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# IMPROVING OVERALL EQUIPMENT EFFECTIVENESS BY ENABLING AUTONOMOUS MAINTENANCE PILLAR FOR INTEGRATED WORK SYSTEMS

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## ABSTRACT
*Integrated Work System (IWS) and Overall Equipment Effectiveness (OEE) are two popular approaches used by production firms to identify and eliminate production losses. In a highly competitive business environment, companies must increase their efficiency in the manufacturing process to support resilient business continuity. While OEE is widely used as a quantitative tool for measuring the performance of total productive maintenance (TPM), the IWS approach integrates equipment, processes, and involvement of people into a unified approach to reduce costs, improve quality, and increase productivity. Principally, there is an alignment between the two concepts. The IWS has the potential to maximize OEE to eliminate equipment failure and defects, minimizing downtime and maximizing productivity with less time, effort, and waste. The purpose of this work is to compare the performance of the OEE with the implementation of the IWS pillar, i.e., autonomous maintenance (AM). The rollout of the AM pillar was carried out on the two identical packaging machines (HLP1) with a speed of 120 packets per minute. The data which is shown in this paper is for both machines during the operational hours. Finally, the analysis showed positive results for both machines within a five-month period, with an increase of 27% and 15% in OEE, respectively. Later in the discussion, the root cause and SWOT analysis were perused for OEE and TPM, respectively, in this paper.*

Keywords: integrated work system (IWS); overall equipment effectiveness (OEE); autonomous management (AM); total productive maintenance (TPM).

## NOMENCLATURE
The follow nomenclature is used in this manuscript.

| | |
|---|---|
| IWS | Integrated Work System |
| OEE | Overall Equipment Effectiveness |
| TPM | Total Productive Maintenance |
| OEE | Overall Equipment Effectiveness |
| AM | Autonomous Maintenance |
| OEE | Overall Equipment Effectiveness |
| OOE | Overall Operational Efficiency |
| PM | Progressive Maintenance |
| FI | Focused Improvement |
| EEM | Early Equipment Management |
| MTBF | Mean Time Between Failure |
| CL | Centre Line |
| CIL | Clean Inspect Lubricate |
| DH | Defect Handling |
| DDS | Daily Direct Setting |
| BDE | Break Down Elimination |

## 1. INTRODUCTION
Growth towards a global economy and manufacturing world has expanded on the basis of competition to meet the best share market [1]. Organizations adopt and practice various approaches to increase their overall manufacturing performance [2–4]. The quantitative assessment of the overall manufacturing performance requires measurements of the performance of individual equipment or small sub-section within the production. For this reason, overall equipment effectiveness (OEE) is the most effective and accessible concept used to measure the performance of individual equipment that identifies the percentage of total planned production time that is truly productive [5–7].

The OEE has three universal elements, availability, performance efficiency, and quality rates [3]. Ultimately, the focus should be on improving equipment reliability while reducing cost of ownership. [5–8]. Firstly, availability (A) is a measure of the effectiveness of maintaining tools in a condition that is capable of running when required [5,9]. Secondly, performance efficiency (P) measures howequipment is used effectively for production, and finally, the rate of quality (Q) is responsible for measuring the efficiency of the manufacturing process to eliminate scrap and rework [4,5,9]. A 100% OEE score represents perfect production: manufacturing finished or quality goods, as fast as possible, with no downtime. The overall effectiveness of the equipment is one of the TPM success benchmarks [10]. Therefore, the OEE measurement is an indicator used to assess and improve productivity, quality, cost, delivery, and safety in the TPM success program.

In Japan, TPM has initially been introduced and developed as a strategy for equipment management designed as a comprehensive strategy for quality management. The origin of TPM can be traced back to 1951, which stressed proactive and preventive maintenance in order to maximize the operational efficiency of equipment [11]. For example, the machine operators clean and lubricate the equipment daily, which increases the time between equipment maintenance. There is a need for greater participation by all individuals in the plant for the successful implementation of TPM. If appropriately implemented in a machine or plant, this can be very effective in the right environment. This way TPM helps to improve productivity in the long run by cycle time reduction and deficiency elimination. The operating principle of TPM and OEE is directly linked to people who make significant efforts and require specialized skills. Integrated Work System (IWS), therefore may play a significant role in shaping and enhancing the TPM and OEE to maximize production and capital.

IWS is a proven approach that helps to improve investor profit, cash flow, and operating expenses (OpEX) through continuous breakthrough. On the other hand, it is a daily process that enhances and builds the culture & capacity for sustained operational excellence [12]. IWS goes beyond the foundational element of traditional operations and builds momentum with early success in those areas where we can quickly identify opportunities for improvement. Lee et al. [13] presented how such method is used successful in gaining improved market shares for majority of brands and goods.

Measures of IWS and allowing it to be used as a cost-effective way for any manufacturing firms to assess their costs per unit of output. A detailed methodology is shown by Wu et al. [14] in regards to cost reduction of product by lowering the material wastages and constantly improving plants performance in order to obtain quality finished goods. The employed method was able to produce at costs lower than its competition by means of efficient-scale facilities and vigorously pursuing cost. Another benefit of the IWS is the self-funding transformation initiative with small leadership qualities. The IWS is setting a platform which has proven to be a valuable measure of individually experienced peaks and troughs in workload over a period of time or within a particular set of scenarios. reductions along the value chain, driven by experience, tight cost, and overhead control.

Good leadership quality is an integral part of IWS that helps in motivating performance and effectiveness at all levels and in all operations of the firm [15–17]. Leadership and ownership management style affect the business performance of individuals. IWS works with people and leads with teams to increase overall performance. The OEE values are a critical performance indicator for all industries, so analytically, OEE can be expressed as the ratio of good production to its reference production in the given period.

Finally, this paper presents the purpose of implementing IWS and how important it is to monitor the company's OEE, downtime, and waste management.

## 2. REFLECTION OF IWS TO IMPROVE THE OEE

In the current dynamic business environment, maintenance has become more challenging. A brief reflection on OEE and TPM with appropriate equations and figures is shown in this section.

### 2.1 TPM

The TPM is an innovative approach to equipment maintenance to improve efficiency, eliminate damage to equipment, and promote autonomous maintenance of the daily process. TPM is an approach that deals with human behavior and skilled employee involvement from management to production level [10,18–19]. According to Randhawa and Ahuja [20], 5S is considered as the foundation of the lean TPM program, as shown in Figure 1. The 5S concept is a lean management tool for workplace organization, with 5S being an abbreviation for five Japanese words that translate into English as Sort, Set in Order, Shine, Standardize, and Sustain [21]. The detailed summary of each TPM pillar is described below:

#### 2.1.1 A Autonomous Maintenance (AM)

AM aims to develop operators to carry out small maintenance tasks. This can be understood because AM is one of the major characteristics of TPM, and its action and benefits are correctly understood [18–19].

#### 2.1.2 Planned Maintenance

Planned or scheduled maintenance is beneficial because it runs machines and equipment without trouble, produces products without defects in the industry, and hence improves productivity [18-19].

#### 2.1.3 Quality Maintenance

In order to minimize the number of rejected or defective products, maintenance activities are carried out in a manner that calls for lower investment in the manufacturing of defective products during the production period [22].

#### 2.1.4 Focused Improvement

It is aimed at continuous inspection resulting in zero losses with regard to unplanned downtime, measurement, adjustments, defects, and avoid unnecessary downtime.

#### 2.1.5 Early equipment maintenance (EEM)

EEM is a structured method that focuses on reducing the real-time complexity associated with equipment operation and maintenance. EEM applies lean principles to the design and produces equipment [18–19].

#### 2.1.6 Education and Training

It is one of the key pillars for the development of multi-skilled workers, improvement of employee morals, efficiency, and performance at work.

### 2.1.7 Health, safety & environment

Ensure safety, health at work and a safe and clean environment. These are all conditions that allow employees to do their job better.

### 2.1.8 TPM in office function

Essentially, TPM aims to integrate the company to acknowledge, release and use its own capabilities. The goal of TPM is to bring trade union members, supervisors and management together to take corrective action as necessary [18–19]. TPM is a productive maintenance program that focuses on the following TPM benefits.

- Maximize the OEE.
- Increase productivity.
- Rectify customer complaints.
- Reduce the manufacturing cost.
- Satisfy the customer needs
- Reduce accidents
- Follow pollution control measure

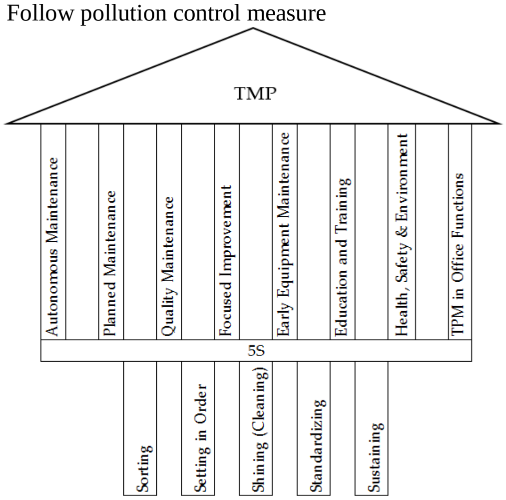


**FIGURE 1:** 5S are considered as the foundation of the lean TPM program.

## 2.2 5S

The 5S concept is responsible for organizing the workplace in a safe environment [20–21]. It is a methodology used for waste reduction and productivity improvement. 5S implementation encourages operators to improve their physical set-up and contributes to waste reduction, unforeseen downtime and in-process inventory. An adequately implemented 5S would result in significant reductions in space, time and effort for existing operations.

## 2.3 OEE

The OEE is a key KPI indicator that the OEE is developed following use of the initially launched Progressive Maintenance (PM) concept [5–7,10,19]. The importance of PM is to achieve zero failures and zero failure related to equipment. Focused Improvement (FI), PM, AM and Early Equipment Management (EEM) are key components of IWS [18].

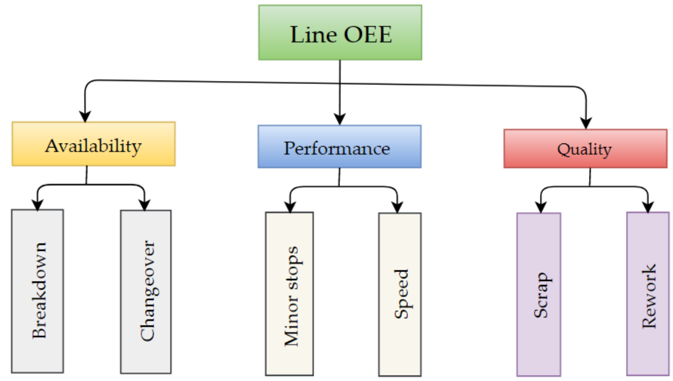


**FIGURE 2:** Structure tree for OEE.

The OEE world-class standard score is 85% [22]. The OEE is divided into three different analyzes with reference to Figure 2, that is availability, performance and quality. Equation 1 shows the classical OEE definition, it shall be considered as an unplanned time to consider the total time of operation as the maximum overall operational efficiency (OOE) [5–7,10,19].

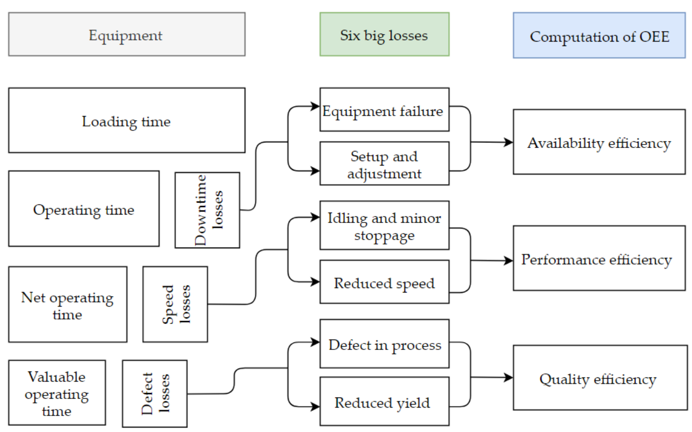


**FIGURE 3:** Structure of OEE and computation procedure.

$$OEE = A \times P \times Q \tag{1}$$

where, $A$, $P$, $Q$ is considered as availability, performance, and quality, respectively.

### 2.3.1 Availability

In accordance with the schedule, the availability parameter is used to measure the downtime losses on the equipment that is to be used in the production process (Figure 3). Calculating the availability does not take preventive maintenance into account since it can result in excessively long operations or excessive process set-up times. Although planned preventive maintenance is omitted, the value of the OEE still seems low, and the need to reduce planned maintenance by implementing TPM [5–7, 10,19] remains to be met. The downtime activities included in the availability activity are therefore: set-up and over time change, minor stops and unplanned maintenance, such as machine failure. Accessibility factor can therefore be formulated using Equation 2.

$$A = \frac{Loading\ Time - Downtime}{Loading\ Time} \tag{2}$$

### 2.3.2 Performance

The second factor used in the calculation of the OEE is the performance efficiency, which is the actual production speed to ideal equipment performance ratio based on design capacity, as shown in Figure 3 and given by equation 3. The performance efficiency will be high if the speed of production is maintained according to the perfect equipment speed. The percentage of waste time contributes to the decrease of the production speed of equipment [5–7, 10,19], based on the performance efficiency calculation.

$$P = \frac{\text{Processed amount} \times \text{Ideal cycle time}}{\text{Operating Time}} \tag{3}$$

### 2.3.3 Quality

The quality rate is the last factor for the OEE (Figure 3). The Quality Factor covers all goods manufactured if they comply with the quality standards. One of the parameters of the quality is to rework a rejected product. Time and resource requirements increase with growing number of rejected products [23].

$$Q = \frac{\text{Good Production}}{\text{Total Production}} \tag{4}$$

### 2.4 Six big losses

As mentioned, these losses have been identified by OEE. Essentially, it's a bottom-up way of achieving an integrated workforce by removing the six major losses [22]. The six main losses are categorized as failures, waiting, minor stops, lower speed, deficiencies in quality and start-up losses [24-25]. Breakdown and waiting are downtime losses, minor stops and reduced speed are considered for performance and quality defects; and start-up losses are considered quality losses.

### 2.5 Mean time between failures (MTBF)

MTBF is a reliability measurement of the system, directly related to the availability of a machine for a certain period. MTBF is the average time between system failures during production given by Equation 5. The higher the number of MTBF, the greater the machine's reputability.

$$MTBF = \frac{\text{Total Uptime}}{\text{Number of Stops}} \tag{5}$$

### 2.5 Total effective equipment performance (TEEP)

TEEP and OEE concepts are extremely similar, but the main difference is that the planned downtime is included in the total time zone of the project. As shown in Figure 4, OEE measures efficiency based on scheduled hours while TEEP measures efficiency against scheduling hours, that is 24 hours a day, 365 days a year. The TEEP is computed by one of the loading parameters in Equation 6.

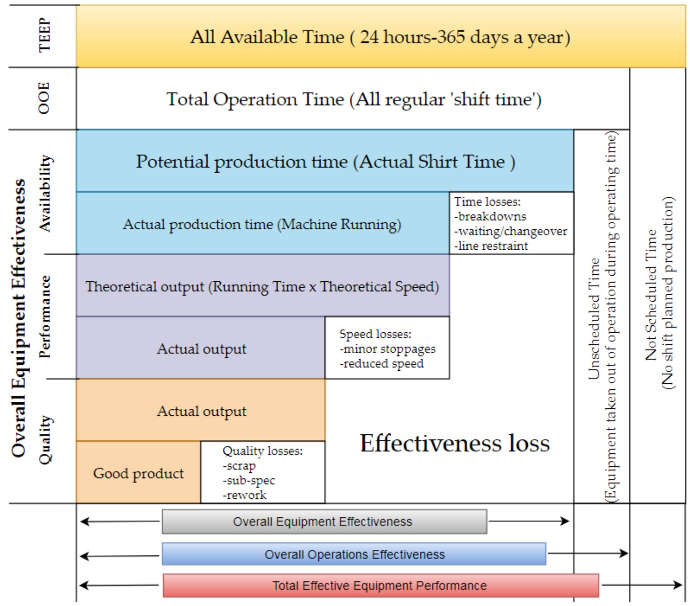


**FIGURE 4:** Summary of OEE, OOE and TEEP [15].

The TEEP metric load portion represents the percentage of time an operation is planned in comparison with the total calendar time available. The Loading Metric is a pure measurement of the efficiency of the schedule and aims at excluding how well it works [26].

$$TEEP = \text{Loading} \times \text{OEE} \tag{6}$$

## 3. METHODOLOGIES

This research particularly looked at rolling out the AM pillar of IWS to improve the OEE of the cigarette factory in the Pacific. Out of twelve pillars given in Figure 5 only AM pillar was accomplished on the two identical packaging machines (HLP1) with a speed of 120 packets per minute. The operating time for each machine was 570 minutes from Monday to Thursday and 540 minutes on Friday.

Along with production, the AM was rolled out to see the performance of the machine in terms of quality production for five months (January to May). The aim for it was to restore and prevent accelerated deterioration, thus positively impact OEE. It is a skill development program which improves the process failure, stabilize equipment conditions and develop training materials on how to run, operate & maintain equipment rather than production teams carrying out maintenance tasks [18].

The five main concepts used for implementing AM pillar were; Centre Line (CL), Clean Inspect Lubricate (CIL), Defect Handling (DH), Daily Direct Setting (DDS), and Break Down Elimination (BDE). Each step is summarized below [15-17,25].

- CL: A Center Line is strictly used in the AM pillar to set parameters and optimal settings for the optimal outcome in a production system. CL is set in a way that keeps all the machine in the right parameter with a coherent state. It helps to keep the machine in the best possible setting for the best possible outcome. All the operators were instructed to follow and maintain the given centerline.

- CIL: It is a critical step in the IWS guidelines, CIL's are intended to return and maintain the equipment at the base condition. Cleaning is done to return and maintain the equipment in the base condition to give the best results. Inspection is done to find and fix defects that prevent stops and breakdowns. Before any breakdown and unplanned stop takes place, an inspection can identify the potential defect and prevent them from happening. Lubrication standards help components last for their expected life span or beyond. It makes the machines run smoothly. CIL is a must; to be done for at least 30 minutes in every 8 hours shift. Without proper CIL, the machine can never perform at its best.
- DH: Defects cause unplanned stopping and decline in machine performance. So, the role for DH is that it ensures identified defects are tracked, prioritized and fixed in a timely manner, and equipment is maintained at base condition. Defects are taken very seriously and usually taken care of right away to ensure smooth performance of the machines. Root causes of the defects are also found out to prevent them from happening again. Operators inspect for defects and, after consulting with the management team, take necessary actions.
- DDS: As mentioned that the working time is about 570 minutes on a single shift. DDS works on a daily basis, but the discussion mainly focusses on previous day operation. It gives a clear idea about the performance of each machine. Production losses are discussed during this stage with root cause analysis. According to IWS the transition should be as smooth so that the machine does not understand that it is being operated by different hands.
- BDE: Breakdown is the biggest fear for both the management team and the operators. Breakdowns severely hamper productivity of the factory, as it takes hours to be repaired. DH and BDE are analyzed using root cause method, and defects are found and fixed in time. If any breakdown takes place, the root cause is identified as soon as possible, and necessary actions are taken to prevent a breakdown from happening again.


**FIGURE 5:** Twelve Pillar of IWS [14].

IWS is an innovative way to improve the equipment effectiveness, eliminate equipment damage and promote autonomous activities for personnel to maintain machines. This approach directly involves the operator, which gives them the opportunity to take ownership of the equipment. To roll out the IWS, it needs to follow basic steps which deal with people management, developing skills, and leadership quality. Each step is summarized below.

- IWS Team: A professionally skilled team is required to manage the team, such as leaders, engineers, and technicians. They are trained with multiple training experts where firm workers will learn and practice during the working period. This training teaches them about IWS and how they could lead this to their staffs and how the benefits can be maximized.
- Pilot line: The pilot line is an initial phase where machines or production lines goes under IWS implementation.
- Preparation of the Pilot Line: the checklist for the Center Line and Clean Inspect Lubricate was made. All the optimal setting of the machine was noted down in the checklist of the center line. All the fast-moving areas and hard to reach areas of the machines were noted down in the CIL checklist. The staffs were given brief training on what IWS is and how they can take the lead in implementing this on their machine. They were also educated on the benefits of IWS to the business and the workers.
- Preparation of the logbook: the defect handling log book was made and given to the operators, and the operator was supposed to note down at least two defects every day. After the defect was noted down, it was the responsibility of the technicians to solve those issues. The management had to make sure that these defects were solved in the shortest time. The engineer had the responsibility of making a note of all the defects and the steps required to solve this issue. The engineer was also supposed to analyze these defects, find the root cause and find preventive measures for the defects,

which were frequently occurring. The checklist of the center line and CIL was printed out and given out to the operators. The CIL was conducted twice in a day. First, in the morning before production and second in the middle of the shift, that is at 12.00pm. The center line was used as a guide before starting the machine and during breakdowns.

- Starting of Daily Direct Setting (DDS): the main idea of this concept was to discuss the previous day's performance. A separate team was made, which was named as the DDS Board. The things which were discussed on this board were the production (expected to actual), OEE, MTBF, Quality issues, Top losses with its root cause, when it will be solved and updates on other follow ups. In this DDS, the OEE and MTBF of the Pilot line is also discussed and suggestions were stated to improve it.

## 4. RESULTS

After the rollout of AM pillar as highlighted in the methodology section of this paper on both identical machines, the observation and improvement were analyzed. This section will look into the OEE, machine downtime, MTBF, and waste management for both machines. The first set of data from September to December in the Figures and Tables given in this section shows the result without implementing IWS, and latter (January to May) shows the impact of implementing IWS.

### 4.1 Machines OEE

The performance improvement trend of both machines is shown in Figure 6. The IWS was implemented in the month of January, and the same was maintained and monitored till the month of May. The implementation of IWS shows a good trend in terms of machine performance (i.e., less failure).

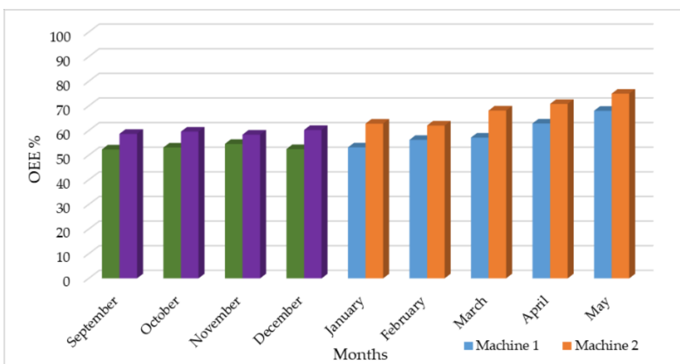


**FIGURE 6:** OEE for Machine 1 and 2.

It is seen that IWS has really impacted the performance of the machine with an increase in OEE of both machines. The OEE trend shown for machine 2 in Figure 7 has a maximum increase of 19%, as IWS works with the daily process, and it takes time to show better results. The operators took time to adjust to the AM process implemented, and as time progressed, better results were seen. The increased OEE predominantly means that the machine's performance has increased with a better quality of output. Such factors can drastically impact a business with quality output, reduced downtime, low manufacturing cost, managing resources, reduced waste, increased MTBF, and less pressure on the management and staff.

### 4.2 Machines downtime

The IWS not only improved the OEE but is also directly related to machine downtime. The machine which was under IWS practice showed a great improvement in machine performance and reduced downtime. Each machine had a working period of 9 hours and 30 minutes. Table 1 shows the downtime for the two machines per month, consecutively. IWS was implemented from January to May. It is clearly noted from Table 1 that the implementation of IWS significantly reduced the downtime for both machines. The AM implemented was taken seriously by the management, operators, and other staff, and training was also provided.

The end results for monitoring downtime have improved the performance, and IWS minimized the stopping time of the machine and improved the MTBF. The performance of the machine is measured using OEE, thus minimizing the downtime improves the MTBF for the machine. This is important to meet the production demand. Figure 7 shows that the frequency of line stops per cycle was reduced after the implementation of IWS. It is importantly noted that not only the downtime reduced but also the number of stops per month also reduced.

**Table 1:** Downtime for the two machines in minutes.

| | Downtime for machine per months (minute) | |
|---|---|---|
| Months | Machine 1 | Machine 2 |
| *September* | *7055* | *7075* |
| *October* | *7050* | *7085* |
| *November* | *7035* | *7060* |
| *December* | *7045* | *7075* |
| January | 7035 | 7060 |
| February | 6850 | 6700 |
| March | 6355 | 6125 |
| April | 5115 | 5220 |
| May | 5045 | 5065 |

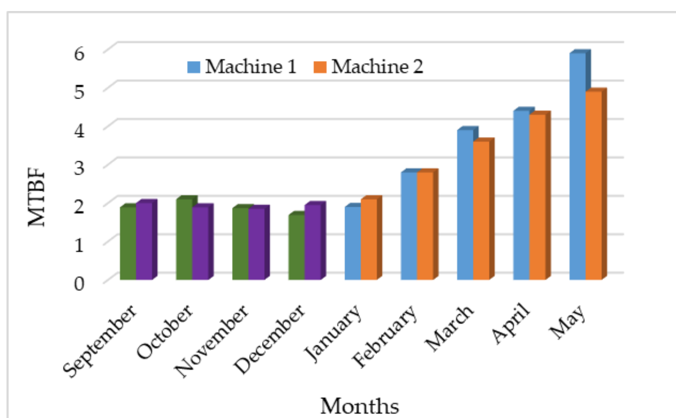


**FIGURE 7:** MTBF of Machine 1 and 2.

### 4.3 Waste management

Once IWS was in practice, wastage was controlled for both machine, this is very important in any firm. Before the implementation of IWS, the non-implemented IWS months stated in Table 2 showed the wastage to be higher, and it was controlled later. Waste management, as discussed in earlier sections, save time, material, effort, and increase productivity and profits.

**Table 2:** Waste produced the machines in kg.

| | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May |
|---|---|---|---|---|---|---|---|---|---|
| Machine 1 | 50 | 52 | 36 | 44 | 40 | 34 | 25 | 13 | 11 |
| Machine 2 | 110 | 96 | 103 | 102 | 92 | 75 | 67 | 61 | 59 |

## 5. DISCUSSION

The trend of OEE, downtime, MTBF, and waste management was seen to be improving after implementing the AM pillar of IWS. AM pillar has improved CL, CIL, DH and BDE for both machines in five months' time. CL, CIL, BDE contributed in reducing the number of stops and giving a smooth-running condition for the machines, whereas, DH helped in reducing the frequent defects which use to occur. People management and skill training session seem to be improving on a daily basis, DDS acts as a reflection tool of the previous day's performance on both machines. During the DDS the top losses were discussed and noticed reduction once AM pillar was rolled out.

Interestingly, strategic plan was developed to meet the KPI's, which was the key motive of IWS.

Through the implementation of the IWS the quality of the output had increased. The duration of the production time had also decreased. The overtime, which not only affected the business financially but also the staff who at times had to exceed their fatigue level was decreased. The attendance also increased as the staff could go home early and get enough rest because the overtime had gone down and staff could be rotated during overtime. Through the implementation of IWS, staff had enough time to carry out housekeeping. There was also very little tension and rush on the floor as the machines were running smoothly.

Techniques such as IWS are essential for the manufacturing industry to expand and compete in today's economy. People development and maintaining machinery is very important for a business to prosper, and IWS provides this with many other beneficial techniques.

### 5.1 SWOT analysis of TPM

After rolling out AM, the TPM SWOT analysis was carried out to understand the importance of TPM and where more improvement is required. The analysis was done from both employer and business perspectives, as shown in Figure 8.

### 5.2 Fishbone Analysis of Low OEE

Fishbone analysis is shown in Figure 9. This analysis provides the reason why there is a low OEE. The four fundamental keys such as Man, Machine, Materials and Method, were used in brainstorming stage. The important factors that lower the OEE were considered as the major contributors.

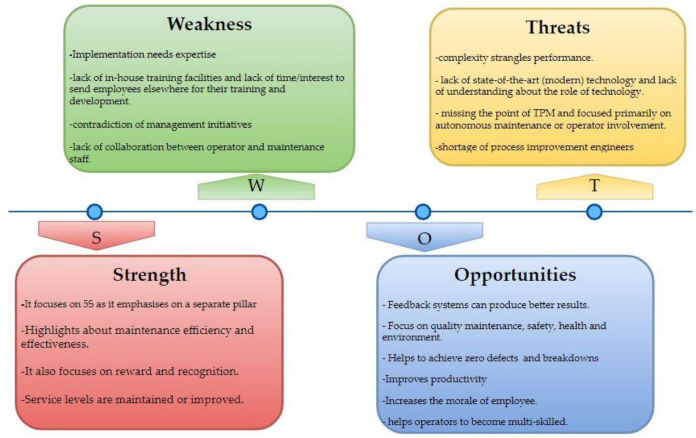


**FIGURE 8:** SWOT analysis of TPM.

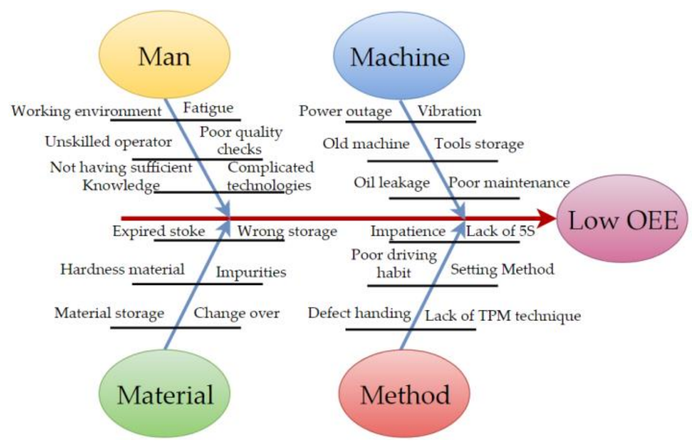


**FIGURE 9:** Fishbone Analysis of Low OEE

## 6. CONCLUSION

This research paper presents an important concept of TPM, which heavily depended on AM pillar of IWS. The importance of implementing the IWS in a workforce has many benefits for improving the productivity of a manufacturing company, and minimize the losses incurred in the company. Not only does it help the business in maximizing the profit, but it is a platform whereby the management can strengthen their leadership qualities while the operators can strengthen their core and technical competence. Operators will have less pressure on them when the machine will run well, as this was evident in the OEE and MTBF.

The losses incurred in the business of manufacturing industry is usually orientated from the production floor, and these losses included high waste, high downtime, low OEE and MTBF, high number of stops and maintenance cost. Deploying IWS can successfully reduce all the mentioned problems. This was shown in this paper that after rolling out of AM pillar it had a huge impact on OEE, an increase of 27% and 15% OEE for each machine was noticed in five months' time, respectively. TPM has greatly monitored the MTBF, downtime and waste management, which maximized OEE, in general.

## REFERENCES


[1] Maskell, P.; Malmberg, A. Localized learning and industrial competitiveness. Cambridge J Economics 1999, 23, 167-185.

[2] Azevedo, S.G.; Carvalho, H.; Machado, V.C. The influence of green practices on supply chain performance: a case study approach. Transport Res Part E: Logis Transport Rev 2011, 47, 850-871.

[3] Raymond, A.N.; John, R.H.; Barry, G.; Patrick, M.W. Human resource management: Gaining a competitive advantage. 4th ed.; New York, NY: McGraw-Hill Education, USA, 2002; pp. 352-370.

[4] Combs, J.; Liu, Y.; Hall, A.; Ketchen, D. How much do high-performance work practices matter? A meta-analysis of their effects on organizational performance. Personnel Psych 2006, 59, 501-528.

[5] Muchiri, P.; Pintelon, L. Performance measurement using overall equipment effectiveness (OEE): literature review and practical application discussion. Int J Product Res 2008, 46, 3517-3535.

[6] Dal, B.; Tugwell, P.; Greatbanks, R. Overall equipment effectiveness as a measure of operational improvement–a practical analysis. Int J Operat Product Manage 2000, 20, 1488-1502.

[7] Braglia, M.; Frosolini, M.; Zammori, F. Overall equipment effectiveness of a manufacturing line (OEEML) An integrated approach to assess systems performance. J Manuf Tech Manage 2008, 20, 8-29.

[8] Muchiri, P.; Pintelon, L.; Gelders, L.; Martin, H. Development of maintenance function performance measurement framework and indicators. Int J Product Econo 2011, 131, 295-302.

[9] Garg, A.; Deshmukh, S.G. Maintenance management: literature review and directions. J Quality Mainte Eng 2006, 12, 205-238.

[10] Hansen, R.C. Overall equipment effectiveness: a powerful production/maintenance tool for increased profits, 1st ed.; Industrial Press Inc, USA, 2001; pp. 105-120.

[11] Cua, K.O.; McKone, K.E.; Schroeder, R.G. Relationships between implementation of TQM, JIT, and TPM and manufacturing performance. J Operat Manage 2001, 19, 675-694.

[12] Bauer, D.L.; McFarlane, K.R.; Flockhart, A.D.; Sanders, L.M.; King, G.S.; Maxwell, D.J.; Russell, S.R.; Stewart, R.A.; Cook, W.S.; Avaya Inc, Integrated work management engine for customer care in a communication system. U.S. Patent 6,690,788, 2004.

[13] Lee, H.L.; Padmanabhan, V.; Whang, S. The bullwhip effect in supply chains. Sloan Manage Rev 1997, 38, 93-102.

[14] Wu, H.L., Lin, B.W. and Chen, C.J., 2007. Contingency view on technological differentiation and firm performance: Evidence in an economic downturn. R&d Management, 37(1), pp.75-88.

[15] Goleman, D. What makes a leader. Organi Infl Proc 2003, 82, 229-241.

[16] Bell DeTienne, K.; Dyer, G.; Hoopes, C.; Harris, S. Toward a model of effective knowledge management and directions for future research: Culture, leadership, and CKOs. J Leader Organi Stud 2004, 10, 26-43.

[17] Hart, S.L.; Quinn, R.E. Roles executives play: CEOs, behavioral complexity, and firm performance. Human Relations 1993, 46, 543-574.

[18] Amorim, G.; Hatakeyama, K.; Rojas-Lema, X. Implantation of Total Productive Maintenance: A Case Study in the Manufacturing Industry. In New Global Perspectives on Industrial Engineering and Management, 1st edi.; Josefa, M., Rafael, B., Manuel, D.M., Raúl, P., 1st edi.; Springer International Publishing, USA, 2019; 1, pp. 259-267.

[19] Nallusamy, S.; Majumdar, G. Enhancement of Overall Equipment Effectiveness using Total Productive Maintenance in a Manufacturing Industry. Int J Perform Eng 2017, 13, 173-188.

[20] Randhawa, J.S.; Ahuja, I.S. 5S–a quality improvement tool for sustainable performance: literature review and directions. Int J Quality Reliab Manage 2017, 34, 334-361.

[21] Singh, A.; Ahuja, I.S. Review of 5S methodology and its contributions towards manufacturing performance. Int J Process Manage Benchmark 2015, 5, 408-424.

[22] Garvin, D.A. Managing quality: The strategic and competitive edge, 1st edi.; Simon and Schuster Inc, USA, 1988; pp. 179-200.

[23] Sowmya, K.; Chetan, N. A review on effective utilization of resources using overall equipment effectiveness by reducing six big losses. Int J Scient Res Sci Eng Tech 2016, 2, 2394-4099.

[24] Catelani, M.; Ciani, L.; Venzi, M. Failure modes, mechanisms and effect analysis on temperature redundant sensor stage. Reliab Eng Sys Saf 2018, 180, 425-433.

[25] Velásquez, R.M.A.; Lara, J.V.M. Reliability, availability and maintainability study for failure analysis in series capacitor bank. Eng Fail Ana 2018, 86, 158-167.

[26] Cheh, K.M. Analysis of Overall Equipment Effectiveness (OEE) within different sectors in different Swedish industries, Masters Thesis, Mälardalen University, Eskilstuna, Sweden, 2014.