The Proposed OEE-SIGMA Prediction for Increased Profits

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Abstract. Most of the organizations adopt methods to measure their operational performance based on timeframe and requirements. One of the most commonly used measures of performance against capability of the equipment is the Overall Equipment Effectiveness (OEE). Overall Equipment Effectiveness (OEE) metric application in industry has been facing a challenge of continuing advancement in industrial operations. A smart OEE is required for a quick response to the dynamism in industrial system. In this study, OEE metric is made smart by integrating sigma continuous improvement tool into it for the enhancement of dynamism required of the traditional OEE model measured basically on three factors: availability, performance and quality. System productivity dynamism is measured and predicted through sigma statistical variation of the production process defined as a ratio of delivered output (supply) to the expected (planned) output. In this research, the model was applied to made dynamics simulation for increased profits of many manufacturing organizations. The result obtained are increased elements in OEE in line with increased of profits. This indicated that smart OEE-sigma model is a better tool for enhancing continuous improvement which can accurately measuring the financial benefits of proposed improvement projects.

Keywords: overall equipment effectiveness, sigma metric, continuous improvement, production process

1. Introduction
Many manufacturing organizations have trouble accurately measuring the financial benefits of proposed improvement projects. Important projects are often overlooked or not properly prioritized relative to average projects. As a result, a manufacturing area can get mired in driving false improvement projects, never making significant gains in reliability and productivity. And the one proposed of improvement projects in every plant is improve the efficiency. Manufacturing plant is required to embrace a continuous innovation in modern manufacturing systems in order to become productive and being competitive. One of the best efficiency measurement method that can achieve the goal is Overall Equipment Effectiveness (OEE). Overall Equipment Effectiveness (OEE) was launched by Nakajima in the 1980s for measuring productivity of individual equipment in a factory. OEE tool exists to identifies and measures losses from important aspects of manufacturing such as availability, performance and quality rate. This tool can support the improvement of equipment effectiveness and there by its productivity [1]. The OEE concept is becoming increasingly popular and has been widely used as a quantitative tool essential for measurement of productivity especially in the semiconductor manufacturing operations [2].
Financial statements are the scorecards used to communicate and benchmark a company’s business. Understanding the link between OEE and financial statements is of paramount importance in ranking reliability and improvement projects.

It is beyond the scope of this paper to investigate financial accounting. This paper uses a generic simplified approach that can fit most specific cases and give you a relevant first look at financial benefits. Our methodology proposes a new OEE approach for measuring effectiveness in order to enrich the solution to this classic financial problem. This study provides an interesting opportunity to know the financial impact of the best projects and can convey the information to your company's decision-makers in terms they understand and fully support.

2. Methods

As stated previously, this paper aimed to optimize the effectiveness and increase profit of company. The OEE has strength to evaluate important aspects of manufacturing through the single measurement tool. The idea is how much impact of changing the factors of OEE element in terms of financial aspects. OEE elements basically can be illustrated as below in figure 1.

![Figure 1. OEE Elements](Source: EXOR / DataVisor Marqueses (2009). The Complete Guide to Simple OEE)

Based on the figure above, effectiveness reduction occurred because losses. There are downtime losses, speed losses, and quality losses. Downtime losses is an event that stop planned production for a length of time such as equipment reparation (planned or unplanned). Speed losses have an affect on manufacturing process to run less than maximum speed or minimum cycle time while production is running. Quality losses is a loss when finished goods can not meet the qualification of quality standard. Each element can be measured by using factors from OEE function.

OEE function that given are as follow.

\[ \text{OEE} = \alpha \times \beta \times \mu \]

Where the factors are,

\[ \alpha \text{ (Availability)} = \frac{\text{delivered production volume}}{\text{expected production volume}} \]

\[ \beta \text{ (Performance efficiency)} = \frac{\text{System performance delivered}}{\text{System performance expected}} \]

\[ \mu \text{ (Quaility Rate)} = \frac{\text{quality produced delivered}}{\text{quantity of production}} \]
In the calculation by using heuristic method, there are some scenarios of solution for increasing the effectiveness. There are three scenarios as follow:

1) **Scenario 1**, by control the number of expected volume production or delivered volume production, which means the availability factor will increased.
2) **Scenario 2**, after the first scenario has applied then increase value of speed rate of equipment, which means the availability and performance factor will increased.
3) **Scenario 3**, after two previous scenarios has applied then increase the number of good product that meet the standard qualification, which means the availability, performance, and quality factor will increased.

Each scenario have to deal with two cases, where 1) Case 1, the production volume after the scenario given still constant. 2) Case 2, the production volume increased.

In addition to OEE, measuring the performance of equipment can be determined by allocating costs associated with OEE factors. According to Robert C. Hansen [6], the costs associated with OEE consist of direct material costs, direct labor costs, factory overhead costs, and operation expenses. Each cost component is shown at table 2 and table 3.

### Table 1. Cost Component and Formula

| Cost component       | Formula                          |
|----------------------|----------------------------------|
| Net sales            | $Q_{sales} \times P_{unit}$      |
| Costs                |                                  |
| Direct Material      | $C_{material} = Q_{material} \times \text{cost material per unit}$ |
| Direct Labor         | $C_{labor} = T_{work} \times \text{cost of labor per hour}$ |
| Overhead Cost        | $C_{overhead} = D+U+I+T+IL+F$    |
| Selling & administration Cost | (Assumption) |
| Operating Income     | $\text{Income} = \text{Net sales} - \text{Costs}$ |

### Table 2. Notation List

| Notation list          | Description                        |
|------------------------|------------------------------------|
| $Q_{sales}$            | Amount of finished goods           |
| $P_{unit}$             | Price of product per unit          |
| $C_{material}$         | Direct Material Cost               |
| $Q_{material}$         | Amount of production volume        |
| $C_{labor}$            | Direct labor cost                  |
| $T_{work}$             | Work duration of labor (hour)      |
| $C_{overhead}$         | Overhead Cost                      |
| $D$                    | Depreciation                       |
| $U$                    | Utilities                           |
| $I$                    | Insurance                           |
| $T$                    | Property tax                       |
| $IL$                   | Indirect labor                     |
| $F$                    | Factory supplies                   |
All these components are accumulated into total cost as a parameter of OEE performance. The change of factor can impact the saving cost or extra cost. By using the Heuristic method, the cost performance can be determined.

3. Result and discussion
The value of allocation expected and delivered each factor are shown below. The calculation of each factor also determined refers to Equation (1)-(4). The result of calculation is shown below.

Table 3. The Data Reference for Analysis

| Year | Expected Production Volume (million) | Production Volume Delivered (million) | Ratio (α) | Performance Expected (%) | Performance Delivered (%) | Ratio (β) | Quality Product Expected (%) | Quality Product Delivered (%) | Ratio (μ) |
|------|-------------------------------------|--------------------------------------|--------|-------------------------|--------------------------|--------|-----------------------------|-------------------------------|--------|
| 2019 | 1.215.000                           | 1.150.000                            | 0.95   | 93.50                   | 80.00                    | 0.86   | 80.00                       | 73.00                          | 0.91   |
| 2020 | 1.421.000                           | 1.321.000                            | 0.93   | 91.50                   | 82.00                    | 0.90   | 72.00                       | 65.00                          | 0.90   |
| 2021 | 1.552.000                           | 1.365.000                            | 0.88   | 92.00                   | 81.50                    | 0.89   | 75.50                       | 70.50                          | 0.93   |

Table 4. Recapitulation of OEE Value (Baseline)

| Year | Ratio (α) | Ratio (β) | Ratio (μ) | OEE  |
|------|--------|--------|--------|------|
| 2019 | 0.95   | 0.86   | 0.91   | 0.74 |
| 2020 | 0.93   | 0.90   | 0.90   | 0.75 |
| 2021 | 0.88   | 0.89   | 0.93   | 0.73 |

Assume that the schedule running 320 days in a year. Then determine the speed rate by using the equation below

\[ R = \frac{\text{Production volume delivered}}{\text{Scheduled Time} \times \text{OEE}} \]  

(5)

Table 5. Speed Rate Calculation

| Year     | Production Volume Delivered (million) | Scheduled Time (hour) | Ideal Speed Rate (Unit / hrs) |
|----------|--------------------------------------|-----------------------|-------------------------------|
| 2019     | 1,150,000                            | 7,680                 | 203                           |
| 2020     | 1,321,000                            | 7,680                 | 229                           |
| 2021     | 1,365,000                            | 7,680                 | 244                           |

Scenario 1
In this scenario, we calculate the OEE and cost performance after controlling the value of availability in order by 2%, 3%, and 4%. For the first case, the calculation for 2% increasing factor are shown at table 9. Then for case 2, we calculate the new number of goods for new OEE. The result are shown at table below.
Table 6. Number of Good Unit Calculation for New OEE (Scenario 1)

| Year | Number of Good Units Made with New OEE | Different Good Units | Different Good Units (%) |
|------|----------------------------------------|----------------------|--------------------------|
| 2019 | 1,174,300                              | 24,300               | +2.07%                   |
| 2020 | 1,349,420                              | 28,420               | +2.11%                   |
| 2021 | 1,396,040                              | 31,040               | +2.22%                   |

Scenario 2
In this scenario, we calculate the OEE and cost performance after controlling the value of availability and performance in order by 2%, 3%, and 4%. For the first case, the calculation for 2% increasing factor are shown at table 10. Then for case 2, we calculate the new number of goods for new OEE. The result are shown at table below.

Table 7. Number of Good Unit Calculation for New OEE (Scenario 2)

| Year | Number of Good Units Made with New OEE | Different Good Units | Different Good Units (%) |
|------|----------------------------------------|----------------------|--------------------------|
| 2019 | 1,201,749                              | 51,749               | +4.31%                   |
| 2020 | 1,379,535                              | 58,535               | +4.24%                   |
| 2021 | 1,427,557                              | 62,558               | +4.38%                   |

Scenario 3
In this scenario, we calculate the OEE and cost performance after controlling the value of availability, performance, and quality in order by 2%, 3%, and 4%. For the first case, the calculation for 2% increasing factor are shown at table 11. Then for case 2, we calculate the new number of goods for new OEE. The result are shown at table below.

Table 8. Number of Good Unit Calculation for New OEE (Scenario 3)

| Year | Number of Good Units Made with New OEE | Different Good Units | Different Good Units (%) |
|------|----------------------------------------|----------------------|--------------------------|
| 2019 | 1,228,088                              | 78,089               | +6.36%                   |
| 2020 | 1,410,097                              | 89,097               | +6.32%                   |
| 2021 | 1,458,134                              | 93,134               | +6.39%                   |

Table 9. Saving Direct Labor Cost Calculation (Scenario 1 in Case 1)

| Year | Scheduled Time (hr) | Ideal Speed Rate (Unit / hrs) | Ratio (α) Increase 2% | New OEE | New Scheduled Time (hr) | Savings Hours | Net Saving Hour (-96 hour) | New Direct Labor Expenses | Saving cash (Million) |
|------|---------------------|------------------------------|-----------------------|---------|------------------------|----------------|-----------------------------|--------------------------|-----------------------|
| 2019 | 7,680               | 203                          | 0.97                  | 0.75    | 7,521                  | 159            | 63                          | $23.80                   | $ 0.20                |
| 2020 | 7,680               | 229                          | 0.95                  | 0.77    | 7,518                  | 162            | 66                          | $23.79                   | $ 0.21                |
| 2021 | 7,680               | 244                          | 0.90                  | 0.74    | 7,509                  | 171            | 75                          | $23.77                   | $ 0.23                |
Table 10. Saving Direct Labor Cost Calculation (Scenario 2 in Case 1)

| Year | Scheduled Time (hr) | Ideal Speed rate (Unit / hrs) | Ratio (α) Increase | Ratio (β) Increase | New OEE | New Scheduled Time (hr) | Savings Hours | Net saving hour (-96 hour) | New Direct Labor Expenses | Saving cash (Million) |
|------|---------------------|-------------------------------|---------------------|---------------------|---------|-------------------------|---------------|-------------------------|--------------------------|-------------------------|
| 2019 | 7,680               | 203                           | 0.97                | 88%                 | 0.77    | 7,349                   | 331           | 235                     | $23,27                    | $0.73                   |
| 2020 | 7,680               | 229                           | 0.95                | 92%                 | 0.79    | 7,354                   | 326           | 230                     | $23,28                    | $0.72                   |
| 2021 | 7,680               | 244                           | 0.90                | 91%                 | 0.76    | 7,343                   | 337           | 241                     | $23,25                    | $0.75                   |

Table 11. Saving Direct Labor Cost Calculation (Scenario 3 in Case 1)

| Year | Scheduled Time (hr) | Ideal Speed rate (Unit / hrs) | Ratio (α) Increase | Ratio (β) Increase | New OEE | New Scheduled Time (hr) | Savings Hours | Net saving hour (-96 hour) | New Direct Labor Expenses (Million) | Saving cash (Million) |
|------|---------------------|-------------------------------|---------------------|---------------------|---------|-------------------------|---------------|-------------------------|-------------------------------|-------------------------|
| 2019 | 7,680               | 203                           | 0.97                | 88%                 | 0.79    | 7,192                   | 488           | 392                     | $22,77                       | $1.23                   |
| 2020 | 7,680               | 229                           | 0.95                | 92%                 | 0.80    | 7,195                   | 485           | 389                     | $22,78                       | $1.22                   |
| 2021 | 7,680               | 244                           | 0.90                | 91%                 | 0.78    | 7,189                   | 491           | 395                     | $22,77                       | $1.23                   |

By using equation in Table 1, the calculation of income and relationship between changing factors and income are shown in Table 12. By the same way, we calculate the other scenario and shown in Figure 2,3 and 4.

Table 12. Financial Calculation

| Case 1 (Scenario 1) | Case 2 (Scenario 2) |
|---------------------|---------------------|
| Net Sales           | $115,00             | Net Sales           | $117,43             |
| Direct Materials used | $26,00             | Direct Materials used | $26,52             |
| Direct Labor        | $23,80              | Direct Labor        | $24,30              |
| Total Factory Overhead | $53,00             | Total Factory Overhead | $53,00             |
| Operating Income Earnings Before Interest and Taxes (EBITS) | $12,20             | Operating Income Earnings Before Interest and Taxes (EBITS) | $13,61             |
4. Conclusion
Based on the results of OEE calculations and measurements of the financial aspects, it is seen that increasing the factors will increase direct material costs, reduce direct labor costs and increase profits from product sales. Case 1 can affect the direct labor cost while in case 2 can affect the direct labor and material cost. All OEE elements need to be considered in order to significantly increase profits. Because the data used is still in the form of historical data, this study needs to examine more patterns of tradeoff between costs and OEE needs in order to get more accurate results.

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