Synthesizing the Machine's Availability in Overall Equipment Effectiveness (OEE)

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ABSTRACT

Overall Equipment Effectiveness (OEE) is an important and reliable method that could be adopted in manufacturing environment. This method is significant to evaluate machines performance and later setting up goals for the industry to keep improving their performance. Previously, numerous researchers have been conducted to adopt these tools and find the OEE value for specific industry. As a bottom-up approach, the method proposed is to implement into the system. However, study on the opposite way which is a top-bottom approach is still unavailable. From the OEE calculation that measure machine's availability, performance and quality, there is no specific study to re-evaluate the value gathered. Thus, this paper proposed a top-down framework to evaluate current performance of the machine. The outcome from the framework can then be used in producing simplified Machinery Failure Mode Effect Analysis (MFMEA). A case study in a manufacturing company has been adopted to demonstrate the implementation of the proposed framework.

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Introduction

Overall Equipment Effectiveness (OEE) is a very well-known and common method in measuring manufacturing performance based on three main components which are availability, performance, and quality [1]. The power of OEE comes from its applicability as a measuring methods of manufacturing performance by gauging the effectiveness of machines/equipment at the plant level. OEE also provides users with the ability to identify limiting factors that hinder better machine operation.

The OEE calculation is a metric that gives daily information about how effectively the machine is running and which of the six big losses we need to improve. OEE measures can also be applied at different hierarchical levels [2];

- OEE can be used to measure the initial performance of the manufacturing plant and can be compared to future values to quantify the level of improvement.
- OEE measures can indicate which resources perform worse than expected and help identify the exact areas that need improvement.
- OEE measures calculated for one manufacturing line can be used as a benchmark to compare performances in other similar lines across a factory.

Up until today, many researches have been conducted to explore and theories behind the idea of OEE. OEE have been correlated with Failure Mode Effect Analysis (FMEA) where the result shows availability component give a positive relationship with RPN number [3]. OEE also has been integrated with reliability method to improve maintenance performance level [4]. Other researchers have also made an effort in developing automation system in measuring OEE by introducing hardware and software development [5]. Design of Experiments (DOE) also has been used in optimizing and analyzing OEE. From the method proposed, to achieve 72.41% of OEE, an optimized value of (1) availability is 95%, (2) performance is 99%, and (3) quality is 99%. These values are also the ideal value for an effective machine.

From various literatures that have been published, many methods to enhance OEE measurement have been proposed and implemented. However, the synthesis on each component to reveal the significant variables and parameters measured for OEE is not yet available. Thus, this paper, proposed a framework with a case study as an example to synthesizing from top to bottom the rational of measuring availability component in OEE.

Methodology

In synthesizing machine availability in OEE component, this study proposed a framework as shown in Figure 1. The framework consists of seven steps. It is a cycle process where the availability of the machine should be keep monitored and improved. Hence, each time the machine availability need to be review, proposed method shall be used.

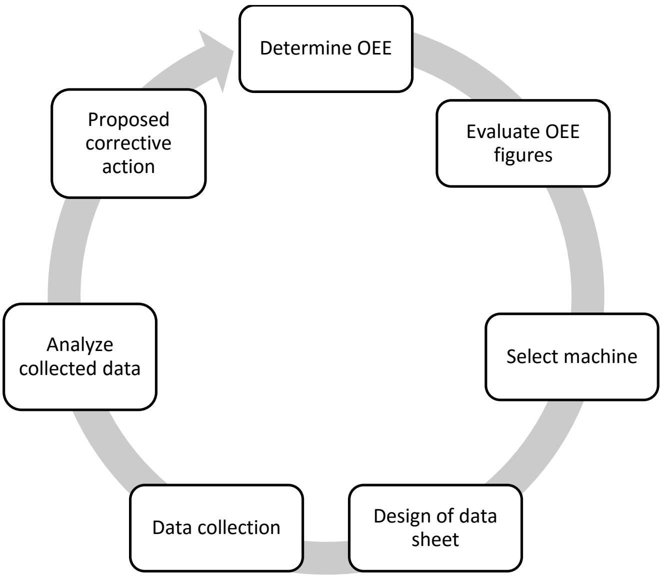

Figure 1. Framework: Synthesize machine's availability in OEE

Determine OEE

In previous researches, there are a lot of interpretation in determining OEE which comprises a components of Availability (A), Performance (P), and Quality (Q) [4]. In this study, the definitions used for all components are:

$$Availability, A = \left(\frac{\text{Planned Production Time} - \text{Unplanned downtime}}{\text{Planned Production Time}}\right) x\ 100$$

Where: $\text{Planned Production Time} = \text{Observation time} - \text{Planned downtime}$

$$\text{Planned Downtime} = \text{Machine set up time /sheduled maintenance time}$$

$$\text{Unplanned Downtim} = \text{Idle time} + \text{Minor stop} + \text{Machine breakdown}$$

$$Performance, P = \left(\frac{\text{Actual Production Output}}{\text{Expected Production Output}}\right) x\ 100$$

$$Quality, Q = \left(\frac{\text{Actual Production Input}}{\text{Actual Production Output}}\right) x\ 100$$

The value from this step will be significantly affecting the following step. Thus, a correct measurement should be conducted. A practical framework to collecting data for OEE has been explained in previous paper [6].

Evaluate OEE Value

From the OEE calculation, evaluate the availability value for each machine. From this evaluation, select the machine with lower availability value. In practice, 85% of OEE is declared as world-class OEE with recommended distribution of: 90% - Availability, 95% -Performance, and 99% - Quality. However, the value is not easy to be achieved. Thus, as starting point, the company may set their goal based on achievable value within certain duration. From the identification of machine, data should be collected using appropriate designed of data sheet.

Design of Data Sheet

In designing the data sheet, it is suggested to consider criteria that cause unplanned downtime such as machine break-down due to machine component failure (more than 10 minutes), machine idle due to waiting material, and minor stoppages due to small machine failure (less than 10 minutes). Also, the column should be provided to calculate the severity (S), occurrence (O), and detection (D) value. Machine components for studied machine should also be included in data sheet. The S, O, and D column as well as machine components will be useful in preparing Machinery Failure Mode Effect and Analysis (MFMEA).

Data Collection

From the designed data sheet, data collection can be conducted to the selected machine. References in collecting data are as below:

1. Severity (S): time taken for the machine to work back in normal condition
2. Occurrence (O): number downtime occurs (repetition of downtime)
3. Detection (D): detection/corrective action on downtime

4. Machine component: Record which machine component that cause unplanned downtime.

Analyze Collected Data

Analysis on the collected data is required to provide a clear picture on the availability status. In this study, Pareto chart is proposed to show the dominant factor in unplanned downtime. The analysis may go deeper up to machine components and its functions.

Proposed Corrective Action

From the abovementioned data and analysis, a revised MFMEA can be produced. Important criteria to be recorded are: (1) potential failure, (2) potential cause, (3) potential risk, and (4) corrective action responsibility. Over the years, the performance of the machine may deteriorate. Thus, the revised MFMEA is useful in determining suitable corrective action at current condition.

Results And Discussion

The framework was implemented in a company located in North of Malaysia. The company practices a job shop layout with seven (7) main departments. In this work, the framework has been implemented in Barbell Department.

Determine OEE

In Barbell department, there are 12 machines available. From OEE data recorded, availability percentage for each machine has been extracted as shown in Figure 2. Machine Num. 3 get the highest availibity value of 97% while the most unavailable machine is Machine Num. 4.

Evaluate OEE Value

For the company, synthesizing availability component is their first trial. Thus, from collected OEE, top management has agreed to set the goal at 80% not at 90% yet. The rationale behind the decision to avoid unrealistic changes and plan for improvement gradually and continuously. Thus, from Figure 2, three machines have been chosen to be monitored closely (Machine number 1, 2, and 4).

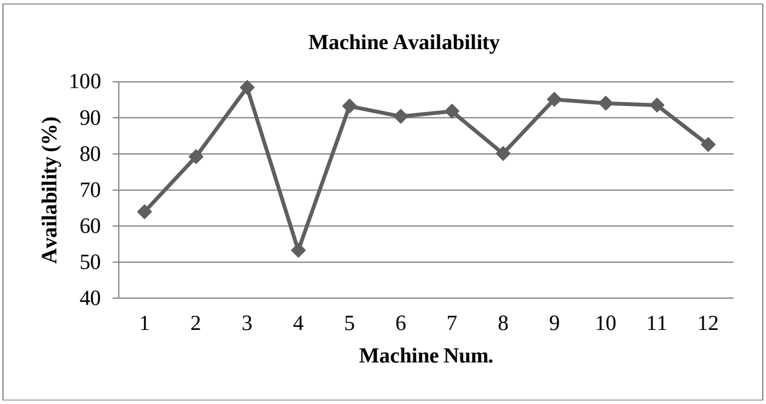

Figure 2. Availability of Barbell machines

Design of Data Sheet

Figure 3 shows a sample of data collection sheet that has been designed for Barbell department in the case study company.

Availability Data Tracking

Model: M/C num: Shift:

Time	Losses	S	O	D	Machine Component
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
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	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT
	B / I / STP				VB/CH/WE/C/T/PS/RT/OT

Reject:

Legend:

B: Breakdown **I:** Idle **STP:** Minor stop

VB: Vibrator bowl **CH**: Chute **WE**: Wheel ejector **C**: Carrier

T: Track **PS**: Part sorter **RT**: Reject track **OT**: Oil track

Figure 3. Data Collection Sheet

Data Collection

Using the sheet in Figure 3, data has been collected for three months during morning shift (7 am – 3 pm). Operator that operates the machine has been brief and trained to collect the required data. An observer is in duty and spent 15 minutes for each machine to ensure correct data collection.

Analyze Collected Data

Figure 4 to Figure 6 shows an example of analyzed data using Pareto chart for three machines (m/c number 1, 2, and 4). From data collected, all machines show the similar trend. More than half of unplanned downtime. To reduce at least 50% of the unplanned downtime, failures that resulting of recorded machine breakdowns should be avoided. Therefore, machine breakdown factor should be further evaluated.

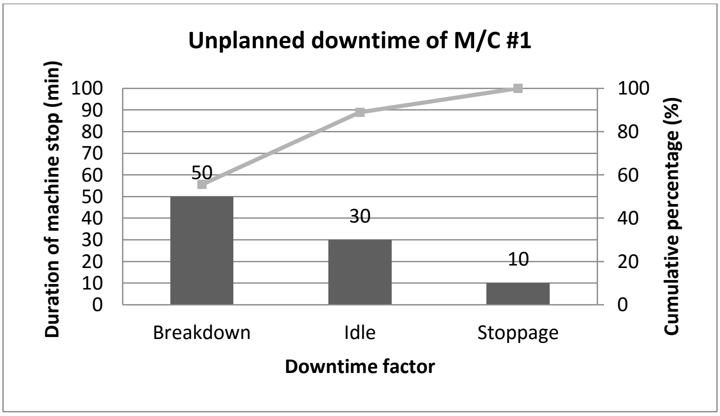

Figure 4. Machine breakdown of machine #1

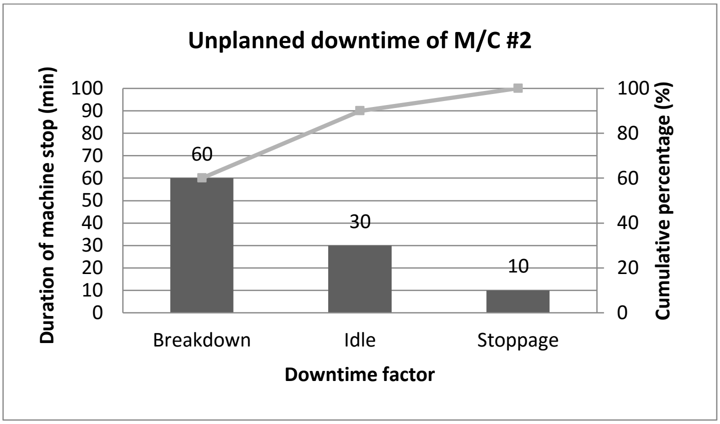

Figure 5. Machine breakdown of machine #2

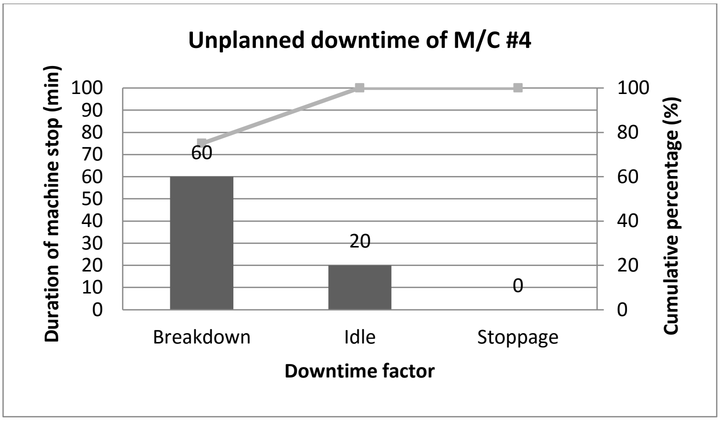

Figure 6: Machine breakdown of machine #4

To evaluate further on machine breakdown, the cause of machine breakdown should be investigated. The information to further elaborate the problem can be extracted from severity and occurrence data. Figure 7 and Figure 8 shows the Pareto from total severity and occurrence of breakdown for 3 machines. The results show that the severity is complementing the occurrence. Longer time recorded is also indicating the potential breakdown to occur again. For Barbell machines, to eliminate breakdown by 80%, three components failure should be taken into close monitoring which are cold heading, wire feeder, and chute. From analyzed data, an appropriate action can be taken since the root cause of the problem is clearly defined.

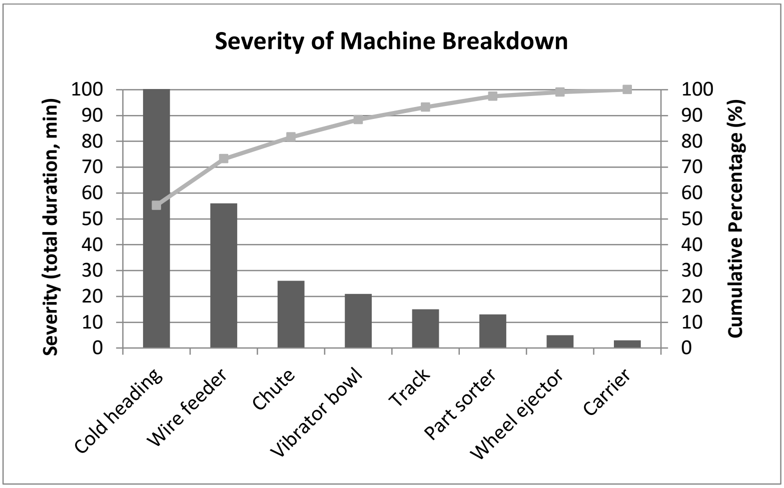

Figure 7: Severity of machine breakdown

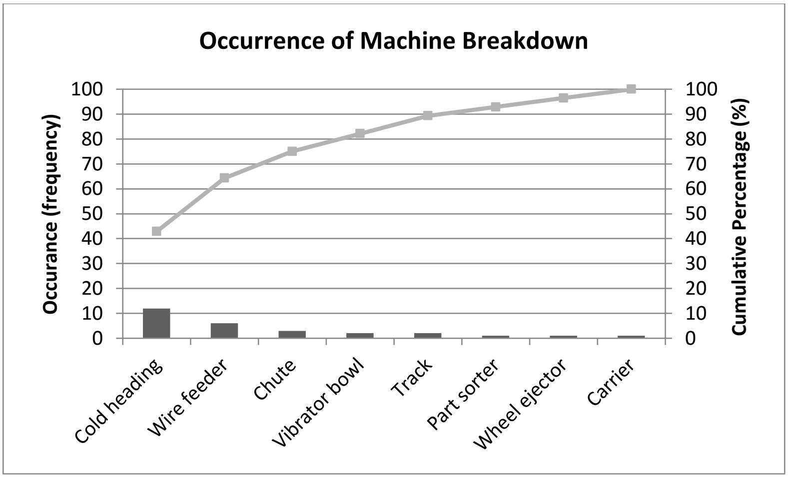

Figure 8. Occurrence of machine breakdown

Proposed Corrective Action

From data collected in previous step, a revised MFMEA can be produced. Figure 9 shows an example of simplified MFMEA produced. It is called a simplified because the analysis is excluding severity, occurrence, and detection. However, additional information has been included which is corrective action responsibility. From this data, the management can decide for particular breakdown, type of maintenance activity shall be carried out to solve the problem. For breakdown that can be solved by operator, we classify it under autonomous maintenance. For minor stop, operator should be able to fix the problem immediately and let the machine working normally. However, for breakdown that been fixed by technician, it is under corrective maintenance.

COMPONENT	POTENTIAL FAILURE	POTENTIAL CAUSE	POTENTIAL RISK	CORECTIVE ACTION RESPONSIBILITY
Vibrator bowl	Wrong orientation of wheel	Wheels being overloaded in the bowl. Thus, it cannot properly sort	Component reject	Operator
Chute	One wheel per barbell	Wheels stuck in the track	Reject parts	Technician
	Double wheel come out	Wheels too free in the track	Machine stop	Technician
Wheel ejector	Machine stop	Unable to eject the wheel	Machine stop	Technician
Carrier	Barbell jump	Unable to carry barbell properly	Machine stop	Operator
* Wire feeder	Wire bent	Misalignment between wire and wheels position	Reject parts	Technician
	Wire feeder malfunction		Machine stop	Technician
* Axle Pusher	Axle does not move	Failure of the programme	Machine stop	Technician
* Cold heading	Miss of head	Unable to create head at ends of wire	Reject parts	Technician
* Axle length checker	Machine stop	Wire does not cut into acceptable length (too short/too long)	Reject parts	Operator
Track	Barbell stuck on the track	Allowance of the track width is small. Some babell will stuck	Machine stop	Technician/Operator
Part sorter	Does not carry the barbell		Overloaded of barbell and when not attended will stop the machine	Operator
Reject track	Does not transfer reject barbell	Sensor unable to detect	Overloaded of barbell and when not attended will stop the machine	Technician/Operator
Oil track	Barbell stuck on the track	Barbell is not landing properly	Overloaded of barbell and when not attended will stop the machine	Operator

*** Is a sub component to the carrier**

Figure 9: Simplified MFMEA

Conclusion

This paper presented a framework to synthesis an availability component in OEE. This top-down method is useful in accessing the current performance of a machine. Thus, appropriate action can be planned and conducted. Also, as the performance of the machine may deteriorate over the time, MFMEA may be needed to be revised. Therefore, the proposed framework provides the package to fulfill abovementioned requirement. The case study presented in this paper has been demonstrated to show the implementation of the proposed framework.

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