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Monitoring Performance of Two-Wheeled Automotive Component Painting Service Companies Through the Implementation of TPM

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Abstract

Company is an organization that provides or produces products/services. Various types of companies and the complexity of the process make the company must be able to continue to grow and compete with competitors. To win the competition, companies must have a strategy to improve performance. TPM is part of the strategy implemented in the company. In Indonesia, not all companies apply TPM, automotive component painting companies apply and measure performance through PQCDSM as a whole. The result of TPM implementation is an increase in production performance which has an impact on reducing quality costs, increasing production, increasing the effectiveness of equipment use because the total of damaged equipment is less. TPM implementation through OEE production performance/engine efficiency increased by 68.7%.

Keywords: TPM, Autonomous maintenance, Benchmarking, Kaizen, PQCDSM.

1 | Introduction

Company is providing organization or produce product/service. Various type company and the complexity of the manufacturing process company must could keep going grow and compete with competitors. For win competition, company must do breakthrough. One of no breakthrough yet many done by many companies in Indonesia are Total Productive Maintenance (TPM) implementation. The results of the survey conducted with using Structural Equation Model (SEM) with Smart-PLS shows that still a little companies in Indonesia that implement TPM. Several inhibiting factors implementation of TPM and lean manufacturing, so proposed structural model for connection between tpm, lean manufacturing, and manufacturing performance [1].

PQCDSM is one step in monitoring the total activity of a company by knowing the performance of each department. Performance affects the results achieved, with the role of all production operators being able to encourage changes in the work environment that can increase productivity [2]. In other studies that the application of TPM related to production can increase machine life, effective use of

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equipment and employee discipline because of the independence that has been carried out [3]. In the service industry the application of TPM can eliminate waste resulting in zero defects, zero accidents and zero breakdown [4]. One of the obstacles that occurs if the machine is not maintained, machine failure will cause delays in the production process and can even cause the process to stop. Application of TPM such as 5S, preventive maintenance and cleaning can be effectively applied to production machines to improve OEE [5].

In another study OEE was used to monitor the machines used, the results of the implementation of TPM in two different companies showed that there was an increase in OEE values [6]. The application of TPM is used to determine the performance of each machine by looking for the OEE value, as well as the factors that cause a decrease in OEE [7] several variations in the OEE value are affected by losses due to downtime, machine idle time so that in order to calculate OEE the influencing factors are identified and steps are taken to improve performance. The application of OEE can increase the value of OEE by implementing lean TPM tools such as Jishu Hozen, Kaizen in manufacturing companies [8]. Good quality will affect product quantity, the results of the analysis [9] show that the strategy between TQM and TPM is integrated systematically and makes a significant contribution to improvements in manufacturing. TPM and TQM can be applied multisectorally so that they can assist managers and practitioners in making strategic decisions so that they can revive competitiveness between companies [10]. On the one hand, research on two different companies shows that implementing TPM can increase OEE, but on other companies increasing OEE is by modifying calculations so that it is necessary to differentiate the weight of comparison for different OEE components [6].

TPM is an effective maintenance strategy to increase the efficiency of operational performance with the main indicator being PQCDSM [11]. TPM is a Japanese concept to realize the best performance standards that are effective and efficient with its fundamental pillar Kobetsu Kaizen, while the production line 1 is the benchmark in the production system [12]. Companies implementing TPM will differ from one another, it all depends on the type of process. One type of component of production is reduction of setup time, cycle time, breakdown loss, and rework time, while the overall effectiveness of the equipment was found to be increased [3]. Ethical and psychological factors also affect the capabilities and morale of employees, so that the application of 5S is used to produce the best productivity [13].

Losses due to machine damage are not the only parameters that affect OEE variations, but machine idle time is a factor that adds to these variations. The percentage of OEE can be increased substantially by implementing a total TPM such as Jishu Hozen, Kaizen [8]. To reduce time loss and improve performance and increase OEE through TPM and RCM by using FMEA, a performance increase of 79% and an increase in OEE of 72% are obtained [14]. The results showed that there was a difference between planned production and actual production, but after the application of TPM production losses decreased by 6% thereby increasing machine productivity [15]. TPM describes the relationship between production and maintenance, for the continuous improvement of product quality, operational efficiency, capacity, assurance, and safety.

One of the things that TPM does is kaizen. Kaizen has a significant impact without adding new technology investments or spending funds but only using existing facilities and relying on the creativity of all staff efficiently [16]. There are many TPM implementation approaches to determine success, but most of the failure rates still occur so that the expected goals have not been achieved [8]. Several TPM implementations have been implemented in several NMMC suppliers in the component assembly section and will be implemented not only for component assembly but throughout the company [17]. Through a comparison between the discussion of literature, research, and perspectives, the key success factors for TPM can be implemented consistently due to the commitment and involvement of management and all employees [18].

Research in the 5 years following the implementation of lean has improved in the long run, with the implementation of JIT and TQM, delivery of kanban, 5S, and TPM having a positive impact on the

work environment [19]. The application of the TPM principle can improve company performance, the TPM maintenance management system is a prerequisite in reducing production costs and losses due to unscheduled failures, applying the principle of autonomous maintenance, so that the principle can be applied in various sections bagian [20]. The application of TPM and Single-Minute Exchange of Dies (SMED) can increase OEE by 60.6% [21]. The development of integrated TPM, TPS, and TQM models through the PDCA cycle to produce perfect product quality, zero defects, zero accidents, and reduced inventory costs, shorter waiting times, better flexibility [22].

Lean maintenance aims to identify sources of waste in all activities, by positioning lean maintenance towards TPM and lean manufacturing [23]. The implementation of TQM, JIT, and TPM are recommendations for implementing an effective agile manufacturing system to improve operational performance [24]. The survey was conducted on 231 manufacturing organizations in the food, beverage, textile, electrical and electronics sectors with a TPM and TQM approach and TPM-TQM integration is applied exclusively to improve manufacturing business performance by developing a multi-sector analytic framework with t-test statistics [10]. Involving all employees by utilizing manpower and equipment optimally can reduce idle time and waiting time by looking for strategies to identify waste, reduce production costs, reduce labor and minimize production process time [25]. The results of the study identified the effect of lean production on operational performance, there was a decrease in lead time due to the application of TPM [26], the application of different TPM and ISO standards can be classified to equate two different standards so as not to be ambiguous [27].

In the manufacturing and service industries productivity, efficiency, and effectiveness are able to identify critical points on the path that require improvement with the TPM strategy [28]. Productivity is the key to manufacturing success in facing business competition and global competition, TPM is a strategy to reduce waste. To improve OEE, FMEA provides a list of priority corrective actions with five steps in the congestion process [29]. Research by integrating four variables shows that management commitment is the most important part in achieving productivity, the function of preventive maintenance in total productive management encourages company management to commit to implementing preventive maintenance programs to ensure the successful implementation of TPM [30].

One company in Indonesia that implements TPM is a company engaged in coating two -wheeled vehicle components, the company is able to meet the needs of several company assembly companies. TPM implementation is carried out after several years of operation and the company has decreased performance. The decline occurred because in the company's activities were not controlled, so the problem was not identified properly and the improvement did not reach the root of the problem. Quality is an important part that must be considered by the company because it involves customer satisfaction. To improve the quality and quantity, future improvement steps are needed, one of which is the application of TPM to increase overall productivity.

1.1 | Production (P)

Measurement with OEE is a performance parameter that is able to provide significant results compared to other performance parameters because it can access time settings and no time [31]. Implementing TPM, RCM with FMEA can increase company performance by 4% and OEE by 6% by reducing loss time in companies [14]. Kaizen is at the center of improving overall performance to increase productivity. After the 6 losses are analyzed, the value of increasing OEE and decreasing the level of loss/waste is obtained [32]. Creating a machine maintenance plan with a predictive maintenance approach, maintenance training can affect the production process because it can eliminate 6 big losses [33]. Improvement 6 major disadvantages with the implementation of TPM is proven to increase OEE, increasing the overall efficiency of the company [34].

Fig. 1. Painting process.

Equipment Cost Loss (OECL) measurements were carried out and compared with benchmarks but did not reach the target, even though there was a significant increase while several other machines reached the target in several periods [35]. OEE measurement with reckoning availability, performance, quality rate. Whereas in manufacturing companies, machine breakdown has an impact on low OEE values, which are the availability component [36]. The maintenance schedule is able to ensure the machine is stable and has an impact on the standard OEE value and is even able to reach the world-class standard target [4].

In more detail the factors that affect the value of OEE/machine efficiency are shown in the following figure.

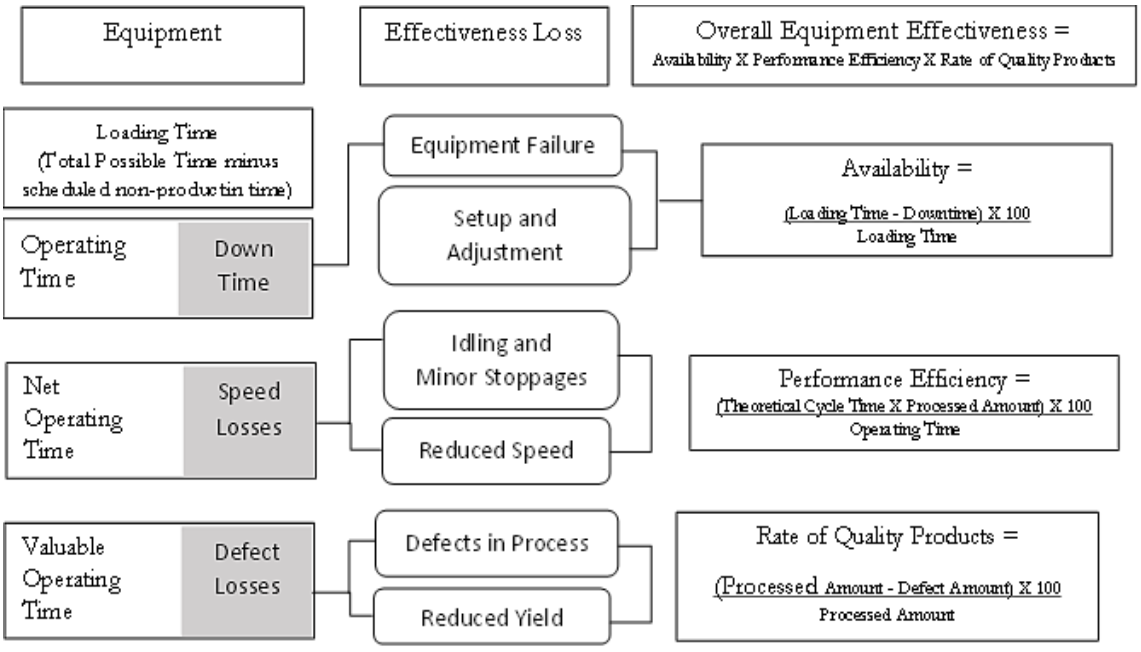

Fig. 2. OEE and Losses [37].

$$OEE = \text{Availability \%} \times \text{Performance \%} \times \text{Quality}.$$

The application of TPM can improve quality in automotive companies and increase machine efficiency significantly up to 94% [38]. OEE evaluation can provide guidance in measuring aspects of production to identify points of improvement through a TPM strategy [28]. To increase the effectiveness of the production process, an analysis is carried out by applying DMAIC as an element of continuous improvement [39]. Improvement measures from OEE junction with autonomous maintenance, training, kaizen with 5S concept of regular machine maintenance plan [40]. In injection molding companies, the factors that affect machine efficiency are related to timing, mchine breakdown. OEE is the main

performance indicator used in measuring equipment (machine) productivity, developing the implementation of TPM to lean manufacturing, and developing OEE-based models which are the focus of research even in the fields of logistics and services [41]. An analytical study with statistical results concluded that damage and machine losses due to speed have the most influence on OEE values, it is necessary to monitor possible losses caused by external factors [42]. Improving production and quality requires organizational involvement, proper planning and implementation, autonomous maintenance, and overall kobetsu kaizen in the company, lack of top management commitment, prioritization, and lack of expertise hinders performance improvement [43].

1.2 | Quality (Q)

The occurrence of defects in products that have been painted is one indicator that affects the percentage of success rate of the final product to be sent to consumers. The role of the quality department in implementing policies will affect performance and quality so that they can contribute to customer satisfaction. Managerial commitment that guarantees company performance and with good quality policies contributes to customer satisfaction, so that managers and operators become one of the successes of TQM [44].

Research from the Federation of Malaysian Manufacturers (FMM) and a directory listing foreign companies in Malaysia shows that TPM is a partial mediator between TQM and business performance so that it can help manufacturing companies improve TQM practices through TPM as a mediator to compete in the global market [45].

1.3 | Cost (C)

Production costs are a measure of expenses for operational processes that need to be analyzed again and compared with company performance, by implementing TPM, production costs can be reduced so that sales can be doubled [46]. The costs incurred are a loss for the company, because they are included in the category of unnecessary costs. To reduce costs in the company's operations, it is necessary to identify the causes, one of which is by identifying the factors related to the effectiveness of the equipment as a whole and identifying production losses. The use of DMAIC, six sigma methodology, statistical analysis, and brainstorming can prove that stoppages, delays in receiving materials, inappropriate maintenance schedules, worn and damaged components, temporary stoppages during production are the main factors in the decrease in the level of equipment availability which results in a decrease in equipment efficiency as a whole [47].

1.4 | Delivery (D)

The accuracy of product delivery to consumers is a benchmark for the PPIC department, to achieve 100% delivery requires collaboration between departments. Several factors can affect delivery, starting from the arrival of materials, the production process to the final process. Among these components, semi-finished materials are the cause of delivery delays because many semi-finished products have to be reworked.

1.5 | Safety (S)

Every company targets 0 work accidents, safety is one of the parameters that must be monitored for employee safety. Apart from work accidents, pollution is one of the basic principles of TPM because it is included in the pillars of environmental health and safety [11]. Several factors for the occurrence of work accidents include unsafe working conditions or wrong workplace designs, inappropriate equipment/machine designs or can be caused by operator negligence. Improvement of work culture has a significant impact on increasing safety because every activity is properly scheduled [48]. Implementation of 5S, TPM, TSM with good work safety standards can increase productivity and provide work safety for employees [49].

1.6 | Morale (M)

Morale is a part of TPM in the form of kaizen, kaizen carried out by all employees of a company has implications for the success of TPM. Kaizen does not affect the relationship between TPM and innovation performance, but the impact that occurs when TPM is implemented is that there is an increase with kaizen in the automotive industry [50]. On the other hand, the participation of all employees shows the amount of kaizen received each month [11]. In addition to kaizen, the presence of employees determines the smooth running of the production process. Employee attendance is one of the moral components that must be measured to determine the performance of the relevant department.

2 | Research Methods

Research method conducted with do interviews and data collection for know achievement performance through TPM implementation.

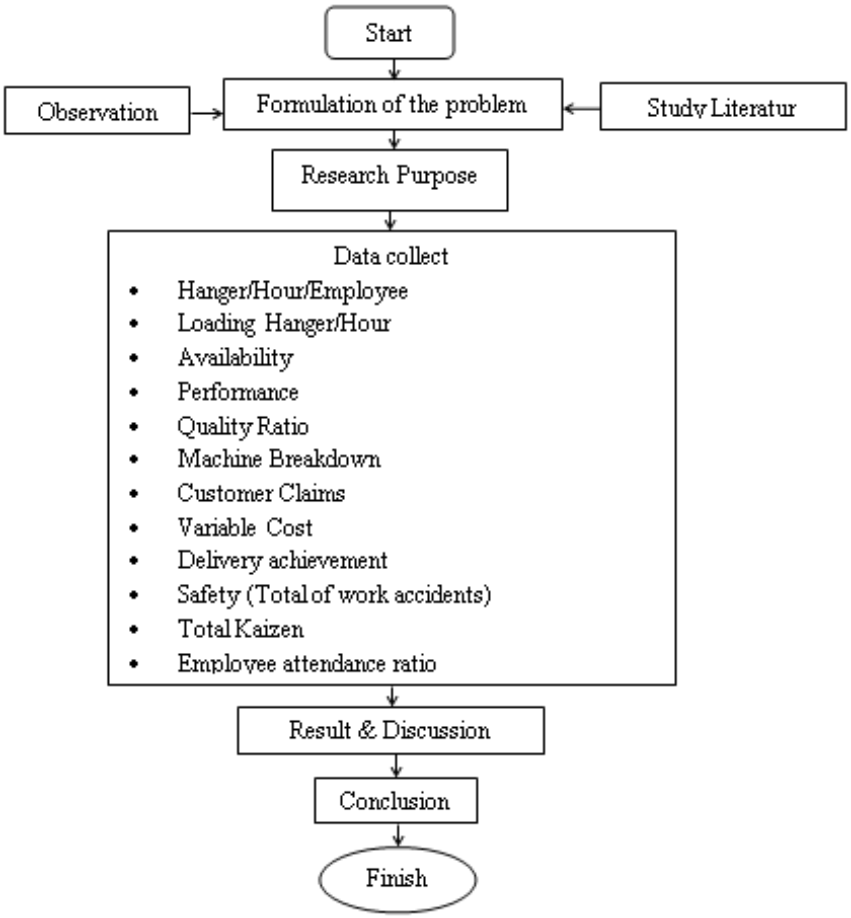

Fig. 3. Research methodology.

The data obtained is then processed with the following formula:

Table 1. PQCDSM formula.

Performance	Formulas
Hanger goods	Number of hangers: working hours/number of employees x production ratio
loading hanger	Number of hangers/employee
OEE	Availability % x performance % x quality %
Machine breakdown	Total breakdown/month
Production ratio	Total product defect : production total
Customer claims	Total of consumer claims
Cost	The amount of electricity consumption + the amount of water usage + the number of product defects
Delivery	Total of products shipped: total order
Safety	Total of work accidents
Kaizen	Total kaizen/employee
Attendance	Total attendance : total working days
Attendance	Total attendance : total working days

In the production department, several things need to be monitored every month to find out and evaluate the performance of the production process and other supporting components that affect goods hangers/hours/employees, loading hangers/hours, overall equipment effectiveness, machine breakdown. Quality is part the most important part of a process because will influence satisfaction customer. Good quality could accepted by customers so that suitability products and complaints from customers could minimized. For know performance quality product, necessary conducted monitoring good product, claims customer. Costs included in the company's losses include losses due to machine breakdown, adjustments, 5S work done, empty hangers to change color, stop for a moment, empty hangers without material & replace parts. Delivery achievements as gauge measuring achievement delivery product to customer every month. Safety work becomes attention main for management. Morality is character well that should be owned by each employee so that could made size performance like kaizen, presence employee.

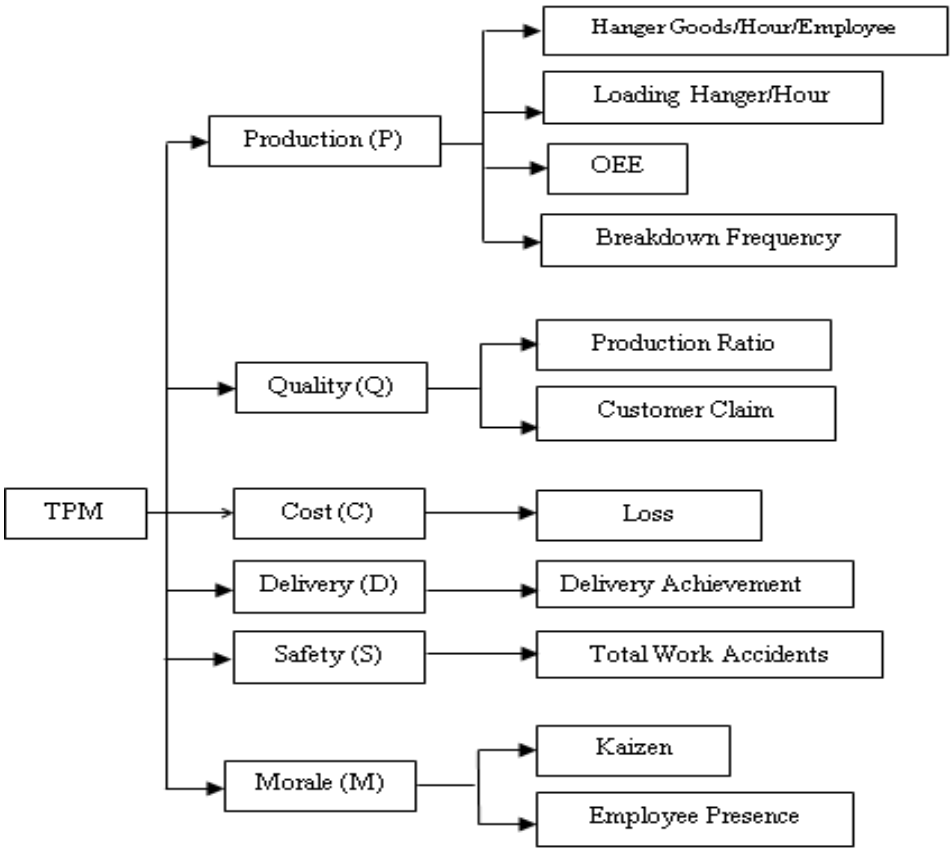

Fig. 4. TPM implementation.

3 | Result and Discussion

To find out the current performance, it is necessary to compare it with the benchmarks set by the management. Measurement systems differ from each other, some are measured monthly, but other performance is based on events within a certain period. To find out the data accurately, the analysis was carried out for 12 months. The performance of each period under the benchmark becomes the company's assessment.

After monitoring for one year, the average achievement of each component has different results. Influencing factors can come from internal and external. The average hanger good performance is from benchmark 3.4. During the first 3 months did not reach the benchmark that has been set. Several causes are influencing factors, but after entering the fourth month until the end of the month it exceeds a predetermined benchmark. The five independent variables (MF, MTF, SF, EF , and ORF) have a direct and significant effect on the implementation of TPM, three of the 5 factors are critical variables that contribute to the implementation of TPM but employee factors and other related factors do not contribute to the implementation of TPM because has a weak relationship with TPM [51].

Table 3. PQCDSM performance.

Performance	Items	Benchmarks	Month												Average
			1	2	3	4	5	6	7	8	9	10	11	12	
Production	Hanger/Hour/ employees	3,4	3,2	3,1	2,8	3,8	3,7	3,8	3,6	3,8	3,8	3,7	3,8	3,9	3,6
	Loading hanger / hour	167.8	160.8	156.4	150.4	178.8	170.8	163.3	158.5	162.5	169,2	162.4	162.0	169.7	163.7
	OEE	67.20%	65.68%	63.22%	65.60%	65.10%	69.09%	62.20%	61.50%	73.00%	70.50%	74.80%	75.60%	78.00%	68.58%
	Breakdown machine frequency	1	0	0	1	0	0	0	0	0	0	0	0	0	0.1
	Production ratio	95.73%	91.75%	90.36%	94.41%	96.00%	97.74%	96.45%	97.24%	95.17%	94.85%	96.42%	97.80%	98.10%	95.5%
Quality	Customer claims	1007	750	906	1002	1071	560	415	444	690	731	564	380	332	653.8
Cost	Total cost	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,173	IDR 539,697,172.8
Delivery	Delivery achievements	98.18%	97.97%	98.07%	99.08%	99.08%	98.52%	99.01%	98.06%	99.43%	98.50%	98.24%	99.10%	99.80%	98.74%
Safety	Work accidents	2	0	0	1	0	0	0	0	0	0	0	0	0	0.1
	Kaizen	3.76	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4,5
Morality	Employee attendance	90.00%	86.01%	94.36%	93.71%	95.14%	95.48%	96.67%	94.75%	94.59%	96.25%	95.88%	96.70%	97.10%	94.72%

The average achievement of each component has different results because it is caused by several factors, both internal and external. The average good achievement of the benchmark is 3.4. During the first 3 months did not reach the benchmark that has been set. Several causes become influencing factors, but after entering the fourth month until the end of the month it exceeds the predetermined benchmark. Five independent variables (MF, MTF, SF, EF, and ORF) have a direct and significant effect on TPM implementation, three of the 5 factors are critical variables that contribute to TPM implementation but employee factors and other related factors do not contribute to TPM implementation because they have weak association with TPM [51].

3.1 | Production (P)

Painting production process, the hanger is one of the variables that affect the amount of production. The performance of Hangers/hours/employee in the last few months has increased, this is due to the better implementation of TPM. The average hanger increase over the year averaged 3.6 from the benchmark 3.4 per hour per employee.

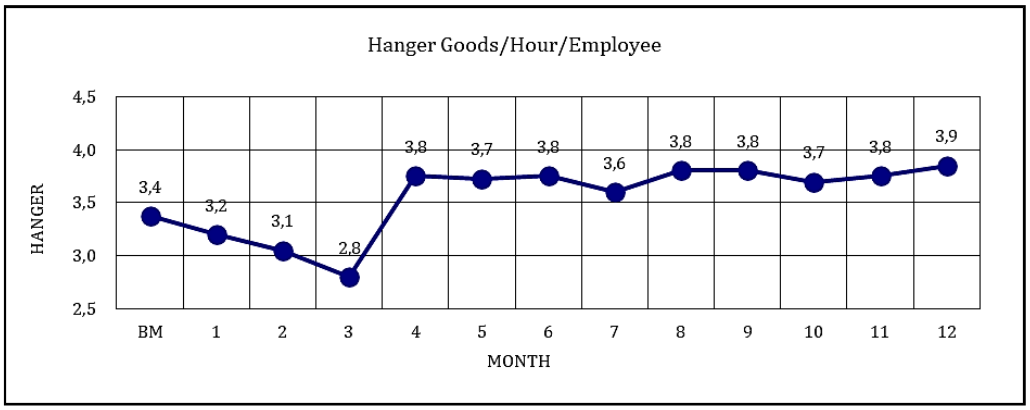

Fig. 5. Hanger graph.

In addition to hangers, the achievement of hanger loading needs to be monitored as a control for product achievement after painting. The hanger achievement was slightly different and decreased by 4.1, although when compared to the previous year, the hanger charge level was higher, the discrepancy experienced an increase which affected the amount charged. The cause of non-standard and dirty hangers is due to continuous use of these hangers without a continuous cleaning schedule.

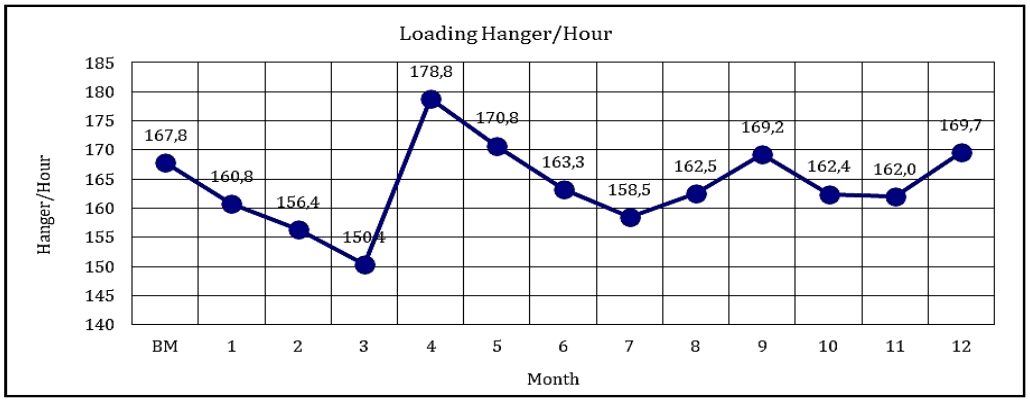

Fig. 6. Loading hanger graph.

The hanger is damaged/non-standard causing the product to be placed on the hanger during the painting process to be uneven/striped or if the hanger is dirty it can result in product contamination. Autonomous is part of the TPM implementation, with this implementation, operators can carry out maintenance independently. Autonomous applications can reduce time wastage, because autonomous operators can

keep the machine functioning properly so it doesn't interfere with the production process. Research shows that the fuzzy approach can be used effectively to provide machine reliability analysis [52].

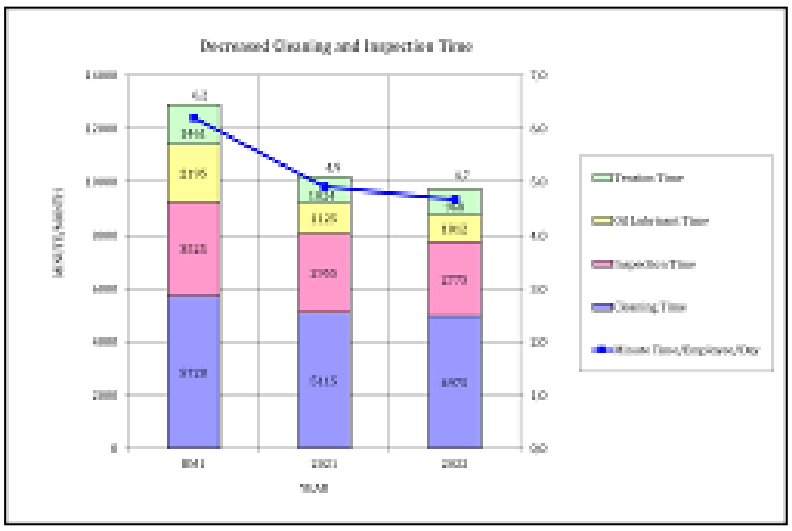

Fig. 7. Autonomous maintenance.

Component painting service company automotive line crankcase perform cleaning, lubrication, and inspection which is part of autonomous maintenance and 5S activities for detect mismatch, so that in one year there is only one breakdown.

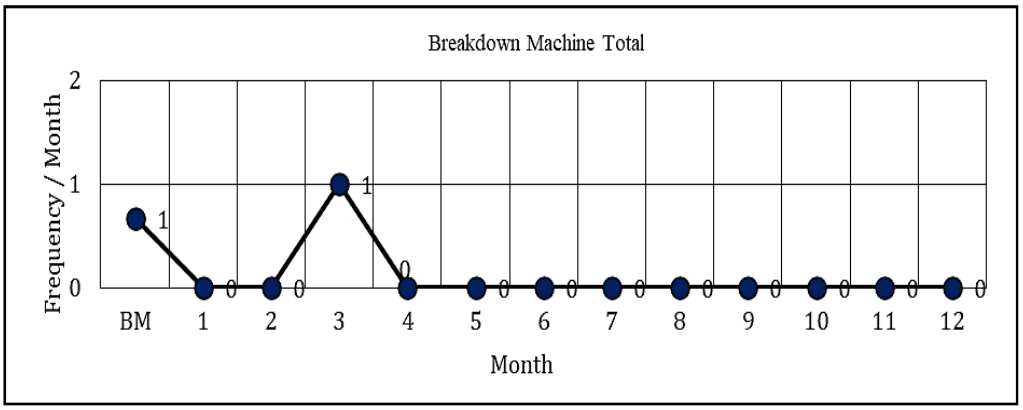

Fig. 8. Machine breakdown.

The impact of implementing autonomous maintenance which is part of the TPM implementation has increased OEE achievement even though it has not shown a significant increase. The TPM implementation can be used to perform identification loss in a manner systematic regarding maintenance and improvement targets performance company manufacture [53]. TPM implementation has produce the increase in OEE in a few months, the average OEE achievement was 68.7% if compared with benchmarks year previously by 67.2%.

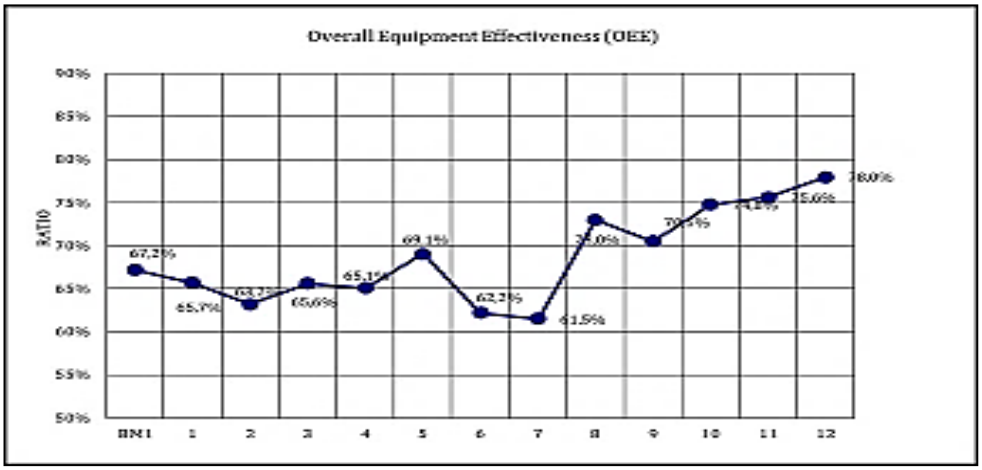

Fig. 9. OEE achievements.

3.2 | Quality (Q)

Ratio painting production is ratio total product disabled to total production. Production defects occur due to several factors, if production increases on hanger ok then production achievement increases, besides that masking affects product quality. Continuous masking need noticed, by carrying out regular checks and maintenance periodically. Masks that are used continuously continuously could causing buildup crust and raise contamination dirty on the product because flakes or details dust from the crust dry could stick to the product. Cleaning process with soak masking using ingredients chemistry/removal so that the crust is attached could peeled off and cleaned return so that ready to use.

Fig. 10. Production hanger.

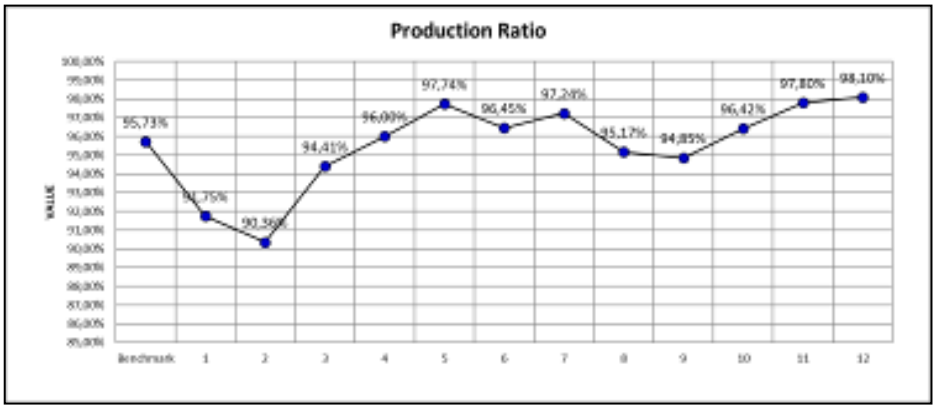

Fig. 11. Production ratio.

Even though the graphic trend of customer claims fluctuated in 1 year, the average for 1 year, especially in the last 4 months, has continued to decline. As shown in the following graph, in December it was 332 ppm and the average for 1 year was 653.8 ppm, a decrease of 353.2 ppm.

Fig. 12. Customer claims.

3.3 | Cost (C)

Cost is shape waste because issued without produce profit. In a few months final shown in the table that costs incurred experience decline. Decline happen because OEE increase, decrease breakdown machines, and patrol activities 5S every 2 weeks once.

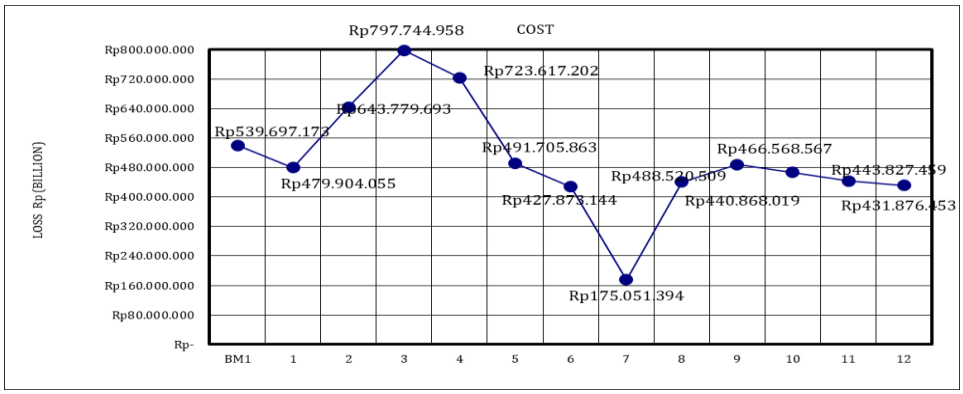

Fig. 13. Cost (electricity, water, gas, defects).

3.4 | Delivery (D)

Delivery is the final process that will be sent to the customer. The customer receives the finished product according to specifications. Deliveries achieved increased due to reduced wastage and product defects. The average increase occurred because TPM implementation was able to run effectively.

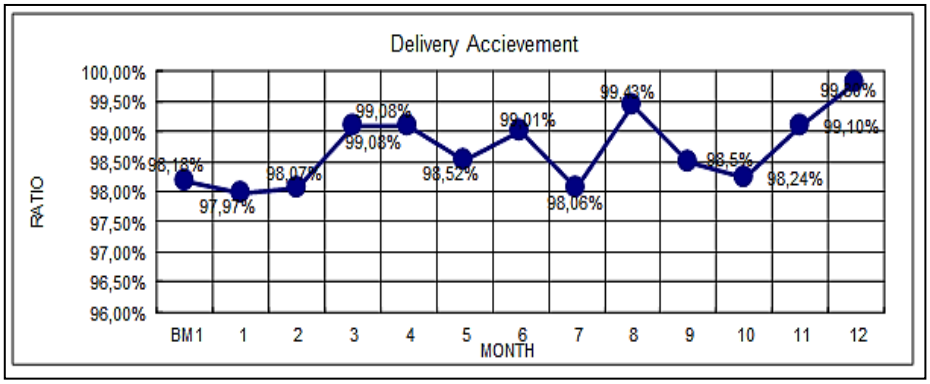

Fig. 14. Achievement of delivery.

3.5 | Safety (S)

Safety be part of the TPM measurement that must be monitored, controlled, and need more attention. In application safety and health work, one the study is integrate IATF and SMK3 requirements use 5S methodology with compare performance maintenance, safety and quality as well as interaction Among both of them keduanya [54]. Prioritize safety is the slogan in each company, 5S is part of safety, implementing 5S in period long could increase performance company manufacturing, standardization and policies that are carried out consistently can improve safety and efficiency [55]. Improving work culture by implementing a periodic schedule on each pillar has a significant effect on improving work safety.

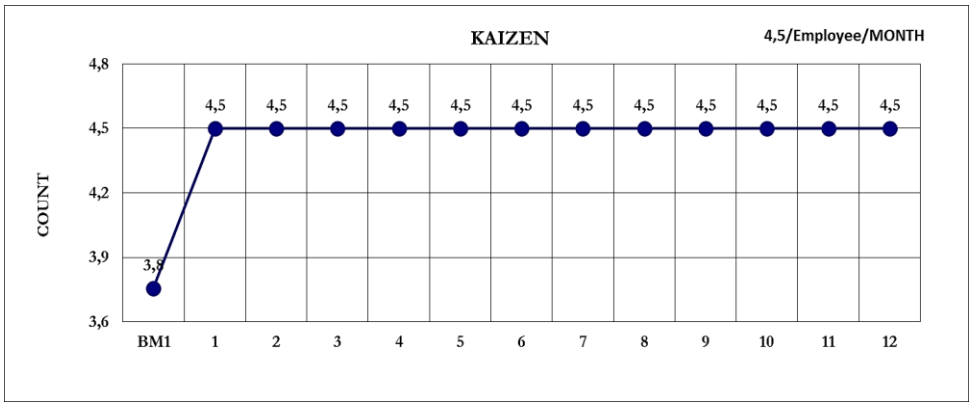

Fig. 15. Work accidents.

3.6 | Morale (M)

Moral performance includes kaizen recommendations and employee absences. Kaizen is implemented by all levels from operators to management. The types of kaizen that can be carried out by employees are all discrepancies that are in the company area, from the simplest and can be corrected immediately to those that require time to make improvements.

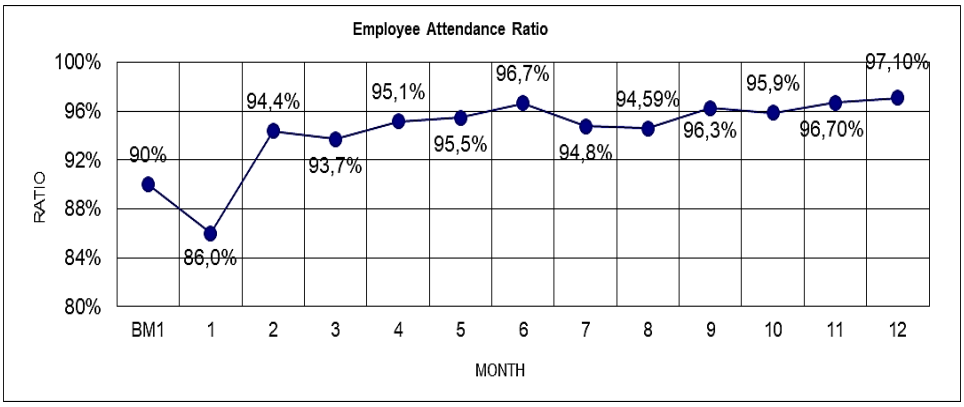

Fig. 16. Employee attendance.

Employee absenteeism is the performance of each department. Each presence and absence whether in the form of illness, permission or without explanation will affect the percentage value of the attendance. This is part of the morale that must be maintained by every employee.

Fig. 17. Kaizen suggestions.

4 | Conclusion

Several studies have concluded that the implementation of TPM can improve company performance. One of the results of TPM implementation studies is successful when the organization and all employees are committed together, changing the mindset that maintaining assets or inventory is part of sharing repairs and maintenance prevention is a key factor for the success of TPM [56]. The implementation of TPM affects the performance of two-wheeled vehicle component coating companies, as can be seen from the achievements of the last few months. An increase in the production ratio affects quality, cost, delivery and delivery which as a whole has a positive impact on improving company performance. In the production of painting automotive components, there was an average increase in the number of hangers by 0.2 compared to the previous year's benchmark. The loading hanger decreased by 4.1 although the decrease in effectiveness was higher because there was a good increase in the hanger after removing the hanger which was closer to the time of use and periodic maintenance.

References

[1] Adesta, E. Y., Prabowo, H. A., & Agusman, D. (2018). Evaluating 8 pillars of Total Productive Maintenance (TPM) implementation and their contribution to manufacturing performance. In *IOP conference series: materials science and engineering* (Vol. 290, No. 1, p. 012024). IOP Publishing. DOI: 10.1088/1757-899X/290/1/012024

[2] Amorim, G., Hatakeyama, K., & Rojas-Lema, X. (2019). Implantation of total productive maintenance: a case study in the manufacturing industry. In *New global perspectives on industrial engineering and management* (pp. 259–267). Springer. DOI: 10.1007/978-3-319-93488-4_29

[3] Majumdar, S. N. & G. (2017). Enhancement of overall equipment effectiveness using total productive maintenance in a manufacturing industry. *International journal of performability engineering*, *13*(2), 173–188.

[4] Shams, A. T., Rabby, F., & Istiak, N. (2019). Development of a maintenance schedule plan to improve the equipment efficiency of an industry : a case study. *International journal of research in industrial engineering*, *8*(2), 140–157. DOI:10.22105/riej.2019.174907.1082

[5] Nallusamy, S. (2016). Enhancement of productivity and efficiency of CNC machines in a small scale industry using total productive maintenance. *International journal of engineering research in africa*, *25*, 119–126. DOI:10.4028/www.scientific.net/JERA.25.119

[6] Stadnicka, D., & Antosz, K. (2018). Overall equipment effectiveness: analysis of different ways of calculations and improvements. *In lecture notes in mechanical engineering* (pp. 45–55). Poland: springer international publishing AG 2018. DOI: 10.1007/978-3-319-68619-6_5

[7] Supriyati, & Hardi Purba, H. (2019). TPM implementation in automotive component manufacturing companies to analyze efficiency injection machine. *Journal of applied research on industrial engineering*, *6*(4), 294–313. DOI:10.22105/jarie.2020.208271.1112

[8] Nallusamy, S., Kumar, V., Yadav, V., Prasad, U. K., & Suman, S. K. (2018). Enhance the overall equipment effectiveness. *International journal of mechanical and production*, *8*(1), 1027–1038.

[9] Sahoo, S. (2018). An empirical exploration of TQM, TPM and their integration from Indian manufacturing industry. *Journal of manufacturing technology management*, *29*(7), 1188–1210. DOI:10.1108/JMTM-03-2018-0075

[10] Sahoo, S. (2019). Assessment of TPM and TQM practices on business performance: a multi-sector analysis. *Journal of quality in maintenance engineering*, *25*(3), 412–434. DOI:10.1108/JQME-06-2018-0048

[11] Sharma, R. (2018). The impact of total productive maintenance on key performance indicators (PQCDSM): a case study of automobile manufacturing sector. *International journal productivity and quality management*, *24*(2), 267–283. https://doi.org/10.1504/IJPQM.2018.091794

[12] Ighravwe, D. E., & Oke, S. A. (2020). Sustenance of zero-loss on production lines using Kobetsu Kaizen of TPM with hybrid models. *Total quality management & business excellence*, *31*(1–2), 112–136. DOI:10.1080/14783363.2017.1415754

[13] Hama Kareem, J. A., & Hama Amin, O. A. Q. (2017). Ethical and psychological factors in 5S and total productive maintenance. *Journal of industrial engineering and management*, *10*(3), 444. DOI:10.3926/jiem.2313

[14] Krachangchan, K., & Thawesaengskulthai, N. (2018). Loss time reduction for improve overall equipment effectiveness (OEE). *2018 5th international conference on industrial engineering and applications (ICIEA)* (pp. 396–400). IEEE. DOI: 10.1109/IEA.2018.8387132

[15] Thorat, R., & Mahesha, G. T. (2020). Improvement in productivity through TPM implementation. *Materials today: proceedings*, *24*, 1508–1517. DOI:10.1016/j.matpr.2020.04.470

[16] Shojaei, M., Ahmadi, A., & Shojaei, P. (2019). Implementation productivity management cycle with operational Kaizen approach to improve production performance (case study: Pars Khodro company). *International journal for quality research*, *13*(2), 349–360. DOI:10.24874/IJQR13.02-07

[17] Madewell, M. (2018). *Total productive maintenance*. https://www.sae.org/publications/technical-papers/content/982092/

[18] Shen, C. C. (2015). Discussion on key successful factors of TPM in enterprises. *Journal of applied research and technology*, *13*(3), 425–427. DOI:10.1016/j.jart.2015.05.002

[19] Dieste, M., Panizzolo, R., & Garza-Reyes, J. A. (2020). Evaluating the impact of lean practices on environmental performance: evidences from five manufacturing companies. *Production planning & control*, *31*(9), 739–756. DOI:10.1080/09537287.2019.1681535

[20] Schindlerová, V., Šajdlerová, I., Michalčík, V., Nevima, J., & Krejčí, L. (2020). Potential of using TPM to increase the efficiency of production processes. *Tehnički vjesnik*, *27*(3), 737-743.

[21] Suryaprakash, M., Gomathi Prabha, M., Yuvaraja, M., & Rishi Revanth, R. V. (2020). Improvement of overall equipment effectiveness of machining centre using tpm. *Materials today: proceedings*, *46*, 9348-9353. DOI:10.1016/j.matpr.2020.02.820

[22] Hailu, H. (2018). An integrated continuous improvement model of TPM, TPS and TQM for boosting profitability of manufacturing industries: an innovative model & guideline. *Management science letters*, *8*(1), 33–50. DOI:10.5267/j.msl.2017.11.002

[23] Mouzani, I. A. L., & Bouami, D. (2019). The integration of lean manufacturing and lean maintenance to improve production efficiency. *International journal of mechanical and production engineering research and development (IJMPERD)*, *9*(1), 593–604.

[24] Khalfallah, M., & Lakhal, L. (2020). The impact of lean manufacturing practices on operational and financial performance: the mediating role of agile manufacturing. *International journal of quality & reliability management*, *38*(1), 147–168. DOI:10.1108/IJQRM-07-2019-0244

[25] Dhiravidamani, P., Ramkumar, A. S., Ponnambalam, S. G., & Subramanian, N. (2018). Implementation of lean manufacturing and lean audit system in an auto parts manufacturing industry – an industrial case study. *International journal of computer integrated manufacturing*, *31*(6), 579–594. DOI:10.1080/0951192X.2017.1356473

[26] Marodin, G. (2019). Lean production and operational performance in the Brazilian automotive supply chain. *Total quality management and business excellence*, *30*(3), 370–385. DOI:10.1080/14783363.2017.1308221

[27] Schiraldi, M. M., & Varisco, M. (2020). Overall equipment effectiveness: consistency of ISO standard with literature. *Computers & industrial engineering*, *145*(2019), 106518. DOI:10.1016/j.cie.2020.106518

[28] Tsarouhas, P. (2019). Improving operation of the croissant production line through overall equipment effectiveness (OEE). *International journal of productivity and performance management*, *68*(1), 88–108. DOI:10.1108/IJPPM-02-2018-0060

[29] Chong, K. E., Ng, K. C., & Goh, G. G. G. (2015). Improving overall equipment effectiveness (OEE) through integration of maintenance failure mode and effect analysis (maintenance-FMEA) in a semiconductor manufacturer: a case study. *In 2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM) (pp. 1427-1431). IEEE.* DOI: 10.1109/IEEM.2015.7385883

[30] Díaz-Reza, J., García-Alcaraz, J., Avelar-Sosa, L., Mendoza-Fong, J., Sáenz Diez-Muro, J., & Blanco-Fernández, J. (2018). The role of managerial commitment and TPM implementation strategies in productivity benefits. *Applied sciences*, *8*(7), 1153. DOI:10.3390/app8071153

[31] Singh, J., Singh, H., Sharma,V. (2017). Success of TPM concept in a manufacturing unit- a case study. *International journal of productivity and performance management*, *67*(3). https://www.emerald.com/insight/content/doi/10.1108/IJPPM-01-2017-0003/full/html

[32] Ahmad, N., Hossen, J., & Ali, S. M. (2018). Improvement of overall equipment efficiency of ring frame through total productive maintenance: a textile case. *The international journal of advanced manufacturing technology*, *94*(1–4), 239–256. DOI:10.1007/s00170-017-0783-2

[33] Sutoni, A., Setyawan, W., & Munandar, T. (2019). Total productive maintenance (TPM) analysis on lathe machines using the overall equipment effectiveness method and six big losses. *Journal of physics: conference series*, *1179*, 1-7. DOI:10.1088/1742-6596/1179/1/012089

[34] Sharma, R. (2019). Overall equipment effectiveness measurement of TPM manager model machines in flexible manufacturing environment : a case study of automobile sector. *International journal productivity and quality management*, *26*(2), 206–222.

[35] Mahmoud, I. A., Fahmyaly, M., Mohib, A., & Afefy, I. H. (2019). Integration of benchmarking with overall equipment cost loss for industrial process improvement. *Jordan journal of mechanical and industrial engineering*, *13*(1), 49–59.

[36] Nurprihatin, F., Angely, M., & Tannady, H. (2019). Total productive maintenance policy to increase effectiveness and maintenance performance using overall equipment effectiveness. *Journal of applied research on industrial engineering*, *6*(3), 184–199. https://doi.org/10.22105/jarie.2019.199037.1104

[37] Supriyati, Wiyatno Tri Ngudi, & Darmawan Heru. (2021). Peningkatan produksi plastik injection dengan analisis overall equipment effectiveness dan single minute exchange of dies (increase of plastic injection production using overall equipment effectiveness and single minute exchange of dies analysis). *Operations excellence: journal of applied industrial engineering*, *2021*(3), 394–406.

[38] Pascu, C. I., Dumitru, I., Gheorghe, S., & Nisipasu, M. (2018). Implementation of total productive maintenance principles for quality improvement in an automotive company. *Applied mechanics and materials*, *880*, 171–176. DOI:10.4028/www.scientific.net/AMM.880.171

[39] Smętkowska, M., & Mrugalska, B. (2018). Using six sigma DMAIC to improve the quality of the production process: a case study. *Procedia - social and behavioral sciences*, *238*, 590–596. DOI:10.1016/j.sbspro.2018.04.039

[40] Annamalai, S. (2019). Implementation of total productive maintenance for overall equipment effectiveness improvement in machine shop. *International journal of recent technology and engineering*, *8*(3), 7686–7691. DOI:10.35940/ijrte.C6212.098319

[41] Ng, C., Enrique, M., & Korner, H. (2020). Applied sciences overall equipment e ff ectiveness : systematic literature review and overview of different approaches. *Applied sciences*, *10*(18). https://doi.org/10.3390/app10186469

[42] Candra, N. E., Susilawati, A., Herisiswanto, & Setiady, W. (2017). Implementation of total productive maintenance (TPM) to improve sheeter machine performance. *MATEC web of conferences*, *135*, (00028). DOI:10.1051/matecconf/201713500028

[43] Pramod, V. R., Devadasan, S. R., Muthu, S., Jagathyraj, V. P., & Dhakshina Moorthy, G. (2006). Integrating TPM and QFD for improving quality in maintenance engineering. *Journal of quality in maintenance engineering*, *12*(2), 150-171.

[44] García-Alcaraz, J. L., Montalvo, F. J. F., Sánchez-Ramírez, C., Avelar-Sosa, L., Saucedo, J. A. M., & Alor-Hernández, G. (2019). Importance of organizational structure for TQM success and customer satisfaction. *Wireless networks*, *5*. DOI:10.1007/s11276-019-02158-5

[45] Ahmad, M. F., Zamri, S. F., Ngadiman, Y., Chan, S. W., Abdul Hamid, N., Ahmad, A. N. A., ... & Abdul Rahman, N. A. (2019). The impact of total productive Maintenance (TPM) as mediator between Total Quality Management (TQM) and business performance. *International journal of supply chain management (IJSCM)*, *8*(1), 767-771. https://core.ac.uk/download/pdf/230752082.pdf

[46] Gupta, P., & Vardhan, S. (2016). Optimizing OEE, productivity and production cost for improving sales volume in an automobile industry through TPM: a case study. *International journal of production research*, *54*(10), 2976–2988. DOI:10.1080/00207543.2016.1145817

[47] Hassani, L. (2004). Ladan hassani the impact of overall equipment effectiveness on production losses in moghan cable & WIRE, *9*(4), 565–576.

[48] Maszke, A. (2019). TPM safety impact–case study. *System safety: human - technical facility - environment*, *1*(1). 639 - 646. https://doi.org/10.2478/czoto-2019-0081

[49] Shankul, V., & Buke, Y. (2019). Relationship of 5S, TPM and SMS to enhance safety performance of manufacturing industry. *Journal of industrial safety engineering*, *6*(2),1-13.

[50] Habidin, N. F., Hashim, S., Fuzi, N. M. & Salleh, M. I. (2018), (2017). Total productive maintenance , kaizen event , and performance. *International journal of quality & reliability management*, *35*(9), 1853-1867. https://doi.org/10.1108/IJQRM-11-2017-0234

[51] Woldesilassie, T. L., & Ivatury, V. M. K. (2020). Critical success variables influencing implementation of total productive maintenance. *International journal on emerging technologies*, *11*(3), 942–947.

[52] Li, Y. F., Huang, H. Z., Liu, Y., Xiao, N., & Li, H. (2012). A new fault tree analysis method: fuzzy dynamic fault tree analysis. *Eksploatacja i niezawodnosc*, *14*(3), 208–214.

[53] Singh, J., & Singh, H. (2020). Justification of TPM pillars for enhancing the performance of manufacturing industry of Northern India. *International journal of productivity and performance management*, *69*(1), 109–133. DOI:10.1108/IJPPM-06-2018-0211

[54] Pačaiová, H., & Ižaríková, G. (2019). Base principles and practices for implementation of total productive maintenance in automotive industry. *Quality innovation prosperity*, *23*(1), 45. DOI:10.12776/qip.v23i1.1203

[55] Singh, A., & Ahuja, I. S. (2015). Review of 5S methodology and its contributions towards manufacturing performance. *International journal of process management and benchmarking*, *5*(4), 408. DOI:10.1504/IJPMB.2015.072320

[56] Szczepaniak, M., & Trojanowska, J. (2020). Preventive maintenance system in a company from the printing industry. In *Lecture notes in mechanical engineering* (pp. 351–358). DOI: 10.1007/978-3-030-22365-6_35