workshops are needed in each area to maximize consumer reach (Habibie et al, 2020). One of the important decisions in the supply chain network is the plan to open a facility (factory or warehouse). This is related to the arrangement of the distribution allocation location system to minimize transportation costs.

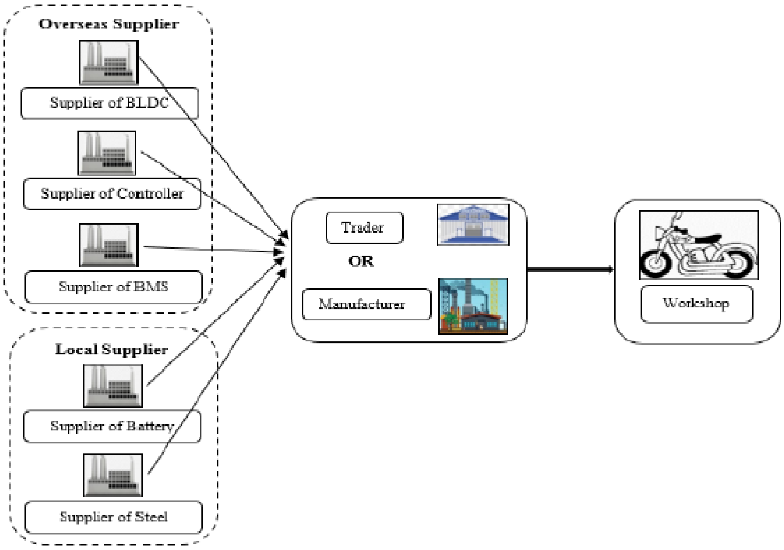


Figure 1. Convertible Motorcycle Supply Chain Network

In the supply chain network of convertible electric motorcycles, the first level is the procurement of raw materials from suppliers. Currently, three of the five components of the electric motorcycle conversion kit still have to be imported from abroad, namely BLDC, BMS, and controller. Meanwhile, batteries and iron supporting components can be obtained domestically. According to the Regulation of the Minister of Finance of the Republic of Indonesia Number 6 of 2017, the company will be subject to tax from the import process. However, through Presidential Regulation No. 55 of 2019 the government will provide tax incentives for pioneer businesses involved in the development of vehicle electrification in Indonesia in accordance with If the company wants to get the tax incentive, it can't just import the conversion kit components and sell them directly to consumers. Habibie, et al. (2020) mentions that the company must establish a manufacturing factory to carry out the assembly process into a conversion kit that is ready to be installed on a motorcycle.

The case study was conducted on the supply chain network of electric motorcycle conversion kit distribution systems in Central Java Province. Central Java has 6 residencies and 35 regencies/cities. In this study, the conversion kit manufacturing is located in the city of Semarang, while the workshops will be opened in 35 districts/cities. Based on the background described above, the purpose of this research is to develop a model of a convertible electric motorcycle distribution supply chain network using the mixed integer linear programming method by considering the cost of ordering raw materials.

## 2. Literature Review

Environmental degradation and rising adoption rates of electric vehicles are an issue for developing countries such as China, India, and Brazil (Wu and Zhang, 2017). Indonesia is one of the emerging countries that is helping to promote the use of electric vehicles. Currently, the development of research on the adoption of electric vehicles is starting to be widely carried out. However, the introduction of electric vehicles to the public is also needed so that people are increasingly aware of the need to use electric vehicles. Before deciding to buy an electric vehicle, consumers certainly consider several factors such as minimum range, charging time, low noise, acceleration, and context factors such as price, perceived benefits, incentives, and infrastructure (Higueras-Castillo, et al. 2021).

In terms of air pollution, Indonesia has pledged to reduce carbon dioxide emissions by 29% by 2030 as a result of the 2015 Paris Climate Change Conference. Electric two-wheeled vehicle penetration barely hit 0.14 percent of the government's aim in 2018. The government's goal is for four-wheeled electric vehicles to account for more than 45 percent of all vehicles on the road by 2025. In 2017, there were over 1,300 public electric charging stations in 24 cities across the country, with DKI Jakarta accounting for 71% (924 recharging stations) (Goldenberg, 2015).

The research map is used as a means to compare the position of the current research to previous research. Several supply chain network models have been developed by previous researchers. Yuniaristanto et al. (2010) developed a supply chain network model but did not consider tax incentives, while Mathirajan et al. (2011) have considered tax incentives in their model. Several previous research models have not included aspects of facility opening in their models (Song and Zhao, 2015; Lv and Sun, 2016). However, the model of Razaullah et al. (2018) has added the aspect of opening the facility. There is a distribution allocation location system that is of the dedicated type and considers area coverage as researched by Shiripour et al. (2017) and Asghari et al. (2014). The Cho and Kim (2019) model has a dedicated distribution system but does not consider regional coverage. Panicker et al. (2012) the distribution system is of the undedicated type but has not considered the sustainability aspect. Hisjam (2013) has considered the sustainability aspect in his model. In this research, the process of optimizing the supply chain network model of the conversion electric motorcycle distribution system will be carried out by considering tax incentives by opening facilities, optimizing the undedicated distribution allocation location system by considering regional coverage, as well as optimizing environmental aspects, namely the problem of reducing carbon gas emissions.

## 3. Methods

Research regarding the opening of manufacturing facilities and workshops for assembling conversion kits was carried out by applying the Mixed Integer Linear Programming (MILP) method. Modification of the method applied from previous research is to consider the cost of ordering each raw material. Order costs are considered because the raw materials used are imported and local. Data on raw material costs, facility opening costs, facility operational costs, production costs, and transportation costs were obtained from previous research. The cost of investment data is used as a decision consideration whether the manufacturer will run as a converter kit component dealer or component assembly then proceed with the distribution of the complete conversion kit. Imported raw materials such as BLDC motors, controllers, and BMS are subject to import duties and tax deductions. Transportation costs are the costs of distributing conversion kits from manufacture to available conversion workshops.

As exhaust emissions released into the air, greenhouse gases (GHG) are the largest contributor to emissions in the form of carbon emissions. Until now, it is estimated that the concentration of CO2 in the atmosphere is the most dominant concentration of all greenhouse gas effects (Setiawan et all, 2010). The carbon footprint or what in English is called Greenhouse Gas Emission is a measure that calculates the total amount of direct or indirect carbon dioxide emissions. This carbon dioxide emission can be caused by activities or accumulation from the use of products in everyday life. Examples of primary carbon footprints can be obtained from burning fossil fuels when using vehicles and transportation. In this study, Reduction of Gas Emissions were calculated to determine how much carbon dioxide emissions were reduced if all transportation were electrificated.

### 3.1 Problem Description

This study discusses the supply chain network model of a conversion electric motorcycle distribution system with mixed integer linear programming. Habibie, et al (2020) compared investments regarding the decision to open an electric motorcycle converter kit manufacturing company or just become a trader and sell electric vehicle components directly. In previous studies, the purchase of conversion kit components such as BLDC motors, BMS, controllers did not consider ordering costs. Likewise for the purchase of local raw materials, previous researchers did not consider ordering costs. Thus, in this latest study, researchers will consider the cost of ordering imported and local raw materials.

## 4. Data Collection

To illustrate the development of the proposed model, all the cost parameters used to perform the modeling are presented in the following table 1- table 4.

Table 1. Cost Parameter

| Parameter | Quantity | Units |
|---|---|---|
| Investement cost | 4.000.000.000 | IDR |
| Operational fixed cost | 10.000.000 | IDR/year |
| Production cost | 1.450.000 | IDR/pcs |
| Transportation cost | 120.000 | IDR/pcs |
| Order Cost (Impor) | 750.000 | IDR/order |
| Order Cost (Local) | 350.000 | IDR/order |

Table 2. Raw Material Cost

| Part | Price | Units |
|---|---|---|
| BLDC | 1.350.000 | IDR/pcs |
| Controller | 850.000 | IDR/pcs |
| BMS | 350.000 | IDR/pcs |
| Battery | 8.500.000 | IDR/pcs |
| Steel | 450.000 | IDR/pcs |

Table 3. Tax rate

| Description | Percentage | Units |
|---|---|---|
| Custom duty tax | 35% | Percent |
| Tax reduction | 20% | Percent |

Table 4. Capacity and Demand

| Description | Quantity | Units |
|---|---|---|
| Manufacturer capacity | 24.000 | Pcs/year |
| Conversion kit demand | 20.000 | Pcs/year |

This study also considers the sustainability aspect in the form of reducing carbon gas emissions from the electric motorcycle conversion program. With the reduction of carbon gas emissions, it is hoped that the air quality in the atmosphere will be better and the people will be healthier. The improvement of this aspect of public health is included in the social aspect. The following is a comparison of the carbon emissions of conventional motorcycles and electric motorcycles (table 5):

Table 5. Comparison of Carbon Emissions

| Criteria | Conventional Motorcycle | Electric Motorcycle |
|---|---|---|
| Carbon gas emission | 2,598 kgCO2/liter gasoline | 0,986 kgCO2/KWH |
| Assumed distance | 50 km/day | 50 km/day |
| Fuel | Gasoline 2 liter/day | Electricity 2 KWH |

| | | |
|---|---|---|
| Carbon gas emission per month | 155,88 kgCO2 | 59,16 kgCO2 |
| Carbon gas emissions per year | 1.870,56 kgCO2 | 709,92 kgCO2 |

Source : *Intergovernmental Panel Climate Change* (IPCC), 2006

From the data above, it can be concluded that by changing a conventional motorcycle, it can reduce carbon gas emissions by 62.05% or 1,160.64 kgCO2 per year for each motorcycle.

- Reducing the amount of carbon gas emissions in a year
  Number of converted motors = 20,000 units
  Emissions reduction per unit = 1,160.64 kgCO2
  Emission reduction per year = 23,212,800 kgCO2

According to previous information, the social aspect in this research is the improvement of public health by reducing carbon gas emissions. Hailemariam and Pan (2019) say that a 10% increase in carbon gas emissions per capita can lead to a 2.2% increase in mortality and a 0.6% decrease in life expectancy and vice versa.

- Indonesia's per capita emissions = 10,500 kgCO2
  Total population of Central Java = 34,718,204 people
  Central Java carbon gas emission = 36,541,142,000 kgCO2
  Reduction of carbon gas emissions = 464,905,958 kgCO2 or 0.13%

With the reduction of carbon gas emissions by 0.13%, it is expected to improve public health and reduce mortality by 0.03% and increase life expectancy by 0.01%.

# 5. Results and Discussion

## 5.1 Mathematical Modelling

Based on the description of the problem above, the objective function of this article is to minimize the total cost of opening an electric motorcycle conversion kit manufacturing facility by developing a model using the mixed integer linear programming method. The following is the notation of parameters, decision variables, and objective functions used to formulate the figure 2:

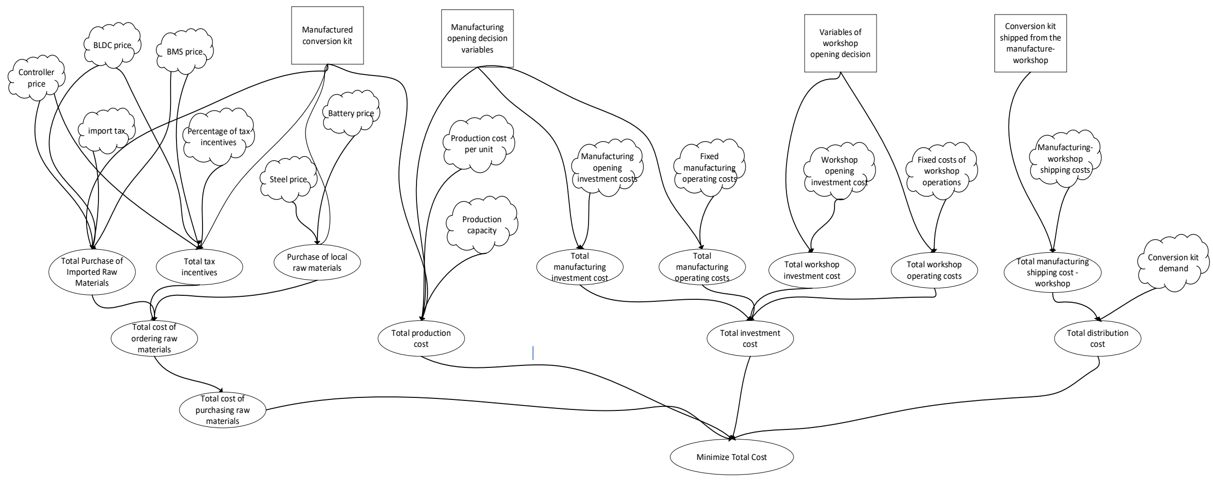


Figure 2. Influence Diagram Model

The structure of the model above describes the mixed integer linear programming model for determining the opening of factory and warehouse facilities, as well as determining the location of the warehouse and the allocation of electric motorcycle conversion kits from the warehouse to the workshop by considering the cost of ordering raw materials. Parameters that affect the minimization of total costs are the total cost of purchasing raw materials consisting of the cost of purchasing imported raw materials, tax incentives, ordering costs for imported raw materials, purchasing costs for local raw materials and ordering costs for local raw materials; total cost of production; total investment costs consisting of factory investment costs, factory operational fixed costs, warehouse investment costs, and warehouse operational fixed costs; total distribution costs which consist of shipping costs from the factory to the warehouse and shipping costs from the warehouse to the workshop.

Index

i : manufacturing index
j : workshop index

Parameter

$TAC$ : total Manufacturing cost i
$IC_i$ : investment cost of opening manufacturing i
$FC_i$ : fixed cost of manufacturing operation i
$PRC$ : production cost per unit conversion kit
OCI : cost of ordering imported raw materials
OCL : cost of ordering local raw materials
$TC_{ij}$ : shipping cost from manufacturer i to workshop j
$PBL$ : BLDC price
$PC$ : controller price
$PBMS$ : BMS price
$PB$ : battery price
$PS$ : price of iron
$TX$ : import tax percentage
$DTX$ : import tax reduction percentage
$CAP_i$ : manufacturing capacity i
$P$ : the maximum number of manufactures that can be opened
$D_j$ : j workshop request

Decision variables
$Y_i$ : Value 1 if manufacturing i will be opened,
value 0 otherwise
$Q_i$ : Number of conversion kits produced in manufacturer i
$Q_{ij}$ : Number of conversion kits sent from manufacturer i to workshop j

Purpose Function
Minimized total cost = TotalPurchasePriceImports –TotalDeductImports + TotalPurchasePricesBBLocal + TotalImport Orders + TotalLocalOrders + TotalProduction Costs + TotalManuf Investment Costs + TotalManuf Fixed Costs + TotalShipping Costs

Objective Function Mathematical Model

$$Minimize \sum_{i=0}^{I} TACi = \sum_{i=0}^{I}\sum_{j=1}^{J}(PBL + PC + PBMS) * TX * Qi ) - \sum_{i=0}^{I}\sum_{j=1}^{J}(PBL + PC + PBMS) * DTX * Qi ) + \sum_{i=0}^{I}\sum_{j=1}^{J}(PB + PS) * Qi) + \sum_{i=0}^{I}(PBL + PC + PBMS) * OCI * Qi ) + \sum_{i=0}^{I}(PB + PS) * OCL * Qi) + \sum_{i=0}^{I}\sum_{j=1}^{J}(PRC * Qi * Yi) + \sum_{i=0}^{I}(ICi * Yi) + \sum_{i=0}^{I}(FCi * Yi) + \sum_{i=0}^{I}\sum_{j=1}^{J}(TCij * Qij) \quad (1)$$

Limit Function

$$\sum_{i=0}^{I}\sum_{j=1}^{J} Qij \leq CAPi \quad (2)$$

$$\sum_{i=0}^{I}\sum_{j=1}^{J} Qij \geq Dj \quad (3)$$

$$\sum_{i=0}^{I}\sum_{j=1}^{J} Qi = \sum_{i=0}^{I}\sum_{j=1}^{J} Qij \quad (4)$$

$$Qi, Qij \geq 0 \quad (5)$$

$$Y_i \epsilon \{0,1\} \quad (6)$$

The objective function used in the model is the minimization of total cost (1). The function of constraint (2) is to ensure that the total number of conversion kits produced is less than the manufacturing capacity i. The constraint function (3) is the workshop demand constraint. This is to ensure that the request for workshop j conversion kits can only be met with the total number of conversion kits shipped. The function of constraint (4) is to ensure that all conversion kits produced in the manufacture are delivered to the workshop. The constraint function (5) is a non-negative constraint for each decision variable. The constraint function (6) is a binary constraint for the decision variable to determine whether manufacturing i is opened or not.

### 5.2 Calculation Results

Based on data processing using Ilog Cplex, the following results were obtained (Table 6).

Table 6. Final Results

| Decision Variable | Quantity | Units |
|---|---|---|
| Conversion kit produced | 20.000 | Pcs |
| Conversion kit shipped | 20.000 | Pcs |
| Opening Manufacture | 1 (open) | Binary |
| Total Cost | 272.060.000.000 | IDR |

The results of this MILP model show that manufacturing must be opened to carry out the process of assembling an electric motorcycle conversion kit. The total cost to fulfill the demand for 20,000 pcs is IDR 272,060,000 if the company decides to become a conversion kit manufacturer, and IDR 278,250,000 if the company chooses to become a trader or sell conversion kit components directly. Thus, the result is that by becoming a producer, you can save IDR 6,190,000 compared to being a trader.

Tax deductions are analyzed to prove whether the company is eligible or not to open manufacturing. The costs listed include the cost of purchasing local raw materials, the cost of purchasing imported raw materials, transportation costs, and import duty taxes. If the company opens a manufacturing facility as a place for assembling conversion kits, the government will provide incentives or reduce import duty taxes. However, the consequences that arise are the emergence of new costs, namely investment costs, fixed operational costs, production costs that consider costs in the initial model.

## 6. Conclusion

This study aims to develop a mathematical model for making decisions about the opening of an electric motorcycle conversion kit manufacturer using the mixed integer linear programming (MILP) model. The inputs of this model are manufacturing investment costs, fixed manufacturing operational costs, raw material costs (imported and local), variable costs of production, tax percentages, tax incentives, transportation costs, and the demand for each workshop. The input constraint in this model is the manufacturing production capacity and the maximum number of manufactures that can be opened.

This model is able to produce outputs in the form of manufacturing opening decisions, the number of conversion kits produced and the number of conversion kits sent from the manufacturer to the workshop. With these outputs, it can help for decision making to determine whether the conversion kit manufacture is worth opening or not. Based on the developed model, it was found that conversion kit manufacturers should be opened up and made into conversion kit assembly manufacturers rather than just being traders. This has an effect on the tax reduction effect.

The limitation of this study is that it has not yet produced a simultaneous model to measure the 3 aspects of sustainability to provide better results. Researchers have considered the impact of reducing carbon emissions, so that companies can apply the concept of sustainable supply chain management in order to open conversion kit manufacturing.

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