Improving efficiency of a production line by Using Overall Equipment Effectiveness:A case study

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Abstract

The quest for improving productivity in the current global competitive environment has led to a need for rigorously defined performance-measurement systems for manufacturing processes. In this paper, overall equipment effectiveness (OEE) is described as one such performance-measurement tool that measures different types of production losses and indicates areas of process improvement (Availability, Performance and Quality). Overall equipment effectiveness (OEE) is a well-accepted measure of performance in industry. This study investigates the analysis of machine failure, imbalanced posts and non-conforming products and was carried out over a period of 4 months. In fact, we have balanced the assembly line, increased the availability of the bottleneck by using the AMDEC-equipment tool, and proposed action plans to reduce the defect ratio.These improvements enabled us to increase the production by 29 wire/shift, increase the time of production of the bottleneck to 7.83h/week, reduce the defect ratio and standardize the processes.Finally, and thanks to the established improvement, we have increased the efficiency of our new line by 37.2% giving it thus an efficiency of about 76.2% exceeding the 63% fixed by the company.

Keywords:
Overall equipment effectiveness (OEE), Efficiency, Availability, Performance, Quality.

1. Introduction

Overall Equipment Effectiveness (OEE) is a way to observe and increase the efficiency of Production plant. OEE is divided into three measure terms that are Availability, Performance and Quality. These terms help to improve the plant's efficiency and effectiveness and classify these basic productivity losses that occur within the production plant. Overall Equipment Effectiveness (OEE) endures manufacturing companies to expand their processes and in turn confirm excellence, uniformity, efficiency and productivity measured at the final line.

Nowadays, production plant facing the capacity problems, they instantaneously decide to increase overtime, purchase new equipment or add shifts. As an alternative they should decide to improve the performance of their present machines to improve equipment reliability, improve operator performance and minimize the whole idle time.All these things can be prepared to increase capacity and will pay greater expenses by allowing a production plant to devote its valuable time and money on their production process as an alternative of new machine procurements.

The main objective of production plant to improve the performance of their present equipment for that purpose Overall Equipment Effectiveness (OEE) tool is used. OEE is an effective tool to analyse and improve your production process.

The OEE tool gives you the capability to measure equipment for productivity improvements. OEE measures the inefficiencies as well as groups them into three categories to help evaluate the machine and have a better appreciative of the production process.

The paper is organized as follows. First, a literature review on OEE is given explaining how OEE can be used for driving manufacturing improvements. The second section is about the case study. In fact, an application of the OEE approach is established to improve the efficiency of an assembly line of electrical wires. At the end, conclusion will be given.

2. Literature review

Overall Equipment Effectiveness (OEE) is a way to monitor and improve the efficiency of the manufacturing process. OEE is a hierarchy of metrics proposed by Seiichi Nakajima to measure the performance of the equipment in a factory. These metrics help gauge the plant's efficiency and effectiveness and categorize the key productivity losses that occur within the manufacturing process.

OEE is a powerful tool that can be used also to perform diagnostics as well as to compare production units in different industries. The OEE has born as the backbone of Total Productive Maintenance (TPM) and then of other techniques employed in asset management programs, Lean manufacturing (Womack et al.), Six Sigma (Harry), and World Class Manufacturing (Womack et al.).

Developed in the mid 1990's, OEE has become an accepted management tool to measure and evaluate plant floor productivity. OEE is broken down into three measuring metrics of Availability, Performance, and Quality. By definition, OEE is the calculation of Availability, Performance, and Quality.

$$OEE = Availability \times Performance \times Quality \qquad (1)$$

Metric 1: Availability

$$Availability(A) = \frac{RunTime}{TotalTime} \qquad (2)$$

By Definition: Percentage of the actual amount of production time the machine is running to the production time the machine is available.
Simple OEE: The total run time of the machine substracting all unplanned downtime.

Metric 2: Performance

$$Performance(P) = \frac{TotalCount}{TargetCounter} \qquad (3)$$

By Definition: Percentage of total parts produced on the machine to the production rate of machine.
Simple OEE: How well a machine is running when it is running?

Metric 3: Quality

$$Quality\ (Q) = \frac{GoodCount}{TotalCount} \qquad (4)$$

By Definition: Percentage of good parts out of the total parts produced on the machine.
Simple OEE: How many good parts versus bad parts a machine has produced.
In addition, OEE can be defined as:

$$OEE = \frac{FinalMachineRunTime}{PlannedMachineRunTime} \qquad (5)$$

There are many events within a manufacturing process that can affect OEE. The major goal behind an OEE program is to minimize or reduce the causes of inefficiency in the manufacturing environment.

The Major Loss Events that commonly occur to decrease the productivity and efficiency of a machine are:

Unplanned downtime losses as a function of Availability:
There are made up of the first two big losses presented below and are used to help calculate the true value for the availability of a machine in an industry.
1) Equipment failure: Breakdown losses are categorised as time and quantity losses caused by failure, breakdown or by defective products. In a brewery plant as analysed by Pintelon et al. (2000), a breakdown of palletizing plant motor led to downtime and thus production loss.
2) Set-up and Adjustment: These are losses that occur when production when production is changing over from requirement of one item to another. Still in the brewery plant, the type of losses encountered during the set-ups, were set-ups between different products, testing during start-ups and fine tuning of machines and instruments.

Speed losses as a function of Performance:
Speed losses are required for calculating the true value for performance of a machine. It cannot be calculated during downtime of machines.

1) Idling and minor stoppage: These losses occur when production is interrupted by temporary malfunction or when a machine is idling. For example, dirty photocells on palletizing machines cause minor stoppages even though they are quickly fixed, due to their frequency, much capacity is lost.
2) Reduced speed: These losses refer to the difference between equipment design speed and actual operating speed. The use of unadapted pallets in a palletizing plant has presented by Muchiri and Pintelon (2008) led to longer processing times for the same number of bottles leading to speed losses.

Quality losses as a function of Quality:
Quality losses affect the quality of the final product. This causes serious economical setbacks in a factory due to waste of resources or cost for recycling. They are based on;

1) Defect in process / rework: These are losses caused by malfunctioning of production equipment. In the case of pallets, some got stuck in between depalletizer and unpacker and are damaged.
2) Reduced yield: They are yield losses during start-up that occur from machine start-up to stabilization. Poor preparation for morning shift by night shift in the brewery led to problems with the filling taps and thus led to reduced yields.

This can be illustrated in the figure 1 presented below:

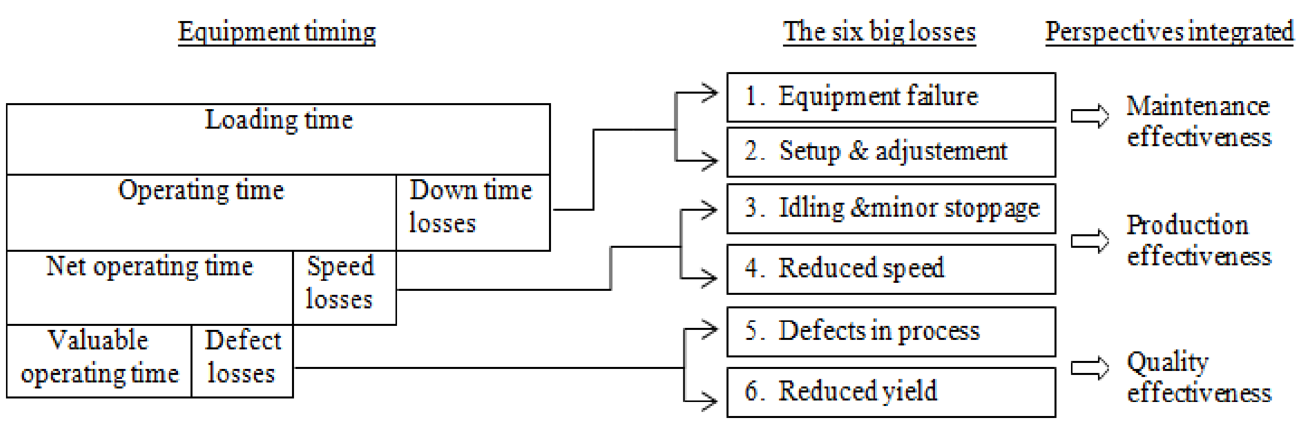

Figure 1.OEE measurement tool and the perspectives of performance integrated in the tool (Muchiri&Pintelon, 2008)

3. Case study

In this section, we present a study that lasted four months to improve the efficiency ofthe assembly line of wiring harnesses by detecting major events that penalize its OEE and bringing up solutions that should increase the assembly line efficiency.

3.1. Description of the assembly line

As illustrated in figure 2, the assembly line is broken into three main phases:

- Assembly of sub components: it provides wiring bars necessary to introduce in the second phase.
- Beam assembly (on a carousel): Using bars to tape and lay up them.
- Testing and installation of fuses and accessories before being packaged, stored and shipped.

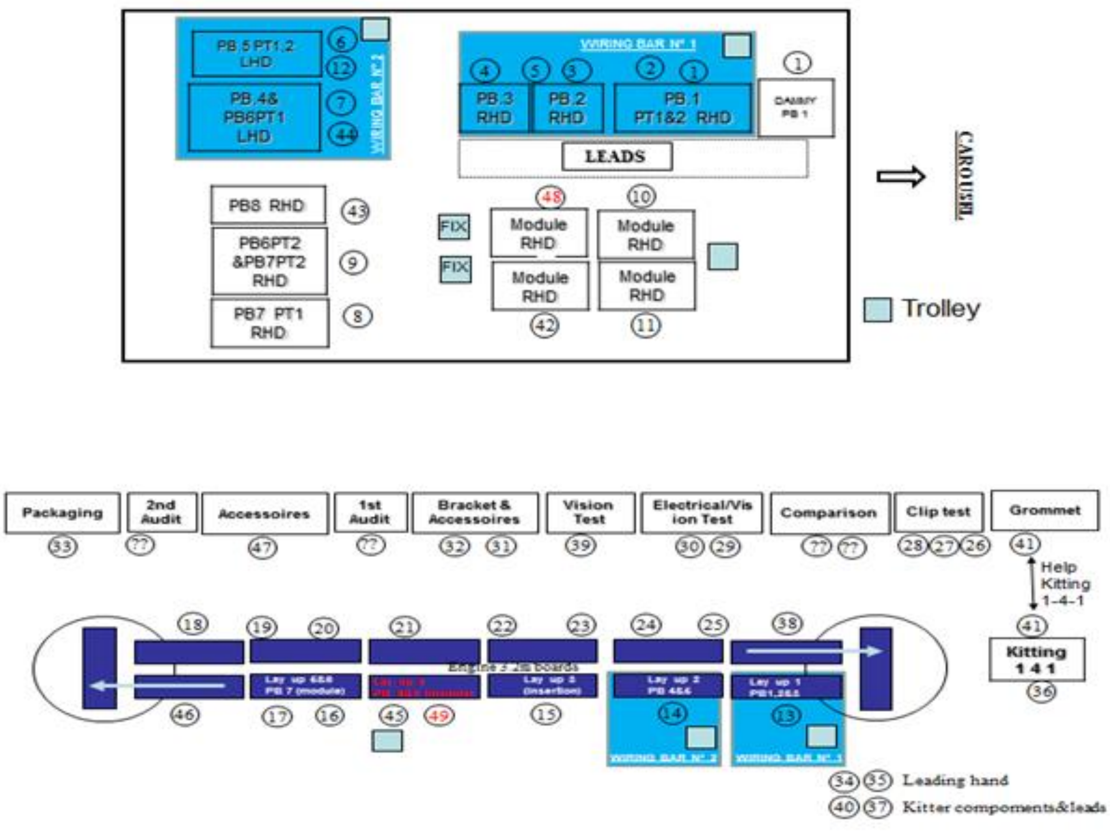

Figure 2. Description of the assembly line

3.2. Diagnostic

In a context of mass production and strong competition, all that is produced can be sold and what you cannot produce a competitor will sell. Produce more and better without additional productive investment is possible if we attack the waste. This finding permeates all Japanese methods among others: 7 MUDAs tool.

Waste (or Muda in Japanese) means any operation that does not generate added value. To minimize or eliminate waste, we will quote the existing waste and classify them according 7 types, commonly called 7 mudas; then we will determine the types of critical waste by Pareto method.
Using data from the value stream mapping and especially operators' comments on the field; we have raised a number of causes that could block the achievement of objectives. However, to complete the list of causes, we conducted a brainstormingin order to identify the remaining causes that create this effect.
The seven Mudas that occur in the zone of work were identified:

- Waiting: Cycle times are not balanced, the processes are not online. The main causes can be related to the problems of reliability of the machines and / or posts' imbalance.
- Transport: unnecessary operators' transport to look for the missing tools.
- Inventory: Total inventory between each two successive posts.
- Motion: Operators often travel to pick up their bars, they make unnecessary gestures that must be minimized or eliminated.
- Defects: Non quality parts or labor necessarily leads to many problems (scrap, rework, resume work ...).

Since we seek to highlight the critical sources of waste, we will use PARETO analysis after having conducted a survey among members of the work team that provides the necessary frequencies shown on table 1.
Pareto diagram is shown on figure 3.

Table 1.Compatibility matrix

Causes	Criticality	Percentage	Cumulative percentage
Imbalanced posts	196	21,75	21,75
Machine reliability problems	182	20,20	41,95
Non-conforming products	169	18,75	60,70
Presence of bottleneck post	156	17,31	78,01
Useless gestures	35	3,88	81,89
Unfulfilled instructions	30	3,32	85,21
intergroup and intragroup conflicts	28	3,10	88,31
Not qualified operators	25	2,77	91,08
Time supply of basic wire	24	2,66	93,74
Accessories supply time	20	2,22	95,96
Demotivated operators	15	1,66	97,62
Moving to seek bars	12	1,33	98,95
Excessive inventory	9	1,05	100

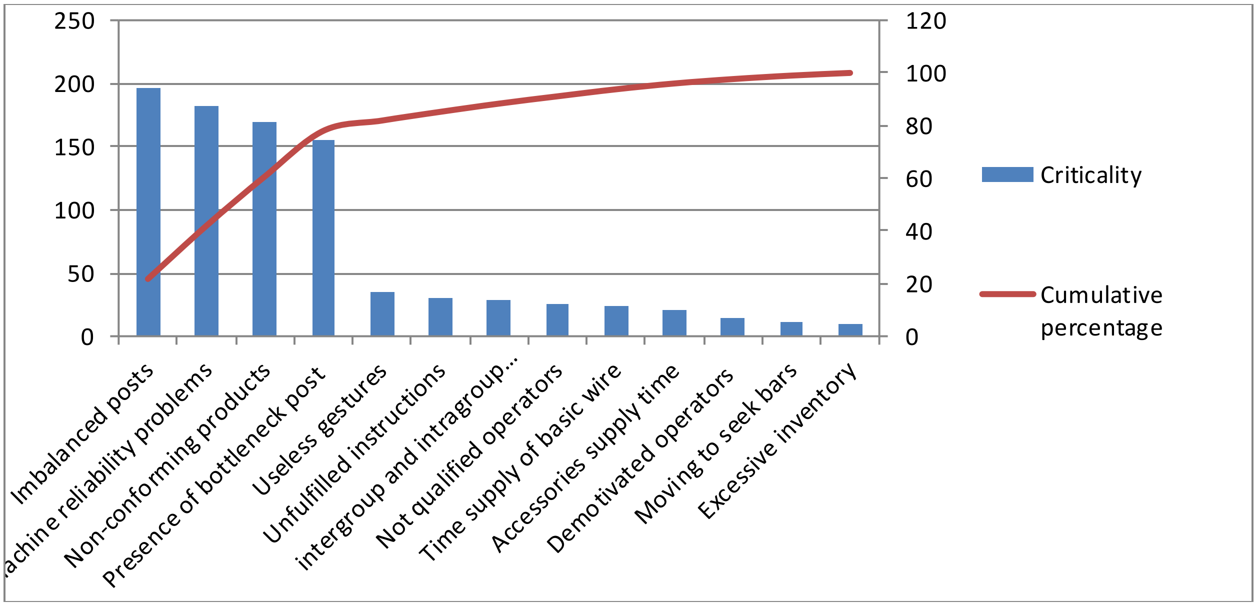

Figure 3.Pareto analysis of critical waste

The results of Pareto analysis show that wastes found at the assembly line are from:

- ✓ Imbalanced posts;
- ✓ Problems of machine reliability;
- ✓ Non-conforming products;
- ✓ Presence of bottleneck post.

⇨ We can obviously notice that critical causes of waste are not other than the components of OEE (See figure 4), in so far as :

- ❖ Imbalanced posts and presence of bottleneck post decrease the line performance.
- ❖ Problems of machine reliability affect availability.
- ❖ Non-conformingproductsassignquality.

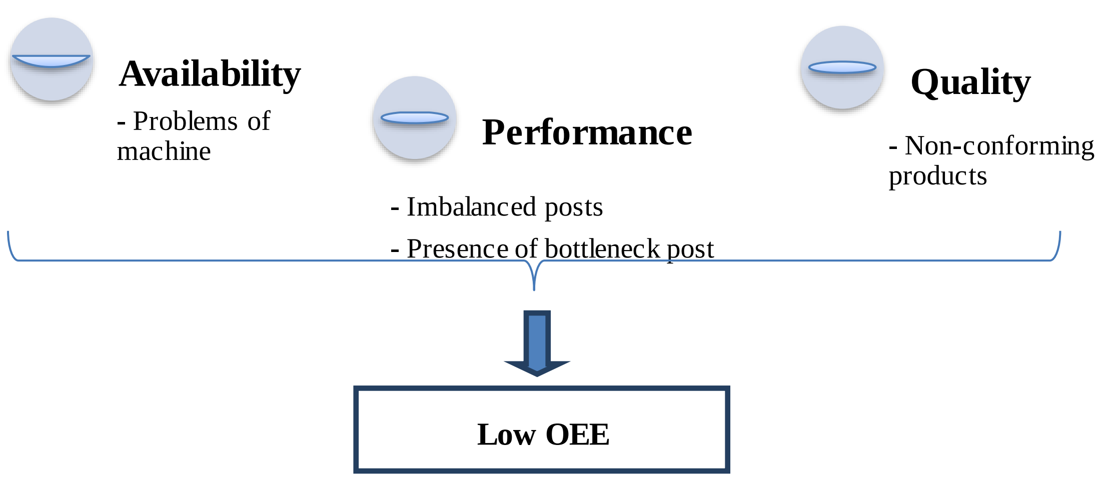

Figure 4.How can wastes decrease the assembly line's OEE

3.3. Propositions

In this section, we will propose action plans for the reduction of muda. Indeed, these action plans will touch the components availability (A), performance (P), and quality (Q) of the OEE.
In fact, an analysis of failure machinewould be established followed by balancing the assembly line and a reduction of non-quality rate.

a) Availability

Various causes can contribute to the increase in production downtime. After detection of those with high influence, we propose a plan of action regarding the implementation of the pillar:

- Autonomous maintenance:

It was observed that the response to the outage could be within reach of the operators themselves. Hence the need of applying the autonomous maintenance to reduce the loss of time punctuating the process.
The principle is that the operator's knowledge level should be high so that he can be responsible for the quality of its equipment.

To achieve this result, we propose operator's forming on understanding machine / process functions, understanding of the function of each sub-set of the machine, and performing simple diagnostics understanding the different problems that can affect their machines.

We propose as well determining the level of operator intervention on machines.

The formations allow changing the culture of the operators. Indeed, the operator would be able to participate in Kaizen (continuous improvement) production resources, improve their skills and know-how relating to procedures, inspection techniques, installation and adjustment, and finally make simple maintenance operations.

These simple steps will reduce the downtime of machines and therefore increase the availability of equipment. A monitoring table is established to assign a score to each operator as to his mastery of procedures and work instructions.

- Preventive maintenance:

To try to prevent outages and maintain optimal machine condition, we make an analysis of the failure of the clip and electrical test tables by the FMEA (Failure Mode Effects Analysis).
First of all, we clearly identify the machine elements to be studied in order to analyze, for each element, the risk of malfunction.

Then, FMEA grid is filled based on the history of the maintenance department, control and observation of the operation during the study period.

We calculate criticality for each machine element, and determine critical failure modes requiring some maintenance operations to reduce the criticality to an acceptable level.

The 5why approach is conducted in order to analyze the root causes of the problems identified to facilitate their resolution.

Finally, we implement corrective actions to decrease the criticality of failures

⇨ Plan action conducted in this part, allows as reducing downtime of 470 min / week = **7.83h / week**, so that availability had increased.

b) Performance

Balancing the different sequences requires understanding and mastery of the work of each operator. Indeed, it is to redistribute tasks so that the operator does not exceed the takt time while ensuring increased production.

Balancing done is to reduce the length of pals on incurred. After simulation of production stations, we make the changes necessary to maintain an almost equal length for all positions.

To do this, we proceed by timing the various operations of each position and then detects positions require a greater time to takt time to drag some operations on the station committed to one under committed.

According to the philosophy of Lean Manufacturing and to manage a workshop by the constraints, it was necessary first of all to ensure the production of non-defective wires on the machine above the gully, to pass on the machine bottleneck those compliant wires. Next, develop the research process control in the gully position and the position after the (electrical test table) and for the position bottleneck that he does not lose the ability to manufacture defective wires and the other post, so that conform wires from gully are not damaged. Finally, perform preventive maintenance to improve reliability of the machine table test clip, the goal is to save production time, therefore, to gain capacity.

⇨ These changes enable us to increase productivity by 29 bundles / shift and thus ensure high performance.

c) Quality

Fabricated wires may not be in accordance with customer requirements. These non-compliance specifications can be manifested in several defects.In this part, we developan action plan to reduce or eliminate critical defects.

First, we conduct a study based on the cause and effect diagram or Ishikawa diagram which is a process that helps us identify possible causes of non-conforming products. Then, history showed that 73.46% of defects are apparent in reversals which will therefore be the subject of our action plan.

To overcome this problem, we:

- Develop visual aids and display them on the reverse substations;
- Propose changes in color of the wires.Indeed, the same colors are the major source of the problem inversions;
- Motivate staff to achieve efficiency and productivity : the team leader plays a key role in the motivation of the team, in fact his behavior was all the more likely to meet the expectations of its employees ;
- Sensitize operators to damage caused by inversions;
- Propose operator forming on correct methodology and view work instructions on the posts where the reversal is high;
- Start phase of training after forming;
- Swap experienced operators, who have mastered their posts and having an almost zero rate of inversions with those having large inversions rate.

⇨ Different actions in this component have as main result the reduction of non-quality rate which should significantly decrease until reaching our goal.

➔The implementation of the proposed solutions generates increased productivity (performance) with reduced downtime (availability) and non-quality rate (Quality).
With these improvements, we have increased the efficiency of the assembly line of 37.2% giving an efficiency of about 76.2% exceeding the 63% set by the company.

4. Conclusion

The strength of the OEE approach is systematic analysis of equipment utilization, efficiency and quality. To have a high OEE, we worked on its three components. Indeed, we reduce downtime and rate losses by increasing equipment utilization, optimize equipment utilization, balance posts to ensure a better performance, increase quality by reducing scrap and reworks. These improvements have important impact to availability, performance, and quality so that we exceeded the efficiency value fixed by the company by using the OEE approach.

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