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RESEARCH ARTICLE OPEN ACCESS

ENHANCING OVERALL EQUIPMENT EFFECTIVENESS (OEE) OF A SELECTED MACHINE IN A LIGHT MANUFACTURING FACTORY IN BANGLADESH

Jonayed Abdullah[1], Md. Al Hossain Rifat[2], Avirup Deb Ray[3]

[1,2,3]Department of Industrial and Production Engineering, Shahjalal University of Science and Technology, Sylhet, Bangladesh.

[1]https://orcid.org/0009-0006-7130-7597, [2]https://orcid.org/0009-0002-1839-6472, [3]https://orcid.org/0009-0005-6675-8345

Email: jonayedabdullah.ipe@gmail.com, rifatsustipe@gmail.com, avirup11@student.sust.edu

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ABSTRACT

Overall equipment effectiveness provides reliable and considerable performance indicators for machinery performance. This research aimed to measure the OEE of the selected machine, identify the reasons behind its poor performance, and take action to improve the machine's overall performance. A tire-curing machine was chosen for the research as the target machine for OEE analysis. After collecting data for a month, we did our calculation using Microsoft Excel and found OEE of just 63%, which is far below the industry standards. We investigated the causes of the low OEE and found that most affected the availability and performance metrics while quality was good. For the following month, several performance improvement activities were taken including maintenance improvements, process optimizations, and operator training. The new data collection and analysis phase was carried out after the implementation phase to measure the impact results of the interventions. The OEE of the machine improved from 63% to 73%, showcasing a significant increase in efficiency; that is, availability increased by 79% to 85%, while performance improved from 82% to 88%. This research also highlights the importance of OEE as it gives a comprehensive view of how machines and equipment may be tracked and improved.

I. INTRODUCTION

In the fast-pacing competition, leading manufacturing firms must closely monitor the performance of all functions, including production and maintenance, to gain a benefit over competitors. As worldwide competition intensifies, executives are shifting from merely enhancing efficiency through economies of scale and internal specialization to meeting market demands for flexibility, timely delivery, and quality. Increasing productivity is essential for businesses looking to succeed in their ventures [1].

Production costs are considerable, and manufacturing systems frequently run at poor productivity and below capacity. Factory maintenance accounts for 25–30% of the overall cost of production [2]. The profitability of a firm is greatly impacted by the quality of maintenance. Since maintenance expenses make up a sizable portion of manufacturing companies' operational budgets, the significance of maintenance functions has grown because of their involvement in maintaining and enhancing product quantity, availability, and safety regulations [3]. The Japanese created and presented the idea of Total Productive Maintenance (TPM) in 1971 in response to maintenance issues that arose in manufacturing environments. TPM is a Japanese maintenance system that was developed by Nakajima and encompasses all aspects of equipment life, including planning, manufacture, and maintenance [4]. To continuously improve product quality, operational efficiency, capacity assurance, and safety, it outlines a synergistic link between all organizational functions, but especially between production and maintenance [5].

A tire vulcanization machine has been selected for this research. Then we collected data for a month and then worked based on the collected data. The objectives of this research are:

- to assess the current OEE of the chosen machine
- to investigate the root cause
- to suggest improvement strategies.

This research explores the effectiveness of using OEE as a performance indicator of the machines in the manufacturing and how to improve where the performance is lower than the standards.

II. REVIEW OF LITERATURE

II.1 LEAN MANUFACTURING

Lean manufacturing can be termed as continuous improvement nowadays [6]. It is used in industries to maximize the production and minimize the cost of production [7]. The foundation of Taiichi Ohno's widely promoted lean manufacturing methodology is lean thinking which is guided by certain principles. Value specification, value stream mapping, flow optimization, pull production system, and perfection or continuous improvement are the five pillars of lean manufacturing [6].

Lean service prioritizes the consumer in addition to the individuals involved in the transformation process. In contrast to production, the client is the initial point of contact when selling services. Unlike most industries, the service firm works directly with the consumer on the front line [8]. While raw materials and equipment are expensive and a major emphasis in manufacturing operations, labor is one of the most important aspects in service operations when it comes to work expenses [9]. Lean manufacturing divides the times into value added time, non-value added time, and unavoidable non value added time and finally works on eliminating or reducing non value added times [10]. Some of the frequently used lean tools are mentioned below.

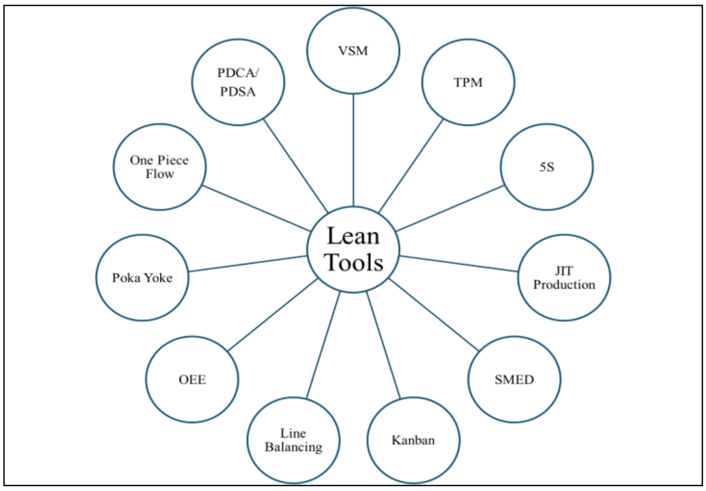

Figure 1: Lean Tools.
Source: [11].

II.2 OVERALL EQUIPMENT EFFECTIVENESS (OEE)

OEE is the ratio of the amount of a product or part that is created without defects to the amount that might be produced based on the design of the equipment. An OEE of 100% indicates that a machine or process is operating at maximum capacity with no problems [12]. Three crucial factors are Availability (A), Performance Rate (PR), and Quality Rate (QR) combined to generate Overall Equipment Effectiveness (OEE). The machine tool that transforms the product from its raw condition into finished items must be dependable when increased production is anticipated [13]. Machine availability with minimal downtime is a component of reliability. The availability of machines for the intended performance is shown by a higher meantime between failures (MTBF). It is necessary to try to increase MTBF and decrease the mean time to repair (MTTR). Root cause analysis and failure data analysis are necessary. OEE is a machine capability metric. It indicates where the scope of improvements is. Statistical data collected from the tire manufacturing process results in useful information for improvement areas. [14],[15]. Six big losses- One of the primary goals of OEE and TPM projects is to address the Six Big Losses, which are the most common reasons of industrial efficiency loss. The connections between the Six Big Losses and the OEE Loss categories are shown in the following.

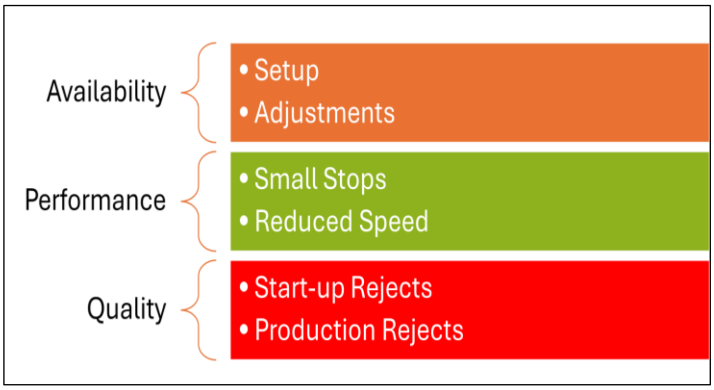

Figure 2: Six big losses.
Source: [12], [14].

II.3 TOTAL PRODUCTIVE MAINTENANCE (TPM)

A complete productive maintenance delivery system encompassing the whole life of the equipment and including all personnel from production and maintenance divisions to top management is how TPM describes its program for equipment maintenance [4]. Through daily operations involving the whole workforce, TPM is described as a new approach to maintenance that maximizes equipment effectiveness, reduces failures, and encourages autonomous maintenance by operators that also integrates 5S in the floor [16]. TPM can also be implemented in service sector to provide error free services [17]. TPM essentially aims to integrate the organization to identify, unleash, and make use of its abilities and potential. Bringing managers, supervisors, and other stakeholders together to take corrective action when necessary is the goal of TPM [18]. One productive maintenance program that emphasizes the following is called Total Productive Maintenance (TPM):

- maximizing the overall efficiency of the device.
- putting in place a planned Preventive Maintenance (PM) scheme for the machine's lifetime.
- involving every worker, from the production floor to upper management.
- giving workers the freedom to start remedial actions [19], [20].

The word 'total' in TPM has 3 meanings:

- Total effectiveness denotes TPM's efforts to increase profitability and economic efficiency.
- Total maintenance system includes Maintenance Prevention (MP) and Maintainability Improvement (MI), as well as PM. Incorporating dependability, maintainability, and supportability features into the equipment design, essentially refers to a maintenance-free design.
- Total engagement of all operators involves Autonomous Maintenance (AM) by operators by small group activities. In essence, a team effort is used to complete maintenance,

and the operator is ultimately in charge of taking care of his or her equipment (Nakajima and Nakajima, 1988).

Pillars of TPM: Eight pillars of TPM have a great impact on the manufacturing of any product. The below Figure 3 illustrates the pillars,

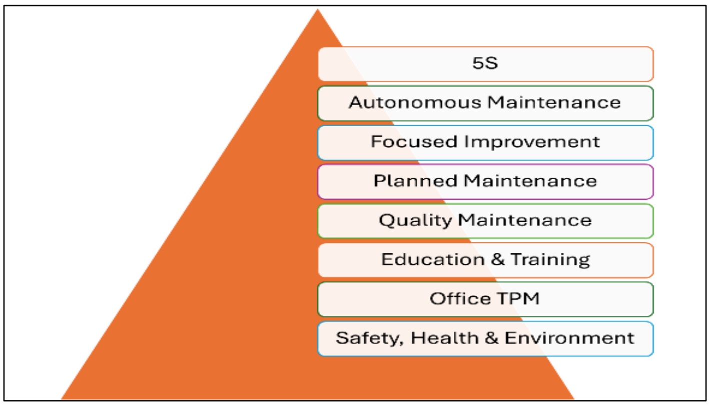

Figure 3: Pillars of TPM.
Source: [21], [22].

II.4 SINGLE MINUTE EXCHANGE OF DIE (SMED)

Shingo created SMED, or quick changeover of tools, and described it as a scientific method to cut set-up times that any machine and industrial facility may use. The time should be less than 9 minutes [23]. Setup time is the preparation period between the end of the last product generated and the first product manufactured in the next process [24]. The shortest length of time required to switch the kind of manufacturing operation, taking consideration of the moment when the final unit of a prior lot was created and the first unit produced by the succeeding lot, was known as SMED [25].

There are four steps involved in reducing the set-up in the SMED: preliminary steps, internal and external set-up separation, internal to external set-up conversion, and simplifying every part of preparation [26]. Two significant activities are involved in Single Minutes Exchange of Die (SMED).

They are the internal and external setups:

- Internal time: may only be performed once the device or operation has finished
- External time: maybe while the device or operation is still running.

The SMED concepts were applied accordingly to specific pre-defined conventional processes, Plan, Do, Check, and Act (PDCA) cycle is a four-step checklist that must be followed to get from problem-faced to problem-solved [11],[26].

II.5 CONCEPT OF QUALITY

Quality is the degree of excellence of a procedure, service, or product that your business provides and that satisfies the standards set by ISO and, of course, by your clients [27],[28]. To understand a little more about quality, this post will cover three fundamental concepts of quality:

- Quality Assurance: Ensuring that the operational quality standards and criteria, which have previously been set, are applied in all subsequent development stages, whether for a product or service, is known as quality assurance.
- Quality Control: This idea, which is mostly implemented through inspections, aims to satisfy the quality criterion. The process of analyzing and evaluating whether a product or service's qualities meet predetermined standards to ascertain whether a nonconformity has occurred is known as quality inspection.
- Quality Management: Coordination of manufacturing process and service operations to ensure high-quality performance is known as quality management [29].

Keeping in mind that the dimensions of quality may be interpreted as performance, dependability, perception, durability, characteristics, conformance, and service, this management strives for perfection in the execution of all activities and operations. One of the phases in Quality Management, which we discussed in the previous post, is the establishment of a Quality Management System (QMS). However, for a QMS to provide outstanding outcomes for a company, the team must practice and adhere to the seven quality principles:

Figure 4: Principles of Quality.
Source: [29].

For the betterment of quality, there are seven QC tools introduced by the researchers,

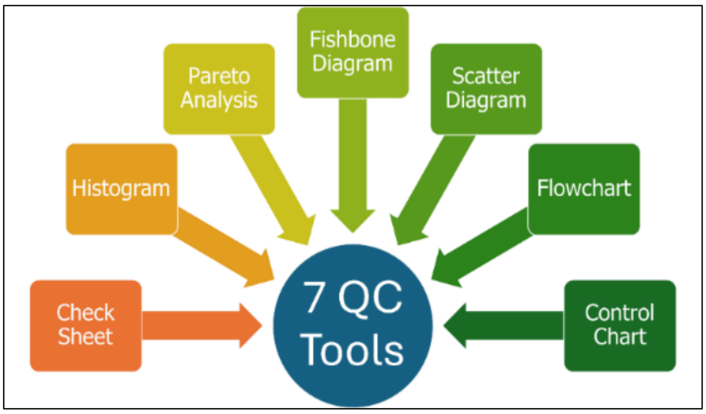

Figure 5: Seven QC Tools.
Source: [27], [30].

II.6 ROOT CAUSE ANALYSIS

Root Cause Analysis (RCA), a key component of quality management systems, helps identify and address the underlying issues that improve quality and productivity in more significant ways. RCA is frequently used as a receptive approach to identify the source of an occurrence or event, uncover problems, and determine their nature [31]. Since the root cause of an undesirable state or issue is the most fundamental factor, root cause analysis (RCA) is too important for a production engineer. RCA is a methodical approach to identifying the basic flaws or underlying causes. The first stage in the RCA is to define and describe the issue. RCA was founded in 1958 when Toyota's production procedures were being developed. The researchers have employed a variety of tools to apply RCA in industrial settings, and the comparative analysis of those tools has been predicated on their suitable applications. Experimental research in the multistage manufacturing sector was carried out to increase product quality and productivity. It was discovered that after implementing countermeasures on the underlying reasons, the defect decreased from 11.87% to 1.92% [32].

III. METHOD AND ANALYSIS

The below flow chart shows the steps we have followed to complete this research.

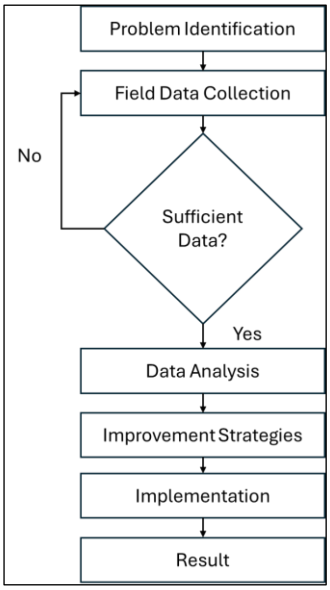

Figure 6: Steps Followed.
Source: Authors, (2025).

For our research, we have selected a vulcanizing machine. The required field data are presented in the Appendices.
As we know,

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

We can find the OEE from our collected data. We need to find availability, performance, and quality from our field data to do this.
Equation for availability.

$$Availability = \frac{Net\ Operating\ Time}{Operating\ Time} = \frac{Operating\ Time - Breakdown\ Time}{Operating\ Time} \quad (2)$$

Equation for performance.

$$Performance = \frac{Production}{Production\ Target} = \frac{Production}{(Cycle\ Time)/(Operating\ Time)} \quad (3)$$

Equation for quality.

$$Quality = \frac{Good\ Qty}{Total\ Production} = \frac{Total\ Production - Rejection\ Qty}{Total\ Production} \quad (4)$$

Finding the values from Equation 2, 3, and 4, we found the current OEE of the selected machine by substituting the values in equation 1that is shown in Table 1.

Table 1: Average OEE.

Availability	Performance	Quality	OEE
79%	82%	98%	63%

Source: Authors, (2025).

From the data analysis, it is visible that the machine can provide a good quality product that is 98%. This value is good enough. Availability is also fair enough, that is 79% and the performance is 82%. Worldwide OEE standard is 85% where 90% availability, 95% performance, and 99% quality [33]. As current availability and performance is lower than the standards, we will work to improve here. So, we will investigate the reasons for lower availability and performance by using some lean techniques. After diving into the reasons for lower availability we found the following reasons presented in Table 2.

Table 2: Unplanned Downtime Reason.

Reason	Duration (min)	%
Manpower Short	1,152	36.25%
Air Problem	936	29.45%
Mold Problem	523	16.46%
Material Shortage	203	6.39%
Electrical Problem	178	5.60%
Color Problem	125	3.93%
Air Pressure Low	31	0.98%
Machine Transfer	30	0.94%

Source: Authors, (2025).

Plotting this duration of unplanned break down in pareto chart we identified the three reasons that are illustrated in Figure 7.

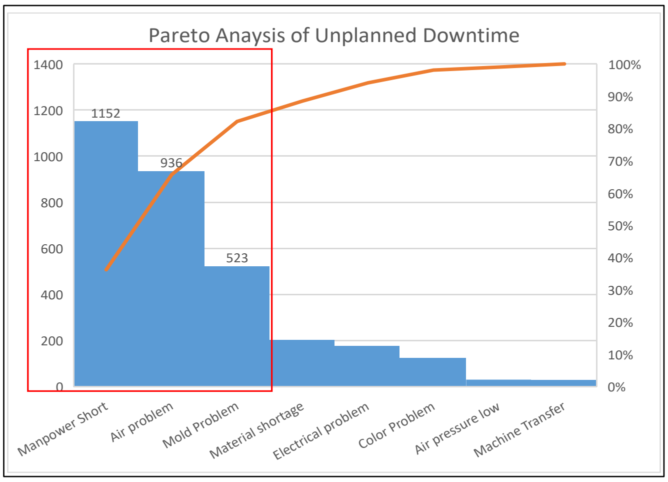

Figure 7: Pareto Chart for Unplanned Downtime.
Source: Authors, (2025).

After studying the total system, we have found some root causes that affected the machine's performance. Those reasons have been shown below by illustrating (Figure 8) cause and effect diagram,

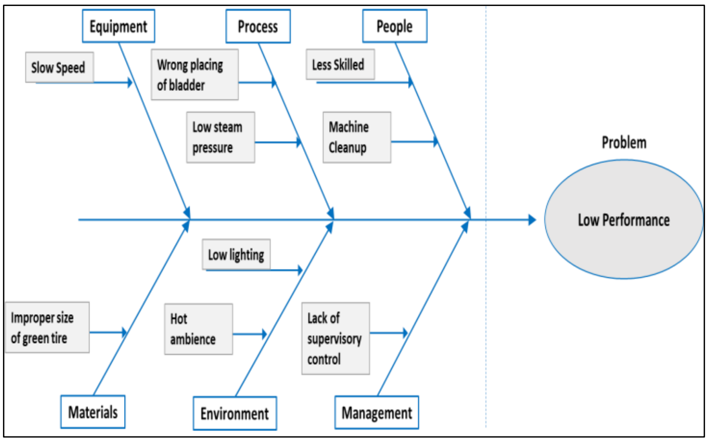

Figure 8: Cause and Effect Diagram for Low Performance.
Source: Authors, (2025).

IV. IMPROVEMENT STRATEGY

From our data analysis, it is clear that we have a good opportunity to improve in the availability and performance aspects. Table 7 & Figure 7 show that Manpower shortage, air problems, and mold problems incur 36.2%,29.5%, and 16.5% of the total downtime respectively. These reasons are 82.2% of total downtime. We may take the following steps to overcome these problems and increase the availability of the selected machine,

a. To overcome the manpower shortage, we worked with the human resource department to find the manpower so that the machine does not have to stay idle. Following this we provided manpower requisition to the HR department.
b. To overcome the air problem, we assigned one person to keep an eye on the compressor room. There might be some power shutdown and for that reason, the compressor takes a short too long time to increase the air pressure. In addition, we installed an air reservoir tank that would reserve a minimum amount of air with the desired pressure to give backup support to production immediately after the power shutdown is over.
c. To overcome the mold problem, molds were properly cleaned by the operators at regular intervals. There should not be any rust or any type of dent on the mold body.

Figure 8 shows the root causes of the low performance of the machine. The following strategies could be effective to increase the performance of the selected machine,

a. As the machine speed was slow, operators strictly followed the regular machine maintenance. Lubricating the moving parts was done as a practice to remove the rust and allow the machine to work at maximum speed.
b. The slow performance of the operator also affected the performance of the machine. Operators were given proper training before working on this machine.
c. Low steam pressure leads to longer cycle time for the selected machine. Steam pressure was controlled by installing a steam regulating valve. Pressure Regulating Valves (PRV) were installed to see the outcome of the machine. The maintenance team was given instructions to implement TPM to reduce breakdown of air compressors.
d. Proper lighting on the production floor is inevitable for the performance of operators. The maintenance team must ensure proper light.
e. An optimum level of airflow is necessary to work properly. Thus, a proper air ventilation system was installed on the production floor.
f. Process control was followed strictly to avoid the mistakes in green tire making.
g. Operators might become lazy sometimes or they might not understand the process. In that case, a supervisor was there to ensure the hourly output from the operators or the machines.

V. RESULTS AND DISCUSSIONS

We have worked on the total system implementing the improvement strategies and we have found the following outcomes for that selected machine shown in Table 3.

The result assures that the there is a visible improvement in availability, performance, and OEE of that machine.

Table 3: OEE after Improvement.

Month	Availability	Performance	Quality	OEE
January	79%	82%	98%	63%
March	85%	88%	98%	73%

Source: Authors, (2025).

The final output showed significant improvements in the machine's performance after implementing the strategies. Though the installation of some mechanical parts and air ventilation took time, we waited for a month and then recorded the data.

VI. CONCLUSIONS

We conducted a detailed study to improve the Overall Equipment Effectiveness of a selected machine. First, we measured the current performance of the machine and recorded an OEE of 63%, which suggested ample scope for improvement. We then conducted a root cause analysis in detail to identify the main causes of the poor OEE. The availability and performance issues were found to be the major problems.

Accordingly, targeted improvement strategies were formulated and implemented. We then waited a month to monitor the machine's performance and determine how the interventions affected performance. For instance, there was an increase in average OEE in March by up to 73%, which constitutes a 10% increase. In addition, there was an increase in availability from 79% to 85%, and its performance went up from 82% to 88%. These improvements show that our methodology is effective.

Even with this improvement, the machine performance has been well below industrial standards, which are 90% availability, 95% performance, and 95% quality. The improvement has reached a very high value, with the potential still open for further optimization to fill the gap between industrial standards.

Our study has some limitations,

- We could not show the cost of some systems installed for the improvements
- Showing a comparison between the productivity growth would make this research more complex. Thus, we could not mention it.

VII. AUTHOR'S CONTRIBUTION

Idea Generation: Jonayed Abdullah, Md. Al Hossain Rifat, and Avirup Deb Ray.
Methodology: Jonayed Abdullah, and Md. Al Hossain Rifat.
Analysis: Jonayed Abdullah.

Discussion of results: Jonayed Abdullah, and Avirup Deb Ray
Writing – Original Draft: Jonayed Abdullah, and Md. Al Hossain Rifat.
Writing – Review and Editing: Jonayed Abdullah, and Md. Al Hossain Rifat.
Resources: Jonayed Abdullah.
Supervision: Md. Al Hossain Rifat, and Avirup Deb Ray.
Approval of the final text: Jonayed Abdullah, Md. Al Hossain Rifat, and Avirup Deb Ray.

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