Supply Chain Performance Analysis Using Hybrid Overall Equipment Effectiveness and Discrete Event Simulation (Case Study: Futura Energy Nusantara)

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Abstract. Abstract. Futura Energy Nusantara is the first manufacturer of lithium-ion battery cell production in Indonesia. Because highly demand, the company must fill the order and increase production. Productivity is one of the most fundamental and important determinants of system production. Productivity measurement help identify the problems and find solutions to improve system performance. OEE (Overall Equipment Effectiveness) is one method used for effective time manufacturing systems related to the existence of equipment in the production system. The Element of OEE is Availability Rate (A), Performance Efficiency (P), and Quality Rate (Q). The study aims to test through the simulation production system in Lithium-Ion Batteries (LIB), by considering factor OEE, with discrete event simulation system. As a result, this study is a model to applicable, for the company to improve Productivity.

1. Introduction
The production process is the transformation of the process or a set of activities that transform a collection of some inputs (human resources, materials, energy, information, etc.) Into output products (finished products or services) that have added value. Productivity is one of the most basic and important determinants of system production. Productivity measurement helps the company to identify the problems and find solutions to improve system performance. [3]. In the manufacturing industry, production productivity is the main thing that needs to be improved. Increased productivity can be realized by the existence of a production process that runs effectively and efficiently. The production process carried out certainly requires production resources such as humans, machinery and materials.[7] nowadays to be competitive, manufacturers must provide excellent reliability and the best quality of their equipment at competitive prices. To have a very reliable machine to ensure the smooth manufacturing process, many organizations have implemented TPM as a tool that makes it possible to maximize the effectiveness of the equipment. [12]. Futura Energy Nusantara is the first manufacturer of lithium-ion batteries in Indonesia. The target of production must 80,000 battery cells. With a total of 20,000 cells for lithium iron phosphate (LFP) batteries and 60,000 cells for nickel cobalt aluminum (NCA) cell batteries [5]. The agreed period of work is seven months with the fulfillment of a weekly period of 4000 cells per week. In February 2018 PT Pertamina (persero) to collaborate in the formulation and production optimization study consultant services prototype of a lithium-
ion battery, in this project, has succeeded in formulating and improving the production capacity of up to 15,000 cells per month with a floor area of 700m² involving 20 employees. The OEE is one of the approaches that can calculation of overall equipment/machine effectiveness and can simplify the complexity of production problems into simple information. OEE can systematically analyze the production process and identify potential problems in influencing the work of the machine. There are three basic metrics of the OEE such as performance, availability, and rate of quality [2]. OEE can measure performance, identify increased opportunities and focus on improvement efforts in areas related to equipment efficiency and effectiveness [9]. OEE calculates how well the performance of the production system is relative to the designed capacity. During the operation period. A survey reported that OEE is often used as a means to increase company output because it focuses on quality, productivity, and the use of equipment simultaneously [1]. OEE aims to reduce or eliminate speed loss in a lean manufacturing environment, consider two types of uncertainties, namely in the speed of production and cessation of measurement of duration, which is used in calculating OEE components. [13]

In this study, we use the input-oriented Overall Equipment Effectiveness OEE-DES hybrid.

Figure 1. Business Process Lithium Ion Batteries SMART UNS
In making the lithium battery production process, it is divided into 3 people in charge of production, the first is mixing-welding which includes the weighting process, which is the weighing process of the main ingredients. This process is carried out with 1 operator 1 machine. Second is the mixing process, this process is the process of mixing several main ingredients. This process is carried out with 1 operator and 1 machine. Third is the screening process, namely the eliminated filtering material, which is carried out with 1 operator and 1 machine, the fourth is the coating process, namely plate making, consisting of 2 namely the cathode and anode, this process is carried out by 3 operators and 2 machines, the fifth is cutting process, namely the process of cutting the plate, into the size of a battery. Sixth is the process of pressing, which is the process of applying pressure to the layer that has been cut. Seventh is the process of slitting, which is then followed by the rolling process, which is the welding process carried out by 2 operators in turn. The second person in charge is winding-welding, which is given a winding process, namely wrapping the anode and cathode into the battery shell with 1 operator and 2 machines. Then start with the installation of the top and bottom insulators, namely the installation on the top and bottom of the insulator cover by 2 operators and 3 machines. After installation is complete, a grooving process is carried out, which is the process of making grooves done by 1 operator and 1 machine. The third person in charge is the electrolyte-packaging process, after the material and the battery compiler have finished, then the electrolyte filling is carried out, which is carried out by 1 operator and 1 machine and the electrolyte content process is finished the sealing process is carried out by 1 operator and 1 machine. After that the grading process is carried out, namely the process of testing the battery price by 2 operators and 8 machines. After the cost test is successful, then a capacity sorting will be completed with sorting per is done by 1 operator and 2 machines. When all processes have been completed, the last meal is packaging, that is, packaging the batteries, and the batteries are ready to be sent.

2. Quantitative Approach

2.1 Overall Equipment Effectiveness

In table 1 is the data collected and processed using the method OEE data processing is performed to determine the level of effectiveness of use machines just for 6 process from 18 process of lithium-ion batteries, there are pressing, slitting, welding, winding, screw & spot welder, and filling electrolyte & punching

| Process         | Available Time (Minutes) | Planned Down Time (Minutes) | Loading Time (Minutes) | Operating Time (Minutes) | Process Amount (Cell) | Ideal Cycle Time (Minutes/Cell) | Defect Amount (Cell) |
|-----------------|--------------------------|----------------------------|------------------------|--------------------------|-----------------------|---------------------------------|---------------------|
| Pressing        | 42596                    | 3205                       | 39391                  | 1687                     | 37704                 | 60288                           | 0,384               | 1463                 |
| Slitting        | 37510                    | 3562                       | 33948                  | 1617                     | 32331                 | 58826                           | 0,527               | 2732                 |
| Welding         | 40164                    | 3227                       | 36937                  | 2077                     | 34860                 | 56094                           | 0,529               | 969                  |
| Winding         | 38744                    | 4119                       | 34625                  | 2159                     | 32466                 | 55125                           | 0,421               | 9204                 |
| Screw & Lid    | 38134                    | 3236                       | 34898                  | 2003                     | 32895                 | 45921                           | 0,498               | 470                  |
Filling electrolyte & Punching

Overall equipment effectiveness (OEE) is the one measure of TPM (Total Productive Maintenance) to evaluate the effectiveness of equipment or machine. The function of OEE is to measure reveals the hidden costs that cause a considerable amount of production loss. The OEE consists of three parameters are availability, performance, and quality. It can be calculated as follows [13]

\[ OEE = \text{Availability} \times \text{Performance} \times \text{Quality} \]  \hspace{1cm} (1)

### 2.1.1 Availability

Availability is the percentage level availability of machine or time scheduled production that compared with the amount of time producing. Which is not included in availability is Scheduled maintenance, planned downtime, or equipment trials. This can help a plant manager to identify whether machine downtime issues are part of a known calendar, or if there is a more serious problem. [10]

The Example of calculate availability of Pressing Machine as follows :

\[ \text{Availability} = \frac{\text{Operating Time}}{\text{Loading Time}} \times 100\% \]  \hspace{1cm} (2)

\[ = \frac{\text{Loading Time} - \text{Down Time}}{\text{Loading Time}} \]

\[ = \frac{\text{(Total Available Time} - \text{Planned Time own Time}) - \text{Down Time}}{\text{Load Time}} \times 100\% \]

\[ = \frac{42596 - 3205}{3931} - 1687 = 95,72\% \]

### 2.1.2. Performance

Performance is the percentage level of the total parts that produced on the machine to the production rate of the machine. This can help the manager to indicate problems with the machine itself if has recurring efficiency issues. [10]

The Example of calculate Availability of Pressing Machine as follows :

\[ \text{Performance} = \frac{\text{Processed Amount} \times \text{Ideal Cycle Time}}{\text{Operating Time}} \times 100\% \]  \hspace{1cm} (3)

\[ \text{Performance} = \frac{60288 \times 0.384}{37704} \times 100\% = 61,40\% \]
2.1.3 Quality.

Quality indicates the level of ability of the machine or equipment inside produces a product that complies with predetermined standard specifications. It can help the manager to compare consistency between individual machines, different manufacturers as well as machine, specifications and even individual operators [8]

The Example of calculate Quality of Pressing Machine as follows

\[
Quality\ Rate = \frac{Processed\ Amount \times Defect\ Amount}{Processed\ Amount} \times 100\% \quad (4)
\]

\[
Quality\ Rate = \frac{60288 - 1463}{60288} \times 100\% = 97,57\%
\]

Total OEE of Pressing Machine as follows :

\[
OEE = 95,72\% \times 61,40\% \times 97,57\% = 57,34\%
\]

3. Results and Discussion

Based on the calculation results in table 1.data analysis was carried out with OEE Methode of 6 process lithium-ion batteries.

| Process                  | Availability (%) | Performance Efficiency (%) | Quality Rate (%) | OEE (%)   |
|--------------------------|------------------|-----------------------------|------------------|-----------|
| Pressing                 | 95,71            | 61,40                       | 97,57            | 57,34     |
| Slitting                 | 95,23            | 95,88                       | 95,35            | 87,07     |
| Welding                  | 94,75            | 85,12                       | 98,27            | 80,33     |
| Winding                  | 94,27            | 71,48                       | 83,30            | 55,83     |
| Screw & Lid Welding      | 93,79            | 69,52                       | 98,97            | 64,85     |
| Filling Electrolyte & Punching | 93,79 | 90,46                       | 98,81            | 83,69     |
| **OEE**                  | **93,79**        | **78,97**                   | **95,38**        | **71,52** |

Table 2. The Result of OEE SMART UNS in January – June 2019
After we calculate the 6 process with OEE element, we get the result.

3.1 Availability
Pressing Process has high availability than the other process with 95.71% because, operators and materials are always there, and has small downtime. In the filling electrolyte & Punching is the lowest availability with 93.79% because the cell must be waited for the process before and has most downtime.

3.2 Performance Efficiency
Slitting process has the highest Performance with 95.88% because the process has the smallest losses idling and minor stoppages. The pressing process has the lowest with 61.40%, because the process has the difference between actual production capacity with an ideal run time very far.

3.3 Quality
Screw & Welding process has the Highest Quality with 98.97% because, in this process has a small defect product, then the other process. In the Winding process, has the lowest Quality with 83.30%, because in this process has big defect product, cause a combination of several materials to become a cell battery.

The result of total availability is 93.70%, total performance efficiency is 78.97%, and the quality rate is 95.38%. And the total OEE is 71.52%.

We get the lower OEE is Winding Process with 55.83% because the machine mostly has long time set up, and get stuck in the middle of the process, besides that, this station has lacked the operator to operate this machine.

To identification furthermore, we make model flowchart simulation. The simulation model get 6 processes of Lithium-Ion Batteries with Discrete Event Simulation to know the model simulation with any logic software.

![Figure 2. Any logic Flowchart](image)
We use Any Logic to make the design model. We make the model with a discrete event method. Utilizes blocks that describe a specific state in the process. There are numerous different blocks in the software library, as a source, delay, resource send to, resource pool, rack store, sink, etc. The blocks are interconnected by connectors. Each block, depending on the type, contains defined properties, such as name; type; delay time; capacity; maximum capacity; agent location; agent type, etc.

![Figure 3. Pressing Process Flowchart](image)

4. Conclusion

Futura Energy Nusantara is the first manufacturer of lithium-ion battery cell production in Indonesia. Because highly demand, the company must fill the order and increase production Productivity is one of the most fundamental and important determinants of system production. To evaluate the production process, we use OEE to find the effectiveness of equipment/machines. Overall equipment effectiveness (OEE) is to evaluate the effectiveness of equipment or machine.

After we calculate the OEE, we get the lower OEE is Winding Process with 55.83% because the machine mostly has a long time set up, and gets stuck in the process, besides that, this station has lacked the operator to operate this machine. And we get that the total OEE is 71.52%, need to improve the score to get 85% to become a world-class manufacturer.

This study also provided a discrete system simulation flowchart model using any logic software. This article has certain limitations, that should be overcome to provide in the deep analysis of the performance measurement analysis. For further research will complete the research with ORE method for accurate performance measures, and run the simulation.

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