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A Cost Estimation Application for Determining Feasibility Assessment of Li-Ion Battery in Mini Plant Scale

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Abstract: We proposed a cost estimation application in determining the feasibility of Li-Ion Battery manufacturing planning. The application is development of previous research about cost estimation model and technical feasibility study in Li-Ion battery manufacturing in mini plant scale. Cost estimation model is constructed in activity-based costing (ABC) model, while the technical feasibility process is constructed in Goldsmith Technology Commercialization Model. The application uses production planning data in ABC model for technical feasibility, market study data for market feasibility and management planning data for business feasibility. Management team can adjust the planning if the application shows that the planning is infeasible. By this application, management team can assess the feasibility of Li-Ion battery manufacturing planning in simple way considering the fluctuation of parameters. Numerical example has been simulated and shows the result in simple and fast way. The result can be consideration for Li-Ion battery management team in producing and business planning.

Keywords: application, cost, estimation, feasibility, Li-ion battery

1. Introduction

One of the consortiums for developing national electric vehicle in Indonesia or literally Mobil Listrik Nasional (Molina) is currently making a prototype electric vehicle (EV) with developed EV battery as the main energy storage [1] – [5]. The developed battery is called Lithium-ion (Li-ion) battery based on $LiFePO_4$ for cathode material. Li-ion battery is one of the types of rechargeable batteries. The Li-ion battery which has many advantages such as light weight, eco-friendly, slow loss of charge when not in use, has great power over, the charging process takes less time than NiMH battery, life cycle up to 3000 cycles and has no memory effect, which means that the charging process only adds energy storage [5] – [7].

In its development, the Li-ion battery is assessed as potential technology for commercialization as it is considered to contribute more to the market industry, because a current national company supplying lithium batteries, especially for the needs of electric vehicles, still imports some components of electric vehicle batteries from other countries [4], [8]. In line with that, another assessment assess that Li-ion battery potential to be commercialized with value of the technology readiness levels (TRLs) is on 6 (Prototype demonstrated in field systems) [9]. In addition, the factor that causes the Li-ion battery potential to be commercialized is the huge market potential. Li-ion batteries demand in the future is predicted to a significant increase in line with the government's vigorous program to develop environmentally friendly vehicles [4]. Moreover, the batteries demand can be triggered also by the use of, notebook battery, battery storage for electric power solar cells, e-bike and electric power tools, which is currently experiencing rapid growth [4], [8], [10] – [12].

It said that intended outcome of this development stage is the technology can be commercialized in a university spin-off scheme, with the TRLs - value on 9, or ready to commercialize [9]. In an effort to continue the process of commercialization that has been done, the previous study develops the technical feasibility based on Goldsmith

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commercialization model, by mapping the correlation of technical feasibility and the TRLs concept, assessing the feasibility of the technology can be made with minimum value is equal to 80% of the fulfillment of the indicators for each stage of TRLs, resulted the technical feasibility can meet the 7th level of TRLs. [13].

In addition, it said that in the technology development phase, according to the Goldsmith commercialization model, price identification should be studied before proceeding to the next stage of commercialization [14]. Therefore, previous study develops a cost estimation model to assess the feasibility of developed product based on the suitability of the targeted cost by market with the estimated cost, it approaches to develop the model is parametric method based on activity-based costing and made to enhance accuracy of the cost estimation [14]. By providing a numerical example into the model, it can predict the cost of lithium ion battery cell (30Ah) and the feasibility assessment carried out by calculating the targeted cost from desire profit and targeted price of market, which the targeted cost is calculated as the cut off value to assess the feasibility of the developed product and the developed product feasible, if the estimated cost is equal or less than the targeted cost [14].

This paper proposes the development of application based on the model have been developed [14] to calculate the estimated cost needed in production, since the cost estimation model is quite difficult for common people. The application will be built in Microsoft Excel. Management team of Li-Ion Battery mini plant can use the application to assess the feasibility of the production planning in simpler way.

2. A Cost Estimation Model

A cost estimation model has been constructed in previous study [14]. As a technical feasibility tool, the model has ben considered international standarization in manufacturing Li-ion battery [13]. Standard from International Electrotechnical Comission (IEC) and United Nation (UN) are apllied in this manufacturing scale. Example of the components that has been standardized are nickel system, cell testing, cell charging and short circuit.

In previous study, they divide into three major topics, namely parametric cost estimation model, numerical example and the feasibility assessment [14]. In this section, we discuss about that topics.

A. Parametric Cost Estimation Model

They use parametric cost estimation as an approach based on mathematical equation that use relationship between product costs and limited number of parameters [2][15]. The production cost Li-ion battery is calculated using the development of basic cost estimation model. To construct the cost estimation model, firstly identify BOM and composition of cost.

1. Bill of Material: The first step to develop the cost estimation model is identifying the BOM of lithium ion battery. BOM tree structure of Li-ion battery by previous study shows in Fig. 2. The Li-ion battery is a parent product that located at level of 0. The components of Li-ion battery are devided until four level number [14].

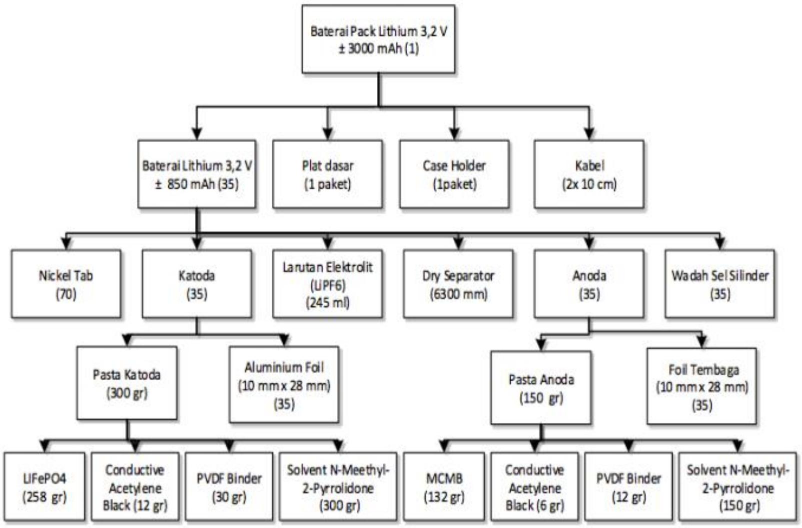

Figure. 2. The bill of material [14]

2. Identification the Composition of Cost: Identification of the composition cost is the next step after the BOM defined. At this step, reference [16] and [17] is used to identify the composition of the Li-ion EV battery manufacturing cost in large scale. Both of reference presents breakdown of battery manufacturing costs. Reference [16] shows the percentage breakdown cost of the Li-ion battery manufacturing for Light-duty vehicles (LDVs) application based on activity as cost drivers, and reference [17] shows the modelling of battery pack manufacturing cost for automotive application based on the type of costs [14]. The cost breakdowns based on the cost type of the manufacturing battery costs in reference [16] and [17] is shown in Table 1.

Table 1. The Cost Breakdowns of Li-Ion Ev Battery

Cost Breakdowns	**[17]**	**[18]**
Material	39%	50.0%
Complementary Material	37%	15.8%
Direct labor	1%	4.3%
Overhead	1%	3.5%
General & Administration Cost	2%	4.2%
Research & Development	4%	3.6%
Depreciation	6%	9.0%
Desire Profit	4%	4.1%
Warranty	6%	5.3%

Source: [14]

3. The Cost Estimation Model: In previous study, the development of activity based costing to parametric cost estimation model, beginning with define the general activities, which driver costs based on the type of cost that identified before. Furthermore the identification of the cost center of each activity should be done to be able to build the model. The identification of general activities that driver costs is shown in Table 2 and the identification of the cost centers of each activity is shown in Table 3.

Table 2. The General Activities In Li-Ion Battery Development Phase

Cost Classification	Component of Cost	Activities
Variable cost	Direct labor	Li-ion battery production
	Material	Purchases of materials and components
	Overhead	Li-ion battery production
Fixed cost	R&D	Research by Inventor
	Procurement	Procurement of machinery and equipment
	Testing & Safety	Testing and quality control of product
	General & Adm.	Administration activities & equipment

Source: [14]

After the cost component for Li-ion battery composed from cost center above, the parametric cost estimation model can be built. All of equation is adopted from previous study [14]. Equation (1) below generated to calculate total cost of battery based on cost center. All of cost parameters are measured in Indonesia Domestic Rupiah (IDR).

$$TC = \sum_{i=1}^{7} CCo_i \tag{1}$$

TC : Total cost of Li-ion battery (IDR)
CCo_i: Cost of components no i (IDR)
i : refers to component of cost as in Table 3.
i = {1, 2, 3, 4, 5, 6, 7}

Each components of cost (CCo_i) have different cost formulation. The variable cost are consist of direct labor, material and overhead cost. Total cost of direct labor is shown in Equation (2). The direct labor cost formulated based on work hours of researchers students, whose have a duty to produce Li-ion cell battery on laboratory scale. On the other hand, the total cost of material, as in Equation (3), is formulated by scale of production of Li-ion battery and material cost of product as a cost centers.

$$CCo_1 = \sum_{i=1} h_i \ x \ CRs_i \tag{2}$$

CCo1: Cost of direct labor (IDR)
h_i : Work hours of research student i (hours)
CRs_i: Cost driver rate of Research student i (IDR/hours)
i : Number of researchers students

$$CCo_2 = \sum_{i=1} (Q_i \ x \ Cm) + TCam_i \tag{3}$$

CCo_2: Cost of material (IDR)
Q_i : Number of cell in day i
Cm: Material cost of a cell Li-ion battery
$TCam_i$: Total cost of auxiliary material in day i (IDR)
i : Days of production

Overhead costs are operational costs of production that are not directly related to production activities such as material costs and indirect labor and maintenance costs over the production activity. Based on the identification of activity and cost center, the estimates model of overhead cost is based on the machining time, with assessment of overhead rates based on the raw materials. Overhead rates assess with material costs, because these costs are the largest percentage of total cost as in reference[16] and [17]. Equation (4) shows the overhead cost formulation.

Table 3. The Cost Center of Each Activity Cost Driver

Cost Classification	No (i)	Component of Costs	Activity Cost Drivers (ACD)	Cost Centers
Variable Cost	1	Direct labor	Work hours	Researchers & students
	2	Material	Scale of production	Material costs
	3	Overhead	Machining time	Overhead rates
Fixed Cost	4	R&D	Work hours	Coordinator team & researchers
	5	Procurement	Number of orders	Delivery & installation costs
	6	Testing & Safety	Number of testing	Testing & safety rates
	7	General & Adm	Work hours	Administration team

Source: [14]

$$CCo_3 = \sum_{i=1} Tm_i \ x \ OHt \tag{4}$$

CCo_3: Overhead cost (IDR)
Tm_i: Machining time in day i (hours)
OHt: Overhead rates (IDR/hours)
i : Days of production

After the model to estimate the cost variables have been developed, the next step is followed by the development of fixed cost estimation model. The fixed cost are consist of research and development (R&D) cost, procurement cost, testing & safety cost, and the last is general and administration cost. Total cost of R&D is shown in Equation (5). The R&D cost formulated based on work hours of coordinator team and researchers. On the other hand, the total cost of procurement, as in Equation (6), is formulated by number of order and delivery and installation cost.

$$CCo_4 = \sum_{i=1} h_i \ x \ CR_i \tag{5}$$

CCo_4: Cost of R&D (IDR)
h_i : Work hours of researcher i (hours)
CR_i: Cost driver rate of Researcher i (IDR/hours)
i : Number of coordinator and researchers

$$CCo_5 = \sum_{i=1} CO_i + CI_i \tag{6}$$

CCo_5: Cost of procurement (IDR)
Co_i: Cost of order i (IDR)
CI_i : Installation cost in order i (IDR)
i : Number of order

The third of fixed cost estimation model is testing & safety cost. The testing & safety cost is formulated as Equation (7), which is formulated based on number of testing as activity cost drive. In another hand, the general and administration cost is formulated by work hours of administration team as activity cost drive. The general and administration cost is shows as Equation (8).

$$CCo_6 = CT \ x \ T \tag{7}$$

CCo_6: Cost of testing and safety (IDR)
T : Number of testing
CT : Cost driver rate of testing and safety (IDR)

$$CCo_7 = \sum_{i=1} (h_i \ x \ Cad_i) + CS_i \tag{8}$$

CCo_7: Cost of general & administration (IDR)

hi : Work hours of administration i (hours)
Cadi: Cost driver rate of administration i (IDR/hours)
CS_i: Cost of stationary in day i (IDR)
i : Number of administration

B. Numerical Example

From the cost estimation model, cost can be estimated with the numerical example of Li-ion battery manufacturing cost. The numerical examples use the cost of the development and production data of cells Li-ion battery on mini plant scale. With a production capacity of mini plant of 100 cells per day, the cost of manufacturing Li-ion battery for a month (2500 cells) shows in Table 4. In calculating the cost estimation, assumptions used are the overhead rate of 10% from the cost of material and the installation cost is 15% from the cost of order. In previous study, there are few mistakes in calculation, so in this study we adjust the calculation. Manual calculation has possibility to make wrong results bigger than semiautomatic calculation using software. So, in this study we develop application to minimize the possibility of wrong.

Table 4. The Cost Etimation of Li-Ion Battery

CCo_i	ACD	ACDR (IDR '000/ACD unit)	Complement Cost (IDR '000)	Total Cost (IDR '000)
1	120 hours	600	-	72.000,00
2	2500 cells	150	357,5	375.357,50
3	525 hours	15	-	7.875,00
4	70 hours	420	-	29.400,00
5	1 order	42570,1	6385,5	48.955,60
6	25 testing	1000	-	25.000,00
7	40 hours	250	1000	11.000,00
		Total cost (IDR '000)		**569.588,10**

C. The Feasibility Assessment

The feasibility assessment carried out by calculating the targeted cost from desire profit and targeted price of market. The targeted cost is calculated as the cut off value to assess the feasibility of the developed product. The developed product feasible, if the estimated cost is equal or less than the targeted cost as a cut off value [14]. The calculation of targeted cost, as in Table 5, is obtained by determining targeted price from PT. Nipress, Tbk., by 1 USD for 1Ah. As the result, the development of Li-ion battery is feasible with the cost estimated of unit battery is less than the targeted cost of the market approach, if the total target sales by 90% and desire profit target by 25%.

Table 5. The Cost Etimation of Li-Ion Battery

Total target sales (90%)	=	US$ 30/unit x 2.250unit x IDR 13.000	=	IDR 877.500.000
Desire profit target	=	25% x IDR 877.500.000	=	IDR 219.375.000
Desire profit target/unit	=	IDR 219.375.000/2.250unit	=	IDR 97.500
Targeted cost/unit	=	(US$ 30/unit x IDR 13.000) - IDR 97500	=	IDR 292.500
Cost estimation (30 Ah)	=	calculation of the cost estimation	=	IDR 568.687.600
Cost/unit of product	=	IDR 568.687.600/2500unit	=	IDR 227.475

Assumption: US$ 1 = IDR 13.000

In this section, we make a adjustment in dollar exchange rate. In the cost estimation application, dollar exchange rate become a important attetion because of the fluctuation. In the application percentage of total target sales and desire profit target can be changed appropriat the condition.

3. Developing the Application of the Cost Estimation

It is necessary to assess the feasibility of Li-Ion Battery production. Determination of feasibility can be conducted by estimate the Li-Ion Battery production cost. Li-Ion Battery in this case, uses Goldsmith Model to leverage the technology readiness level. In that model, the feasibility study stage consists of three sequential steps for different aspects: technical feasibility as technical aspect, market study as market aspect and economic feasibility as business aspect. Combination of those three aspects becomes a set of feasibility study in Li-Ion Battery as shown in figure 1.

Components	Technical	Market	Business
Concept Phase			
Stage I Investigation	Technical Analysis	Market Assesstment	Venture Assessment
Development Phase			
Stage II Feasibility	Technical Feasibility	Market Study	Economic Feasibility
Stage III Development	Engineering Prototype	Strategic Market Plan	Strategic Business Plan
Stage IV Introduction	Pre-Production Prototype	Market Validation	Business Start-Up
Commercial Phase			
Stage V Growth	Production	Sales & Distribution	Business Growth
Stage VI Maturity	Production Support	Market Diversification	Business Maturity

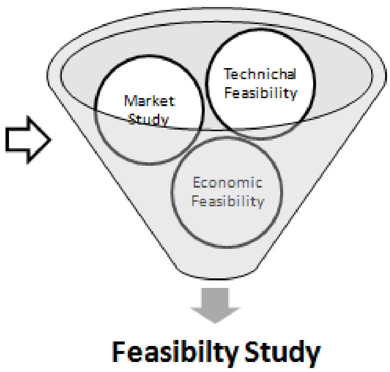

Figure 1. Feasibility Study Set in Li-Ion Battery Case

The cost estimation model seems too difficult for common people, moreover if it is done manually. Besides, there are fluctuating values in foreign exchange, total target sales, desire profit target etc. For the reason, it is necessary to create an application to help the calculation and determining the feasibility. This paper proposes an application to assist the calculation of the estimated cost. The application will be built in Microsoft Excel. Management team of Li-Ion Battery mini plant can use the application to assess the feasibility of the production planning in simpler way.

Calculation model of the application has been developed in previous research (Sutopo, 2014). The calculation uses activity-based costing (ABC) model in estimating the manufacturing cost. There are seven activities that should be considered with each activity cost driver (ACD). Management team input the value of ACD, ACD-rate (ACDR) and complement cost to calculate the total activities cost. Total activities cost will be compared with manufacturing capacity to assess the technical feasibility. This assessment is one of whole feasibility assessment of Li-Ion Battery Mini Plant as shown in figure 4.

After management team assesses the technical feasibility, they assess the market feasibility aspect. The assessment can be done by market study of Li-Ion Battery in Indonesia. This study does not explain how the market study of Li-Ion Battery conducted. Main output of market study is feasible total target sales.

Last step of the feasibility assessment is assessment in business aspect. Economic feasibility method used in this assessment. Economic feasibility assessment based in previous research (Sutopo, 2014), is calculated by comparing the targeted cost/unit and cost/unit of product. To calculate targeted cost/unit management team need to input the desire profit target.

All of the steps are a set of feasibility study step in manufacturing Li-Ion Battery mini plant scale. If the application shows infeasible for technical feasibility assessment, management team can re-input the variables value of technical feasibility assessment (ACD, ACDR and complement cost). So do with market feasibility assessment. Management team can re-input the variables value, so that it shows feasible for market aspect. After the two assessments are feasible, management team can assess the business aspect by inputting the desire profit. If it shows feasible, management team can do the production planning. Otherwise, the desire profit should be changed. These steps can be shown in figure 2.

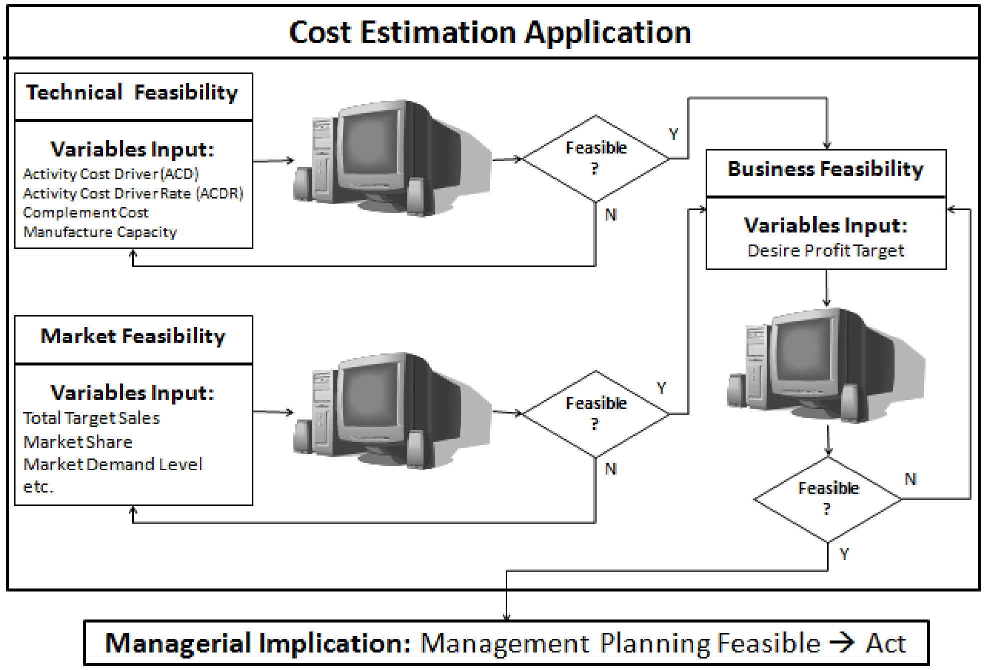

Figure 2. Cost Estimation Application Flowchart in Feasibility Assessment

4. Discussion and Analysis

Parametric Cost Estimation Model

Production Capacity	2500	Selling Price	USD 30,00,

Cost Classification		ACD	ACDR	Complement Cost	Total Cost
Variable Cost	Direct Labor	120	IDR 600000,00	IDR -	IDR 72000000,00
	Material	2500	IDR 150000,00	IDR 357000,00	IDR 375357000,00
	Overhead	525	IDR 15000,00	IDR -	IDR 7875000,00
Fixed Cost	R&D	70	IDR 420000,00	IDR -	IDR 29400000,00
	Procurement	1	IDR 42570100,00	IDR 6385500,00	IDR 48955600,00
	Testing & Safety	25	IDR 1000000,00	IDR -	IDR 25000000,00
	General & Adm.	40	IDR 250000,00	IDR 1000000,00	IDR 11000000,00
				Total Cost	IDR 569587600,00

USD to IDR	IDR 13000,,
Target Sales (%)	90%
Total Target Sales	IDR 877500000,,
Profit Target (%)	25%
Desire Profit Target	IDR 219375000,,
Desire Profit Target	IDR 97500,0,00000

Target Cost / Unit	292500,00
Cost/unit of product	IDR 227835,04,

Figure 3. Cost Estimation Application Display

Application of cost estimation models can be made by identifying the parameters that must be inputted. Application requires many input cost, such as direct labor, material, overhead, R & D, procurement, testing & safety, and general & administration [14]. Before running the application, users should adjust many variable, such as dollar exchange rate, percentage total target sale, percentage desire profit target, and complement cost. Display applications cost estimation model can be seen in figure 3.

5. Conclusion

It has been compiled the application concept of cost estimation for the feasibility assessment of Li-ion battery. In addition, experiments using a numerical example. Finally, the developed application can be used in calculating the cost estimation. For the future research, it is expected to develop applications based on Macro Excel.

6. Acknowledgement

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