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Article

Parametric Cost Estimation Model for Li-ion Battery Pack of E-motorcycle Conversion based on Activity Based Costing

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Abstract: Universitas Sebelas Maret (UNS) through SMART UNS Company has conducted research and development of e-motorcycle conversion using Li-ion battery pack as a substitute for ICE energy source from the conventional motorcycle. Currently, the battery-pack that used for e-motorcycle conversion is in the development phase towards commercialization. The challenge of estimating production costs is the complicated production process and storing hidden expenses that can be a problem. This hidden cost is often a missing or varied factor that costs less or more expensive. This study presents an integrated parametric cost estimation model with activity-based cost assignments to estimate production costs through cost calculations for each activity. Activity-based costs break the production process into a specific cost element for each step. Each activity's cost is put into a parametric cost estimation model to calculate the cost of each activity into the total cost of production. Cost estimation results will be analyzed using a regression method to determine which variables most affect the production cost of Li-ion battery packs for the conversion of e-motorcycles in the SMART UNS company.

Keywords: activity-based costing; battery pack; e-motorcycle conversion;

1. Introduction

The level of motorcycle sales in Indonesia in 2019 increased by 1.6% from the same period last year [1]. The motorcycle still uses the Internal Combustion Engine (ICE) technology, which is very influential on the level of fuel oil usage from fossil energy [2]. For ten years, the consumption of fossil fuels increased by an average of 1.3 percent annually [3] and its annual amount of 14% emissions caused by fossil fuels from the transportation sector. Emissions from the transport sector are mainly coming from vehicles that dominate the release of long-lived greenhouse gases. This makes increased contributions to the total effect of the anthropogenic greenhouse [4]. Emissions resulting from fossil fuels cause an increase in CO_2 that results in climate change [5]. The growth rate of CO2 has a strong correlation with global temperature anomalies with CO2. Global warming rates have been accelerated in the last decade. The global surface temperature in 2019 is the 2nd highest in the period of instrumental measurement in the Goddard Institute for Space Studies (GISS) analysis. The global temperature 2019 is + 1.2 °c (~ 2.2 °f) warmer than in the base period 1880-1920 is a reasonable estimate of the 'pre-industrial' temperature [6]. Electric vehicles are automotive products that have capabilities to improve vehicle performance and mitigate the negative effects of the environment [7]. Electric vehicles contribute to the reduction of greenhouse gas emissions evidenced by previous research to date has shown that electric vehicles produce lower greenhouse gas emissions [8]-[9].

One alternative offered as an effort to overcome the problem in this is to use electricity technology to be used as an energy source in all types of vehicles. The use of batteries as energy storage devices replace fossil fuels in the ICE system. There are two types of products in realizing electric motorcycles: the new design of electric motorcycles and the conversion of technology from ICE to electric technology. There are several previous studies on the new design of an electric motorcycle, including research conducted by Mutyala [10]; Godlewski & Pawlak [11]; and Zarandi, Ebrahimi [12]. The second type of electric motorcycle production is conversion electric motorcycle. This motorcycle converts conventional technology into electrical energy through the Battery-Pack, BMS, and Drivetrain, which substitutes motor and engine parts [13]. Although many countries have Produced BEVs, there are fewer researches that have been conducted for e-motorcycle conversion.

SMART UNS has become a company that has conducted research and development on e-motorcycles conversion using lithium-Ion batteries as a substitute for ICE energy sources for conventional motorcycles. UNS as a member of the consortium team to develop a national electric vehicle is developing a lithium-ion battery (Li-Ion) for energy storage in electric vehicles. Battery-pack test results with power 1 kWh are E-motor conversion can travel about 35-40 km, with speeds that can reach 125 km/h. This result means that the battery can replace the vehicle's fuel oil. Following the research phase, UNS is currently researching to prepare the commercialization of Li-ion e-motorcycle conversion [14].

Technological developments allow electrochemical energy storage based on lithium-ion cells. In order to use the lithium-ion battery massively, one of the major constraints is low system cost [15]. Battery-Pack for the e-motorcycle conversion is a new product manufactured by SMART UNS that has a complicated production process and saves hidden costs. After determining the requirements for a particular vehicle (e.g., maximum speed, acceleration, and range), as well as the cellular portfolio arrangement to be considered in determining investment costs that indirectly affects the production cost [16]. Production costs include many variables, such as materials, machinery, equipment, and labor. These hidden costs often represent missing or unmeasured factors. It is important to estimate the cost to identify and select which variables can be used to determine the battery pack's final price. Revealing these hidden costs is required to make a good decision between making an alternate production process or developing a device. The parametric model approach is the most appropriate in estimating the cost of new products that are still under development [17].

Parametric estimation is a cost estimation technique using mathematical equations to integrate costs with physical parameters related to items to be estimated. In this study, the parametric cost estimation method is integrated with activity-based costing. The activity-based costing method can allocate costs accurately by charging product costs based on the consumption of resources needed for each activity. Horngren [18] states that one of the best ways to estimate costs is to implement a cost calculation system based on activity or activity-based costing (ABC). The main step of Activity-based costing (ABC) is to identify activities based on the system. This method identifies the costs needed for each activity to facilitate cost tracking. This activity improves the cost calculation system by identifying individual activities as fundamental (object) cost objects. Ben-Ariech & Qian [19] stated that the application of activity-based costing on a parametric cost estimate can improve the accuracy of the calculation. There have been some previous studies using this method conducted by Sutopo, Atikah, Purwanto, Danardono, & Nizam [14]; Ardiansyah, Sutopo, & Nizam [17]; Sutopo, Nizam, Purwanto, Atikah and Putri [20]; W. Sutopo; A. Eliza; R. Ardiansyah; Yuniaristanto; and M. Nizam. Parametric [21], MY Abu; KR Jamaludin; and MA Zakaria [22]. The cost estimation model will be analyzed using the regression analysis method to improve the accuracy of the estimated cost's final results and to identify variables that affect the cost of producing lithium-ion battery packs produced by SMART UNS.

Based on the explanation above, it is known that the lithium-ion battery pack for motorcycle conversion moves from research to commercialization, therefore the estimation of production costs to concern. As a new product, the company requires an accurate cost estimation model that can identify each activity element's entire cost to calculate the cost of production of the lithium-ion battery-pack electric convertible motorcycle. Therefore, this research aims to build a parametric cost estimation model of the battery-pack by implementing activity-based costing and identifying the factors that most affect the production cost of battery-pack conversion motors.

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2. Materials and Methods

2.1 Data Collection

This study developed a parametric cost estimation model with an activity-based costing approach. Figure 1 shows the flow of research using this approach. The initial phase of this research begins with collecting data such as the bill of materials from battery packs and business processes from the SMART UNS company. The bill of materials and business processes of the Li-ion battery pack by SMART UNS are shown in Figure 2 and Figure 3. Through these data, we can identify cost driver rates and cost centers for each activity. Cost driver rates are the main component in the parametric cost estimation model. The estimated cost estimation model is used to calculate production costs.

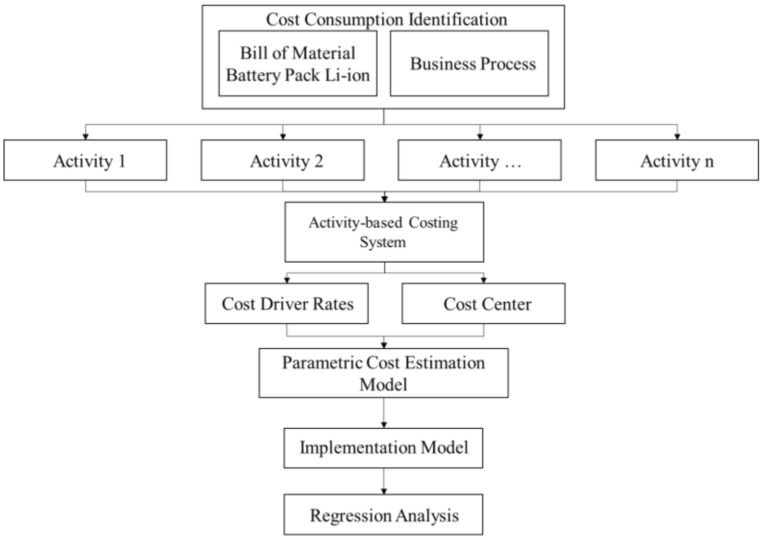

Figure 1. Research Process

The development cost estimation model starts with identifying the BOM Li-ion battery pack. The BOM tree structure of a Li-ion battery is shown in Figure 2. Through the bill of material provides information related to the components forming a Li-ion battery pack. BOM is used as an essential data parameter in product life cycle management that represents product information such as the hierarchical part associated with a particular product. Through multi-levels BOM can be used to determine the engineering bill of materials needed in estimating costs.

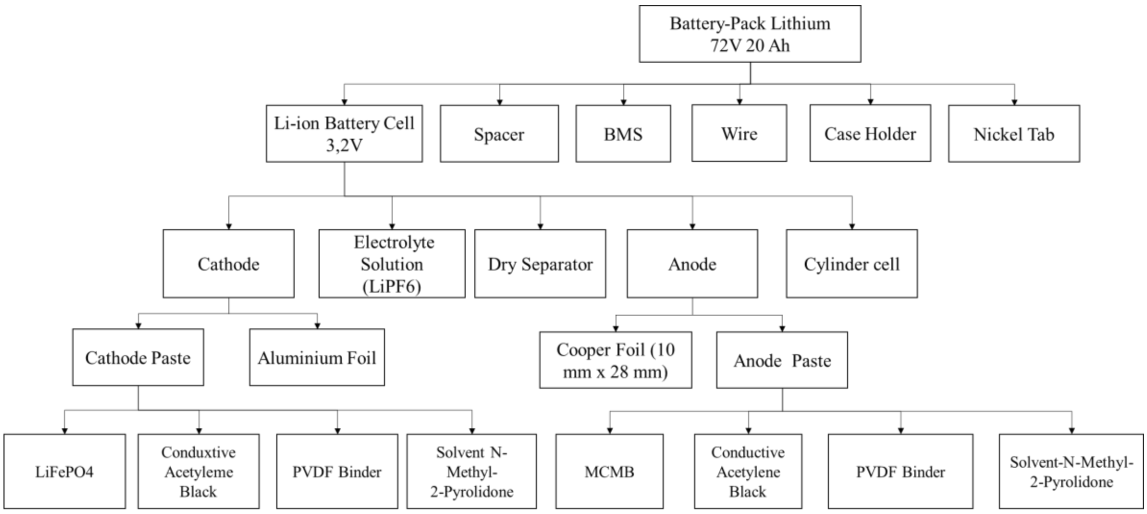

Figure 2. Bill of Material

The business process at SMART UNS is divided into 4 groups, such as management as administration and activities outside of production, the Li-ion battery module team is a group working on a production at the battery module stage. The electrical component assembly team is a

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group working on the production process of the electrical component assembly stage. The charging and testing team is a group that is working on the final stages of the production process, namely charging and final tests. There are two types of li-ion battery packs produced at SMART UNS type A for 150cc and type B for 110cc. Both models have the same production process, and the difference is the specifications of the material used.

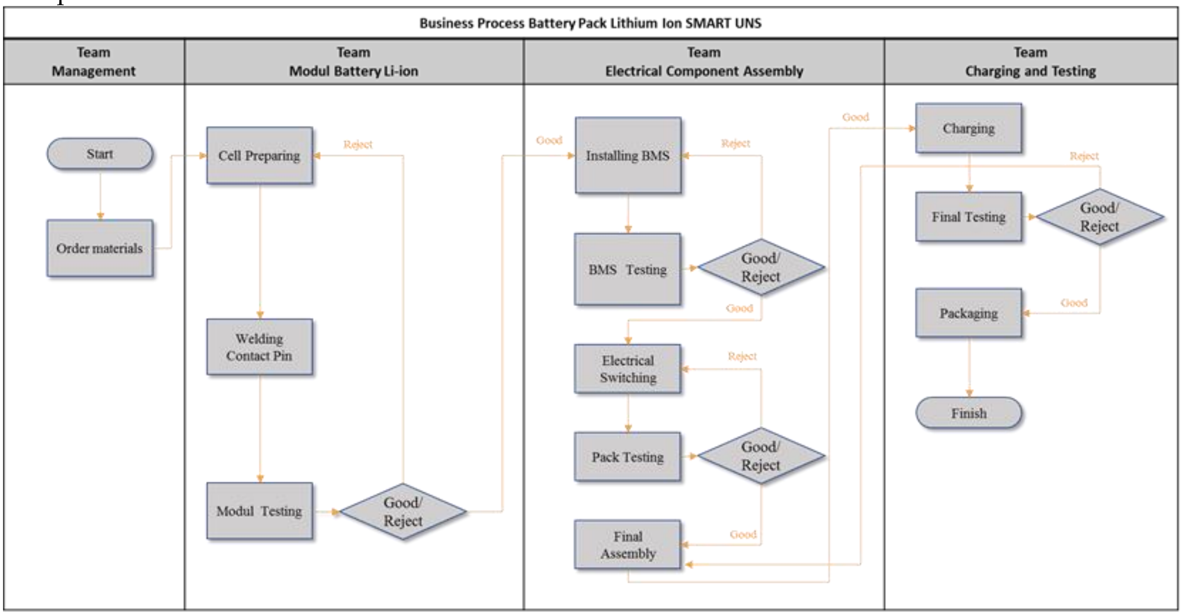

Figure 3. Business Process

2.2 Cost Driver and Cost Center Identification

Activity-based costs are developed to get a more accurate cost estimate [23],[24]. The difference between activity-based costing with the traditional system is the determination of cost drivers [25]-[27]. Cost driver is a driving factor that triggers cost and intermediate factors between cost objects with activities and resources [28]. For selecting the cost driver should be done carefully to ensure the accuracy of the cost. Some researchers have conducted research related to cost drivers as conducted by Cokins and Căpuşneanu [27], Sheng [28], Geiger [29], Răvaş and Monea [30], Dražić-Lutilsky and Dragija [31].

According to Sheng, the cost driver has some specific characteristics such as concealment, relevance, application, and accountability [28]. Cost drivers must have a causality relationship with the activities and costs, it must be measured and explain the use of resources consumed during an activity [30]. Cost drivers should demonstrate correctly the relationship between specific activity and cost objects [31],[32]. One of the requirements of the construction of the cost driver is the cost parameter. Each cost driver relates directly to the process engineering, it can be used in creating task chains. The engineering process associated with this cost driver can be triggered to generate value for cost parameters.

SMART UNS with the business processes that have been described are important for identifying costs associated with various activities in the process, and this is to assess and evaluate inefficiencies based on their economic impacts. The activity-based costing approach in the parametric cost estimation model begins with defining general activities and their cost drivers. Activities, cost drivers, and cost centers can be identified through the results of field observations and maps of the operation process of producing Li-ion battery packs for e-motorcycle conversion. Some studies are used as a reference in the determination of cost driver and parameter costs, including research conducted by Sutopo, Nizam, Purwanto, Atikah and Putri [20]; W. Sutopo; A. Eliza; R. Ardiansyah; Yuniaristanto; and M. Nizam. Parametric [21], MY Abu; KR Jamaludin; and MA Zakaria [22], Fog [33], Erick Ten Bright [34], Katrin and Tatjana [35].

Table 1. Cost Driver and Cost Center Identification

Resource	Activity	Activity Cost Driver	Cost Center
Indirect labor and computers	Order	Working hours	Procurement
		Number of Orders	
Indirect labor and computers	Inbound Logistics	Working hours	Procurement
		Quantity of Material	
Trolley	Material Handling	Product Amount	Material Handling
Dehumidifier Machine	Product Storage	Engine Clock	Save cost
Indirect labor	Machine maintenance	Working hours	Maintenance
		Number of Machines	
Indirect labor and computers	Administration	Working hours	Administration
Research materials	Research and development	Number of Research Projects	Research and development
Production machine	Depreciation of manufacturing equipment	Number of days	Machine Depreciation
	The cost of electricity in the production process	Engine Hours	Electrical energy
	Cost of supporting materials	Quantity of Material	Supporting Materials
Multimeter	Control and Inspection	Process Hours	Quality
Screwdriver	Assembling and Securing Battery Pack Connector	Process Hours	
		Total Production Type A	
		Total Production Type B	
Automatic Battery Spot Welding Machine	Welding	Process Hours	Production
		Total Production Type A	
		Total Production Type B	
Module Tester	Module Testing	Process Hours	Quality
Solder	Soldering	Process Hours	Production
		Total Production Type A	
		Total Production Type B	
Hardware in the loop system and set up for battery management system	BMS Testing	Process Hours	Quality
Screwdriver	Electrical Switching	Process Hours	Production
		Total Production Type A	
		Total Production Type B	
EOL Tester for Battery Module and Pack	Testing Pack	Process Hours	Quality
Screwdriver	Install Case	Process Hours	Production
		Total Production Type A	
		Total Production Type B	
Charging Machine	Charging	Process Hours	Production

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Resource	Activity	Activity Cost Driver	Cost Center
EOL Tester for Battery Module and Pack	Final Testing	Process Hours	Quality

2.3 Parametric Cost Estimation Model Development

In calculating the cost estimation model with the activity-based costing approach, it can generally be done by multiplying the cost driver rate by the number of driving activities as in equation (1).The cost driver rate is the cost that must be incurred for each activity undertaken. The equation (2) is used to calculate cost driver rates.

$$C_j = \sum_{k=1}^{K} (R_{jk} \; x \; Q_{jk}) \tag{1}$$

$$R_{jk} = \frac{TA_{jk}}{V_{jk}} \tag{2}$$

Where C_j is activity costs j, R_{jk} is cost driver k for activity j, Q_{jk} is number of activity in activity, TA_{jk} is total activity costs j, V_{jk} is the predicts number of activity drivers k in activity j.

The total cost of the activity considers several things. In indirect activities, it is necessary to consider overhead costs such as indirect labor costs, machine depreciation costs, electricity costs, consumables costs, and other costs that support these activities. Whereas the direct activity costs that are considered in the calculation of activity costs are the direct labor cost and raw material costs.

2.4 Monte Carlo Simulation

In this research, monte Carlo simulations are carried out to produce data on the amount of production, considering that the battery pack is a new product with no historical data. The monte Carlo simulation through the generation of random numbers is performed using the function on equation (3). This data is used in multiple linear regression analysis to analyze the variables that affect the cost of making a battery pack at SMART UNS.

= RAND () * (Max Prod-Min Prod) + (Min Prod) (3)

3. Results and Discussion

3.1 Parametric Cost Estimation Model

Through business processes and field observations, it was found that there were ten indirect activities and 11 direct activities. Through these activities, the cost driver is identified to build a parametric cost estimation model. Table 2 shows the parametric cost estimation model with an activity-based costing approach.

Table 2. Parametric Cost Estimation Model Based on Activity

Activity	Activity Cost Driver	Parametric Model
Order	Working hours Number of Orders	$Co = (Ro_1 \; x \; h) + (Ro_2 \; x \; Qo)$
Inbound Logistics	Working hours Amount of Material	$Ci = (Ri_1 \; x \; h) + (Ri_2 \; x \; Qo)$
Material Handling	Product Amount	$Cmh = Rmh \; x \; Qmh$
Product Storage	Engine Hours	$Cpp = Rpp \; x \; h_m$
Machine maintenance	Working hours	$Cmm = Rmm \; x \; Hm$
Administration	Working hours	$Cad = Rad \; x \; Had$
Research and development	Number of Research Projects	$Crd = Rrd \; x \; Qrd$
Depreciation of manufacturing equipment	Number of days	$Cdm = Rdm \; x \; Qdm$

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The cost of electricity in the production process	Engine Hours	$Cel = Rel\ x\ h_m$
Cost of supporting materials	Amount of Material	$Cim = Rim\ x\ Qim$
Quality Assurance Activities	Process hour	$Cqc = Rqc\ x\ h_{qc}$
Production Activity	Process Hours	$Cl_j = Rl_j\ x\ h_j$
	Total Production Type A	$Cm_{ij} = \sum_{i=1}^{n}(Rm_{ij}\ x\ Q_{ij})$
	Total Production Type B	

3.2 Numerical Example

In this section, an estimated battery-pack production cost is calculated for one period. This section begins with calculating the cost driver rates for each activity using equation two and calculates the production cost using the parametric cost estimation model in table 2. Table 3 is a recapitulation of the calculation of cost driver rates for each activity.

Table 3. Recapitulation of cost driver rates

Activity	Activity Cost Driver	Cost Driver Rates (USD)
Order	Working hours	0.76
	Number of Orders	2541.19
Inbound Logistics	Working hours	0.76
	Amount of Material	0.01
Material Handling	Product Amount	0.05
Product Storage	Engine Clock	0.30
Machine maintenance	Working hours	1.63
Administration	Working hours	0.87
Research and development	Number of Research Projects	5450.68
Depreciation of manufacturing equipment	Number of days	238.30
The cost of electricity in the production process	Engine Hours	4.91
Cost of supporting materials	Amount of Material	4.12
Control and Inspection	Process Hours	6.04
Assembling and Securing Battery Pack Connector	Process Hours	2.06
	Total Production Type A	3.69
	Total Production Type B	2.64
Welding	Process Hours	6.18
	Total Production Type A	370.08
	Total Production Type B	264.64
Module Testing	Process Hours	2.06
Soldering	Process Hours	2.06
	Total Production Type A	2.50
	Total Production Type B	2.50
BMS Testing	Process Hours	2.06
Electrical Switching	Process Hours	2.06

Activity	Activity Cost Driver	Cost Driver Rates (USD)
	Total Production Type A	0.55
	Total Production Type B	0.55
Testing Pack	Process Hours	2.06
Install Case	Process Hours	2.06
	Total Production Type A	9.67
	Total Production Type B	9.67
Charging	Process Hours	2.06
Final Testing	Process Hours	2.06

The calculation uses the parametric cost estimation model in table 2 for a period of 1 month with total production for type A is 40 units and type B for 35 units. Table 4 is calculated the estimated costs for total production and unit costs of each type of li-ion battery pack for e-motorcycle conversion. Detailed calculations of estimated production costs for one month are shown in Appendix A2.

Table 4. The Result of Calculating the Estimated Costs (USD)

Battery-pack	Total Production Cost	Production Cost	Unit Production Cost
Battery-pack Type A	**43269.671**	25096.1881	627.4046818
Battery-pack Type B		18173.48315	519.2423972

3.3 Simulation Design

In this section, the Monte Carlo simulation design for the number of lithium-ion battery pack production for e-motorcycle conversion. Monte Carlo simulation aims to develop data that will be used to analyze multiple linear regression models. Monte Carlo simulations can predict errors from simulations that are proportional to the number of iterations. For new products, the specified error value is 58% [36]. Equation (4) to calculate the number of iterations needed to get a result with an error of 58%.

$$N = \left(\frac{3\ x\ \sigma}{\varepsilon}\right) \quad (4)$$

Where N is the number of iterations, σ is a standard deviation, and ε is an error value. The results of the calculation of the number of repetitions using equation (4) are 1512 iterations. Table 5 is the result of random numbers generated through the RAND function of Microsoft Excel using equation (3) and the calculation of estimated costs using the parametric model in table 2.

Tabel 5. Li-ion Battery-pack Production Data

Iterate	Battery Pack Type A	Unit Production Cost (USD)	Battery Pack Type B	Unit Production Cost (USD)	Total	Production Cost (USD)
1	**38**	612.34	**34**	504.15	**72**	40411.00
2	**35**	628.75	**32**	520.63	**67**	38665.55
3	**36**	632.32	**30**	524.20	**66**	38489.53
4	**37**	618.66	**33**	510.47	**70**	39734.40
5	**38**	609.32	**35**	501.13	**73**	40695.13
⁝	⁝	⁝	⁝	⁝	⁝	⁝
1508	**37**	621.89	**32**	513.76	**69**	39450.26
1509	**40**	606.37	**34**	498.25	**74**	41195.65
1510	**38**	618.66	**32**	510.47	**70**	39842.59
1511	**39**	639.87	**25**	531.68	**64**	38245.62
1512	**38**	618.66	**32**	510.47	**70**	39842.59

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3.4 Estimation of Multiple Linear Regression Models

This section analyzes multiple linear regression to establish the relationship between the dependent and independent variables. There are 3 regression models built, the first regression model to determine the total cost of producing lithium-ion battery packs for e-motorcycle conversions. The second and third regression models are used to determine the cost of production per unit of lithium-ion battery packs for Type A and Type B. In calculating cost estimation using activity-based costing, costs are triggered by the existence of resource usage activity. Each activity has an activity cost driver that determines the number of costs incurred according to the resources used. Wagner (2012) stating that production volumes are a fundamental trigger cost. Therefore, independent variables in multiple linear regression analyses used the number of total production and the number of battery-pack production for type A and type B. This section is used IBM SPSS Statistics 25 software to estimate the regression model between the dependent variable and the independent variable.

1st Model :

$$y = 15839.108 + 108.162\ x_1 + 284.190\ x_2 \tag{5}$$

y : Total cost of production (USD)

x_1 : Total production of lithium-ion battery packs for Type A (Unit)

x_2 : Total production of lithium-ion battery packs (Unit)

2nd Model :

$$y = 864.806 - 0.016\ x_1 - 3.505\ x_2 \tag{6}$$

y : Unit production cost of Lithium-ion pack-battery for Type A (USD)

x_1 : Total production of lithium-ion battery packs for Type A (Unit)

x_2 : Total production of lithium-ion battery packs (Unit)

3rd Model :

$$y = 756.554 - \ 0.015\ x_1 - 3.504\ x_2 \tag{7}$$

y : Unit production cost of Lithium-ion pack-battery for Type B (USD)

x_1 : Total production of lithium-ion battery packs for Type A (Unit)

x_2 : Total production of lithium-ion battery packs (Unit)

3.5 Classical Assumption Test

The classic assumption test aims to provide certainty that the regression equation obtained has accuracy in estimation, is unbiased and consistent. The classical assumption test consists of 4 parts, namely, multicollinearity, autocorrelation, heteroscedasticity, and normality.

Table 6. Multicollinearity Test Results

Coefficients

Model		Collinearity Statistics Tolerance	VIF
1	(Constant)		
	Total production of battery-packs Type A	.793	1.261
	Total production of battery packs	.793	1.261
	a. Dependent Variable: Total cost of production		
2	(Constant)		
	Total production of battery-packs Type A	.793	1.261
	Total production of battery packs	.793	1.261
	a. Dependent Variable : Unit production cost of pack-battery Type A		
3	(Constant)		
	Total production of battery-packs Type A	.793	1.261
	Total production of battery packs	.793	1.261
	a. Dependent Variable : Unit production cost of pack-battery Type B		

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Based on table 6. the VIF value for each independent variable is less than 10. This shows a regression model free of multicollinearity.

Table 7. Autocorrelation Test Results

Model	**Model Summary**	
1	Durbin-Watson	**2.041**
	DU	1.9166
	4-DU	2.0833
	a. Predictors: (Constant), total production of battery-packs Type A, total production of battery packs	
	b. Dependent Variable: Total cost of production	
2	Durbin-Watson	**1.972**
	DU	1.9166
	4-DU	2.0833
	a. Predictors: (Constant), total production of battery-packs Type A, total production of battery packs	
	b. Dependent Variable: Unit production cost of pack-battery Type A	
3	Durbin-Watson	**1.974**
	DU	1.9166
	4-DU	2.0833
	a. Predictors: (Constant), total production of battery-packs Type A, total production of battery packs	
	b. Dependent Variable: Unit production cost of pack-battery Type B	

Based on table 7. these three models have a DW value between DU and 4-DU (DU<DW<4-DU) therefore the regression model is declared free of autocorrelation problems.

Table 8. Heteroscedasticity Test Results

		Coefficients	
Model			ABS_RES
1	(Constant)		.346
	Total production of battery-packs Type A	Sig. (2-tailed)	.787
	Total production of battery packs		.019
2	(Constant)		.000
	Total production of battery-packs Type A	Sig. (2-tailed)	.095
	Total production of battery packs		.277
3	(Constant)		.000
	Total production of battery-packs Type A	Sig. (2-tailed)	.109
	Total production of battery packs		.195

In the heteroscedasticity test, if the significance value (2-tailed)> 0.05 then there are no symptoms of heteroscedasticity. Based on table 8 it is known that the three models do not have heteroscedasticity symptoms.

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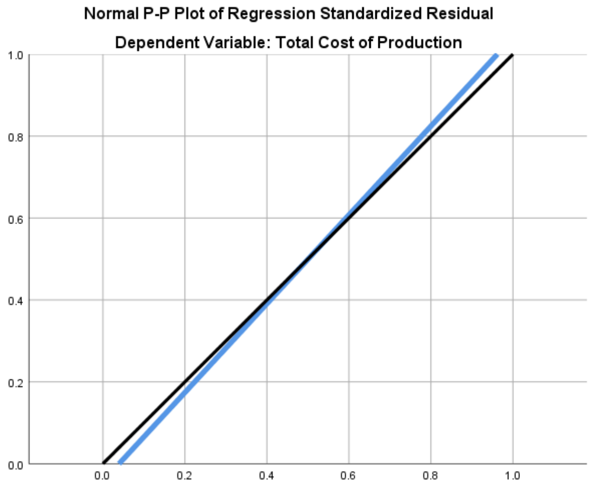
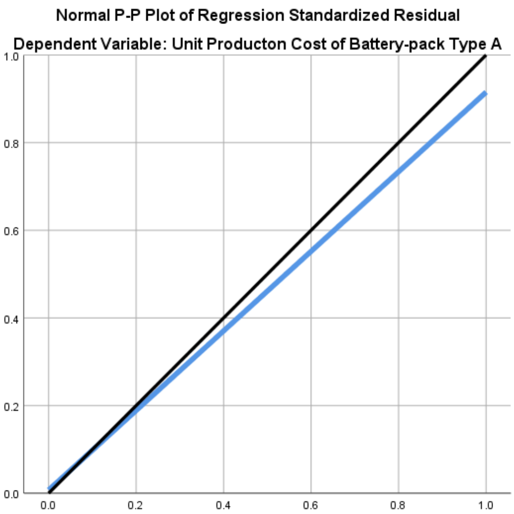
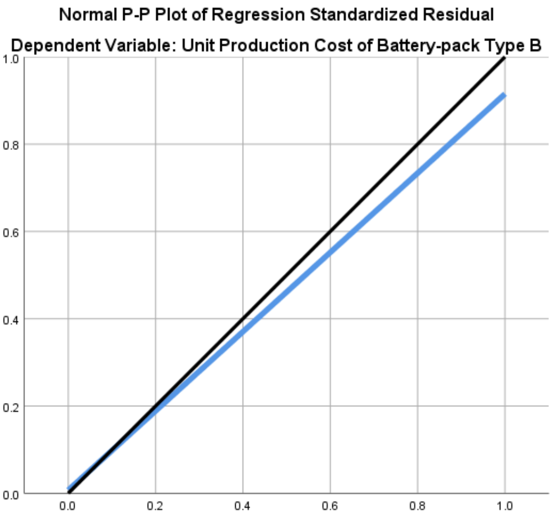


(a)





(b) **(c)**

Figure 3. Normal Plot Graph (a) Model 1; (b) Model 2; (c) Model 3

Based on Figure 3 it is known that the distribution of points is relatively close to the diagonal line so that the residual data criteria are normally distributed with the Normal Plot approach.

3.6 Model Feasibility Test

In this section, test the estimation of the regression model that has been formed in section 3.4 to measure the accuracy of the regression model in estimating the actual value. This section uses the F test and the T test.

3.6.1 F Test

In this section, an F test is performed to determine whether the independent variables simultaneously affect the dependent variable. 2 hypotheses are used. In general, these two hypotheses are:

a. H0 = Simultaneous independent variables do not significantly influence the dependent variable.
b. H1 = Simultaneous independent variables simultaneously have a significant effect on the dependent variable.

Hypothesis testing is done by comparing the significance value with 5%. If the significance value < 0.05 then H0 is rejected, and if the significance value> 0.05 then H0 is accepted.

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Table 9. F Test Results

ANOVA[a]			
Model		F	Sig.
1	Regression	2325861160635.100	.000
	a. Predictors: (Constant), total production of battery-packs Type A, total production of battery packs b. Dependent Variable: Total cost of production		
2	Regression	224077.572	.000
	a. Predictors: (Constant), total production of battery-packs Type A, total production of battery packs b. Dependent Variable: Unit production cost of pack-battery Type A		
3	Regression	234110.173	.000
	a. Predictors: (Constant), total production of battery-packs Type A, total production of battery packs b. Dependent Variable: Unit production cost of pack-battery Type B		

Because the significance value <0.05, the three models have a simultaneous influence between the independent variables on the dependent variable.

3.6.2 T Test

T-test is a method of testing the model to determine the effect of each regression coefficient on the dependent variable. There are 2 hypotheses are used, in general these two hypotheses are:

a. H0 = The independent variable has no significant effect on the dependent variable.

b. H1 = The independent variable has a significant effect on the dependent variable.

Hypothesis testing is done by comparing the significance value with 5%. If the significance value <0.05 then H0 is rejected, and if the significance value> 0.05 then H0 is accepted.

Table 10. T Test Result

Coefficients[a]				
Model		**t**	**Sig.**	**Significant Influence**
1	(Constant)	1241735.455	.000	
	Total production of battery-packs Type A	305884.845	.000	V
	Total production of battery packs	1761879.852	.000	V
a.	Dependent Variable: Total cost of production			
2	(Constant)	1858.380	.000	
	Total production of battery-packs Type A	-1.228	.228	X
	Total production of battery packs	-595.543	.000	V
a. Dependent Variable: Unit production cost of pack-battery Type A				
3	(Constant)	1662.276	.000	
	Total production of battery-packs Type A	-1.206	.285	X
	Total production of battery packs	-608.751	.000	V
a. Dependent Variable: Unit production cost of pack-battery Type B				

Based on table 10 it is known that in 1st model the independent variables have a significant effect on the dependent variable. In 2nd model it is known that the total variable production of battery type A pack does not have a significant effect on the dependent variable, while the total production variable has a significant effect on the dependent variable. Then the 3rd model it is known that the total variable production of battery type A pack does not have a significant effect on the dependent variable, while the total production variable has a significant effect on the dependent variable. Although there are non-significant variables in the second and third models, the model can still be used because if the model runs simultaneously, significant variables will influence the insignificant variables.

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3.7 Determination of the Most Influential Variables

To find out the independent variables that most influence the dependent variable, use the Standard Coefficient Beta test. The highest beta coefficient marks the independent variable that has the biggest effect.

Table 11. Beta Coefficient

Coefficients[a]				
Model		Standardized Coefficients Beta	Most Influential Variables
1	(Constant)		
	Total production of battery-packs Type A	.159	X
	Total production of battery packs	.917	V
	a. Dependent Variable: Total cost of production		
2	(Constant)		
	Total production of battery-packs Type A	.002	X
	Total production of battery packs	-.997	V
	a. Dependent Variable: Unit production cost of pack-battery Type A		
3	(Constant)		
	Total production of battery-packs Type A	.002	X
	Total production of battery packs	-.997	V
	a. Dependent Variable: Unit production cost of pack-battery Type B		

The relation of total cost per unit with change of the activity output is known by reviewing the behavior of cost [37]. In literature, the cost behavior is described as fixed or variable with respect to changes in production volumes. Volumes of output as the fundamental cost driver. Variable costs change proportionally to the change in production volumes [38]-[39]. In standard cost models, variable costs change proportionately with changes in the activity driver, implying that the magnitude of a change in costs depends only on the extent of a change in the level of activity, not on the direction of the change [40].

Based on the first model, it is known that the number of production variables has the highest beta coefficient, 0.917. Therefore, production costs are more influenced by the number of production variables compared to other variables. The factor owned by the total variable production is positive, this shows that if the total production increases, the total production cost will increase as well. Based on the second model, it is known that the number of production variables has the highest beta coefficient, which is 0.997. Therefore, production costs are more influenced by the number of production variables compared to other variables. The coefficient owned by the total production variable is negative, this shows that if the total production increases, the production cost of type A battery units will be smaller. Based on the third model it is known that the number of production variables has the highest beta coefficient value, which is 0.997. Therefore, production costs are more influenced by the number of production variables compared to other variables. The coefficient owned by the total production variable is negative, this shows that if the total production increases, the cost of producing a B type battery unit will be smaller. In this study when the assumption expanded by enlarging the value of significance then it is possible that the H0 can be accepted even if it is wrong and resulting in a change of influence between the dependent variables to the independent variables.

Based on the analysis, the company can maximize the amount of production according to the production capacity to reduce the cost of unit production. By maximizing the amount of production, the price of the product can be more competitive. To achieve production capacity, the company can create an operation process chart and apply standard operational procedures without override product quality.

4. Conclusions

This research chooses an activity-based costing method to classify the cost of producing a Li-ion battery pack for e-motorcycle conversion. Activity-based costing methods provide a more accurate view of product costs than traditional cost methods by identifying each activity element's entire cost. This method determines all activities related to the production process, allocates costs for these activities, and helps classify the production process costs more easily and faster.

The activity-based costing method is integrated with the parametric cost estimation method, which is the right method to be applied with the estimated cost of producing a Li-ion battery-pack for e-motorcycle conversion through a mathematical model. Cost estimation results that reflect a significant difference between product specifications. In addition, cost estimation also reflects the overall use of the company's resources. Activity-based costing helps companies in resource management to get a more competitive cost. Moreover, changes in the operation process for cost reduction will allow the company to fulfill customer needs. Therefore, the battery-pack company can use the activity-based costing method to accurately estimate the cost.

This research also used the regression analysis to analyze. The results of data processing show that the total production costs and unit production costs of the two types have the greatest influence on the total production. However, the total production variable has a different effect on the calculation of total production costs and unit production costs. In the calculation of the total production costs, if the amount of production is increases, the total production costs will increase. Whereas in the calculation of unit production costs it is known that if the total production amount increases, the unit production costs will decrease.

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Appendix A

Table A1. Notation Description

Notation	Description
Co	Order Fees (USD)
Ci	Logistics inbound costs (USD)
Ro_1	Fixed fee per hour for order activities (USD / order)
h	Working hours (hours)
Ro_2	Tariff for one order (USD / order)
Qo	Order Amount (order)
Ri_1	Fixed fee per hour for inbound logistic activities (USD / order)
Ri_2	Inbound logistics tariff per unit of material (USD / unit)
Qi	Amount of material (unit)
i	Order number
Cmh	Material handling costs (USD)
Rmh	Hourly Material Handling Rates (USD / unit)
Qmh	Number of products (units)
Cpp	Storage fee (USD)
Rpp	Product hourly storage rate (USD / hour)
h_m	Engine hours (hours)
Cmm	Machine maintenance costs (USD)
Rmm	Hourly engine maintenance rate (USD / hour)
Hmm_i	Number of technician working hours (hours)
Crd	Research and development costs (USD)
Rrd	Research rates per research project (USD / project)
Qrd	Amount of research projects (Projects)
Cad	Administration fee (USD)
Rad	Hourly administration fee (USD)
Had	Total administrative hours (hours)
Cdm	Cost of depreciating machinery and production equipment (USD)
Rdm	Depreciation rates for machinery and production equipment per day (USD / unit)
Qdm	Number of days in a month (unit)
Cel	Production machine electricity costs (USD)
Rel	Electric machine production hourly (USD / hour)
Cim	Cost of supporting materials (USD)
Rim	Rates of auxiliary materials per unit (USD / unit)
Qim	Amount of auxiliary material used (unit)
Cqc	Quality control costs (USD)
Rqc	Hourly quality control and inspection rates (USD / hour)
h_{qc}	Number of QC hours (hours)
Cl	Direct labor costs (USD)
Cm	Material cost (USD)

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Notation	Description
Rl	Hourly direct labor rates (USD / hour)
Rm_i	Material tariff for series i battery packs per unit battery pack (USD / unit)
Q_i	Number of pack-battery (unit) production
i	Type of battery pack
j	Activity Type

Appendix B

Table A2. Calculation of Estimation Cost (USD)

Activity	Cost	Cost Driver Rates	Quantity	Unit Production Cost Type A	Unit Production Cost Type B	Total
Order	Order activity overhead	0.764	200	81.487958	71.301963	152.789922
	Charge order fees	2541.187	1	1355.299696	1185.887234	2541.186929
Inbound Logistics	Inbound logistic overhead	0.764	200	81.487958	71.301963	152.789922
	Material costs	0.009	43980	234.357737	146.820268	381.178005
Material Handling	Material handling costs	0.046	75	1.830622	1.601794	3.432416
Product Storage	Save cost	0.296	525	82.910273	72.546488	155.456761
Machine maintenance	Machine maintenance costs	1.629	200.0	173.796053	152.071547	325.867600
Administration	General & administrative costs	0.936	200	99.794175	87.319904	187.114079
Research and development	Research and development costs	5450.676	1	2907.027299	2543.648887	5450.676186
Depreciation of manufacturing equipment	Depreciation of manufacturing equipment	204.934	30	3278.940294	2869.072758	6148.013052
The cost of electricity in the production process	The cost of electricity in the production process	3.674	525	1028.643827	900.063349	1928.707176
Cost of supporting materials	Cost of supporting materials	4.119	1	2.196746	1.922153	4.118899
Control and Inspection	Labor costs	27.344	4.52	65.988739	57.740147	123.728885
Assembling and Securing Battery Pack Connector	Labor costs	2.061	25.34	27.852706	24.371118	52.223824
	Material costs for Type A	372.744	40	14909.754926		14909.754926
	Material costs for Type B	266.246	35		9318.596828	9318.596828
Welding	Labor costs	6.183	12.67	41.779059	36.556677	78.335736
	Material costs for Type A	1.030	40	41.188989		41.188989
	Material costs for Type B	1.030	35		36.040365	36.040365

Activity	Cost	Cost Driver Rates	Quantity	Unit Production Cost Type A	Unit Production Cost Type B	Total
Module Testing	Labor costs	2.061	13.57	14.921093	13.055956	27.977049
Soldering	Labor costs	2.061	12.67	13.926353	12.185559	26.111912
	Material costs for Type A	2.504	40	100.171621		100.171621
	Material costs for Type B	2.504	35		87.650168	87.650168
BMS Testing	Labor costs	2.061	13.57	14.921093	13.055956	27.977049
Electrical Switching	Labor costs	2.061	27.15	29.842185	26.111912	55.954097
	Material costs for Type A	0.549	40	21.967461		21.967461
	Material costs for Type B	0.549	35		19.221528	19.221528
BMS Testing	Labor costs	2.061	13.57	14.921093	13.055956	27.977049
Install Case	Labor costs	2.061	9.05	9.947395	8.703971	18.651366
	Material costs for Type A	9.666	40	386.627308		386.627308
	Material costs for Type B	9.666	35		338.298895	338.298895
Charging	labor costs	2.061	54.30	59.684370	52.223824	111.908194
Testing Pack	Labor costs	2.061	13.57	14.921093	13.055956	27.977049
			Total Production Cost	**25096.188**	18173.483	43269.671
			Unit production cost of pack-battery	**627.405**	**519.242**	576.929

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