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A NEW SCORING APPROACH TO CALCULATE OVERALL EQUIPMENT EFFICIENCY: A CASE STUDY*

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ABSTRACT

Purpose: The aim of the study is to compare and analyze Overall Equipment Efficiency (OEE) and Total Effective Equipment Performance (TEEP) metrics, identify deficiencies and suggest a new and usable OEE calculation methodology for a manufacturing company.

Methodology: The results of OEE, TEEP, and the proposed method were compared in a faucet production company in Turkey. The defined scorings were used to maintain the structure of the OEE focused on losses, and the TEEP metric was used to include planned downtimes in the proposed method.

Findings: According to the results of the study, the proposed metric broaden the structure of OEE that focuses solely on equipment, while maintaining its structure that focuses on losses.

Originality: No other study has been found in the literature that compares OEE and TEEP metrics over the same production data, and then focuses on the strengths of the two metrics and proposes a new method. It is predicted that the study will fill this gap in the literature and will be a guide for the development of different new metrics.

Keywords: Total Productive Maintenance, Overall Equipment Efficiency, Total Effective Equipment Performance.

JEL Codes: D20, D24, M11.

GENEL EKİPMAN VERİMLİLİĞİNİ HESAPLAMAK İÇİN YENİ BİR PUANTAJ YAKLAŞIMI: BİR VAKA ÇALIŞMASI

ÖZET

Amaç: Çalışmanın amacı, Genel Ekipman Verimliliği (GEV) ve Toplam Efektif Ekipman Performansı (TEEP) metriklerini karşılaştırmak ve analiz etmek, eksiklikleri belirlemek ve bir üretim işletmesinde yeni ve kullanılabilir GEV hesaplama metodolojisini önermektir.

***Yöntem*:** Türkiye'de bir armatür üretim işletmesinde GEV, TEEP ve önerilen metod uygulanarak sonuçları karşılaştırılmıştır. GEV'in kayıplara odaklanan yapısını korumak için tanımlanan puantajlar kullanılmış, planlı duruş sürelerinin önerilen metoda dahil edilmesi için ise TEEP metriğinden yararlanılmıştır.

Bulgular: Çalışmanın sonuçlarına göre, önerilen metrik, GEV'nin sadece ekipmana odaklanan yapısını genişletirken, kayıplara odaklanan yapısını ise korumaktadır.

Özgünlük: Literatürde aynı üretim verileri üzerinden GEV ve TEEP metriklerini karşılaştırıp, devamında iki metriğin güçlü yönlerine odaklanarak yeni bir metot öneren başka bir çalışmaya rastlanmamıştır. Çalışmanın literatürdeki bu eksikliği dolduracağı ve farklı metriklerin geliştirilmesi için de yol gösterici olacağı öngörülmektedir.

Anahtar Kelimeler: Toplam Verimli Bakım, Genel Ekipman Verimliliği, Toplam Efektif Ekipman Performansı.

JEL Kodları: D20, D24, M11.

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1. INTRODUCTION

Lean manufacturing is a philosophy evaluated under the Toyota Production System (TPS), which aims to create value by responding better to the needs and demands of customers. For this purpose, lean manufacturing aims to develop an ideal manufacturing process in which all activities that do not create value for customers are eliminated (Abdallah, 2021). Among the various lean tools, this research focuses on OEE, the performance metric that compares the theoretical potential of an equipment with its actual performance, enabling the determination of hidden losses (Wojakowski, 2015). The main contribution of OEE can only be seen when it is part of TPM as well as lean production. TPM focuses on preventing breakdowns and delays of all equipment used in manufacturing processes to provide perfect working conditions. In addition, TPM activities also involve preventing small stoppages, slow running, defects and ensuring a safe production environment (Rahman, 2015). The TPM includes three related activities: Autonomous maintenance, small group activities and efforts to maximize equipment efficiency (Nakajima, 1988: 106-109).

OEE is a method used for defining equipment efficiency under the TPM philosophy (Bon and Lim, 2015). Moreover, OEE can be defined by the combination of maintenance, equipment management and available resources (Chan et al., 2005). OEE is a simple and clear overall measurement tool. Therefore, executives would prefer this comprehensive method rather than complex and detailed other methods (Huang et al., 2003). Using OEE also has numerous benefits such as measuring the productivity of facilities, identifying the reasons for stoppages and losses, monitoring production quality and performance and determining the precedence of improvement activities (Çayır and Yanmaz, 2005). Reaching the targeted OEE results increase profit, attain a competitive edge, identify equipment ownership and reducing expenses (Stamatis, 2017: 21). The OEE was firstly introduced by Nakajima (1988: 21-29) and standards for the definition and measurement of OEE was established by Semiconductor Equipment and Materials International (SEMI). Nowadays, the industrial application of OEE varies from one sector to another. Although the basis for measuring efficiency is derived from the original OEE concept, manufacturers have to customize OEE to suit their specific industrial requirements (Munchiri and Pintelon, 2008). Hence, the control of OEE is not always simple, and many industrial applications still involve many challenges (De Ron and Rooda 2006; Braglia et al. 2008).

According to Ljungberg (1998), OEE cannot take into consideration all the factors that decrease capacity utilisation (lack of labour, lack of material input, planned downtime etc.). Similarly, Jeong and Phillips (2001) showed that the standard calculation methodology of OEE is not appropriate for capital intensive industries. Because there is a need to account for additional causes of losses such as holidays, off-shifts and preventive / planned maintenance. Therefore, it is believed in the literature that it would be more useful to base the total time as opposite to the original OEE structure. On the other hand, there are some problems when collecting the necessary data for efficiency analysis when it is needed to adapt the OEE's losses classification structure to comply with certain industrial requirements (Zammori et al., 2011).

The objective of this paper is to analyze the OEE structure and compare with TEEP metric in order to identify deficiencies and suggest a new and usable OEE calculation methodology to a manufacturing company. The proposed OEE structure must be able to easily adapt to the needs of different sectors. In addition, the structure of the existing performance metric, which focuses only on the equipment, should be expanded. In other words, it is aimed to expand the structure that focuses on equipment level efficiency (original OEE) to operational level efficiency (recommended method).

The remainder of this study is organized as follows: The second section is on the literature review of TPM and OEE. The following section consists of information about the methodology of the study. The next section includes the introduction of the company in which the case study was carried out, sources of data and variables and comparison of the existing productivity calculation method with its alternative ones. The last part concludes with information about results, interpretations and policy proposals.

2. LITERATURE REVIEW

Maintenance is one of the important activities in manufacturing workshops. Failures of machines during production may have negative effects on the production schedule, delay delivery or overtime to compensate employees for production losses (Habidin et al., 2018). Despite the investments of enterprises in lean production programs, with the unreliability and inflexible structures of machinery and equipment, the benefits of lean manufacturing are limited (Tajiri and Gotoh, 1992: 37). Businesses that saw maintenance as a source of expense had in the past used equipment until it broke down and then repaired it. But over time, this reactive maintenance was replaced by new maintenance theories: Preventive Maintenance and Productive Maintenance. Introduced in Japan in the 1950s, these theories aim to prevent equipment failure in advance with continuous maintenance work (McKone and Weiss, 1998). In response to the concept of "I operate it, you fix it", Seiichi Nakajima, vice president of the Japanese Institute of Plant Maintenance (JIPM), developed TPM in 1971. TPM aims to provide a company-wide maintenance management approach with the participation of all employees (Fernandez, 2016).

TPM is applied in diverse industries so TPM has several different definitions. However, according to the most comprehensive definition, TPM aims to maximize the efficiency of production systems by applying it in all units from production to administrative departments. To realize zero accidents, zero failures and zero defects in the entire life cycle of production systems, it needs the participation of all employees and achieves zero losses through overlapping small group activities (Shirose, 2002: 11). The key word in “total productive maintenance” is “total” not “maintenance”. Total has three meanings in TPM. These are total effectiveness, total participation and total preventive maintenance. (Nakajima, 1988:11).

TPM minimizes the probability of equipment failure, improper production and safety accidents (Patil and Raut, 2019). Other benefits include increased productivity and employee output (Ali, 2019), reduction in overtime and absences (Xiang and Feng, 2021), reduced changeover time (Bon and Lim, 2015), increased confidence (Maran et al., 2016), increased maintenance ability (Singh and Ahuja, 2015; Xiang and Feng, 2021). TPM is not a specific maintenance policy; it constitutes a culture, a philosophy, a new way of thinking for employees (Ahuja et al., 2006). Cultural change covers all units from senior management to operators by emphasizing the importance of implementing TPM methods and setting policies and targets related to the implementation stages (Meca Vital ve Camello Lima, 2020).

Arguably, TPM is multi-faceted and structured in eight pillars (Hatipoğlu, 2016), as shown in Figure 1. Namely autonomous maintenance, focused improvement, planned maintenance, quality maintenance, education and training, early equipment management, office TPM, safety - health and environment. However, the number of these pillars may vary according to the industrial needs of enterprises (Chong et al., 2012; Madanhire et al., 2018). The pillars have separate duties and responsibilities in the TPM philosophy and keep the whole TPM process alive, just like the conveyor walls in the structure of a house. Therefore, this structure can also be named as TPM house (Aksoy ve Hatipoğlu, 2021).

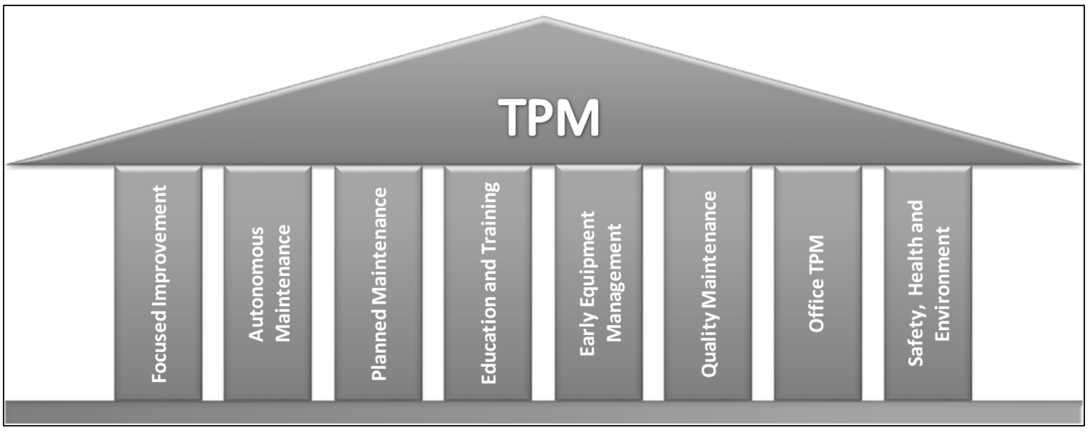

Figure 1. TPM pillars

Firstly, introduced by Seiichi Nakajima in 1988 as a tool for measuring the success of TPM, OEE is one of the widely accepted metrics in this field (Zandieh et al., 2012). OEE is the performance indicator tool to manage and monitor the equipment performance (Slaichová and Marsíková, 2013). Furthermore, the OEE assessment is not limited to evaluating production performance. The investigation of OEE provides a systematic process to easily identify sources of productivity loss for effective use of resources (Ghafoorpoor et al. 2018). Hence, faultless equipment performance data is the essential necessity for the long-term success of TPM activities. These activities cannot solve major problems and define poor performance when the causes of failures and losses are not properly understood (Ericsson, 1997). Briefly, OEE identifies the equipment potential, losses and opportunities (Stamatis, 2017: 21).

In recent decades, both practitioners and researchers have expressed many opinions about the calculation of OEE metric with new approaches. There is no doubt that the most important criticism of OEE requires custom modifications, since companies need to adapt to their typical needs and the scope and structure of OEE, which focuses only on equipment, needs to be expanded (Iannone and Nenni, 2013: 38). For instance, OEE metric does not take into account the planned downtimes such as lack of material, absence of operators or even weekend breaks that can decrease the capacity utilization (Wojakowski, 2015). This situation gives an opportunity for production supervisors to consider these losses that are not under their responsibility (Wudhikarn, 2012). Therefore, alternative methods to OEE are derived in measuring efficiencies (Muchiri and Pintelon, 2008). Among these alternatives, the TEEP method developed by Ivancic (1998) with its widespread use stands out as a step forward. OEE and TEEP are commonly used two metrics, closely related and both reporting the overall utilization of facilities, time and material for manufacturing operations. In fact, OEE and TEEP indicate the gap between the ideal and the actual performance (Slaichová and Marsíková, 2013).

When the studies on OEE in the literature are examined, it is realised that some of these studies are aimed at understanding the structure of OEE (da Costa and de Lima, 2002; De Ron and Rooda, 2005; Jeong and Phillips, 2011). Nevertheless, it is seen that the literature is dominated by OEE case studies carried out in various sectors and industries; for instance, pharmaceutical industry (Zubair et al., 2021), electronic components industry (Fam et al., 2018), automotive and engineering industry (Dal et al., 2000; Jiang et al., 2011; Šajdlerová et al., 2020), plastic processing industry (Slaichová and Marsíková, 2013), machinery industry (Xiang and Feng, 2021). Moreover, Munchiri and Pintelon (2008) conducted a literature review in order to compare different performance metrics (OEE, TEEP, Overall Factory Effectiveness, Overall Plant Effectiveness, Production Equipment Effectiveness, and Overall Asset Effectiveness). In addition, Missalla et al. (2017) and Wojakowski (2015) compared OEE and TEEP with case studies.

On the other hand, Özveri et al. (2016) tested the applicability of two different OEE approaches and compared the calculation results in the newspaper printing company. Lastly, Çelik (2020) suggested a new metric named General Operation Effectiveness to OEE in order to expand the structure of OEE. However, his suggested metric and TEEP have the same disadvantage that they cannot identify the roots of the losses. Therefore, Çelik (2020) has suggested to future studies that both planned and unplanned losses need to be examined in order to expand the boundaries of OEE as a policy proposal. Hence, no other study has been found in the literature that compares OEE and TEEP, and then eliminating the cons while protecting the pros of the two metrics and proposes a new method. It is predicted that the study will fill this gap in the literature and will be a guide for the development of different new metrics.

3. METHODOLOGY

The OEE tool is designed to identify losses that reduce the equipment effectiveness. These losses are activities which absorb resources without creating value (Fernandez, 2016). These are grouped into six big losses under the TPM philosophy. The main goal of the TPM applications is to detect these losses and remove them to maximize the OEE value. Nakajima (1988: 14) showed these big losses under three main topics as downtime losses, speed losses and defect losses (Table 1).

Table 1. Six big losses

Downtime Losses	Setup and Adjustment
	Equipment Failure
Speed Losses	Reduced Speed
	Idling and Minor Stoppages
Defect Losses	Reduced Yield
	Defects in Process

Source: Nakajima (1988: 14)

The equation of OEE was formed starting from the six big losses model. Muchiri and Pintelon (2008) indicated the effects of six big losses starting from the loading time to reach valuable operating time. This process is shown in Figure 2.

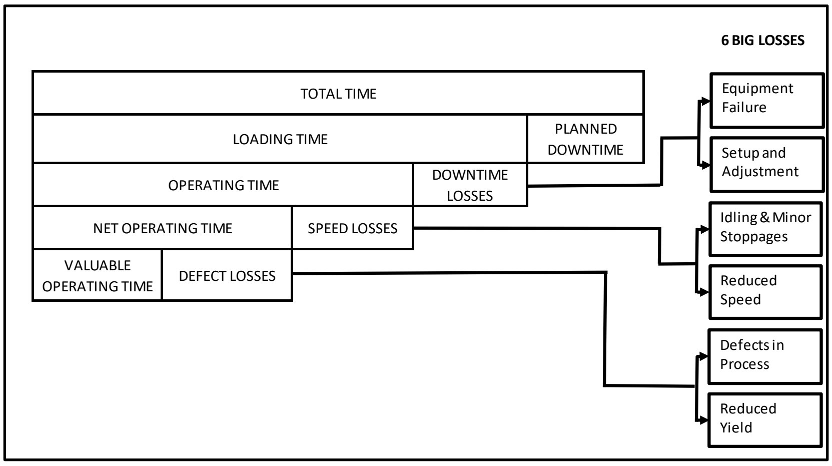

Figure 2. Allocation of six big losses under loading time

Starting from the total time; loading time, operating time, net operating time and valuable operating time can be found with Equations 1-4.

$$Loading\ Time\ =\ Total\ Time\ -\ Planned\ Downtime \quad (1)$$

$$Operating\ Time\ =\ Loading\ Time\ -\ Downtime\ Losses \quad (2)$$

$$Net\ Operating\ Time\ =\ Operating\ Time\ -\ Speed\ Losses \quad (3)$$

$$Valuable\ Operating\ Time\ =\ Net\ Operating\ Time\ -\ Defect\ Losses \quad (4)$$

These six losses are compounded in one efficiency metric and form the OEE (Chakravarthy et al., 2007). On the other hand, OEE includes the availability ratio (A), performance efficiency ratio (P) and rate of quality products (Q) (Özkan et al., 2019). The multiplication of these three components gives the OEE (Giegling et al., 1997). The equations for OEE, (A), (P), (Q) are given in Equations 5-8.

$$OEE\ =\ A\ x\ P\ x\ Q \quad (5)$$

$$A = \frac{Operating\ Time}{Loading\ Time} \quad (6)$$

$$P\ =\ \frac{Net\ Operating\ Time}{Operating\ Time}\ =\ \frac{Theorical\ Cycle\ Time\ \ x\ Processed\ Amount}{Operating\ Time} \quad (7)$$

$$Q\ =\ \frac{Valuable\ Operating\ Time}{Net\ Operating\ Time}\ =\ \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount} \quad (8)$$

OEE reveals how well a production unit is performing during the scheduled period (Zubair et al., 2021). It can be expressed as the ratio of the valuable operating time to the loading time. This metric takes into account downtime losses (unplanned downtime), speed losses and quality (defect) losses. However, the loading losses identified as planned downtime on the Figure 2, are not included in the OEE calculation. To take into account these loading losses, Ivancic (1998) introduces a new metric called Total Equipment Effectiveness Performance (TEEP). It is expressed as the ratio of the valuable operating time to the total time. TEEP reveals how well a production unit is performing during the time the factory is opened. The TEEP tool covers the OEE tool, and provides information about the impact of the scheduled maintenance on equipment effectiveness (Fernandez, 2016). OEE is used at the workshop level, while TEEP is used by production managers to design maintenance strategies (Muchiri and Pintelon, 2008).

To sum up, both planned downtimes and downtime losses are added to the performance measurement in the TEEP metric. Furthermore, the other components of the TEEP metric are speed rate and quality rate, the same as with performance efficiency ratio and rate of quality products on OEE. TEEP can be found with Equations 9-12. (Hansen, 2001; Jiang et al., 2011).

$$TEEP\ =\ Asset\ Utilization\ x\ Speed\ Rate\ x\ Quality\ Rate \quad (9)$$

$$Asset\ Utilization\ =\ \frac{Operating\ Time}{Total\ Time} \quad (10)$$

$$Speed\ Rate\ =\ \frac{Theorical\ Cycle\ Time\ \ x\ Processed\ Amount}{Operating\ Time} \quad (11)$$

$$Quality\ Rate\ =\ \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount} \quad (12)$$

Under TEEP metric, both planned and unplanned downtime losses can be added to efficiency calculation. However, issues at some points are still waiting for a solution. Firstly, faultless equipment performance data is the basic requirement for TPM activities and accuracy of OEE is based on the accuracy of the collected data (De Ron and Rooda, 2006). Secondly, OEE classifies major losses and provides the basis for the beginning of improvement priorities and root cause analysis. Moreover, the loss classification scheme largely depends on the industry type (Jeong and Phillips, 2011). Hence, manufacturers have to customize performance metric to suit their specific industrial requirements. The following part case study, shows how the proposed scoring-based approach is implemented to suit the individual needs of industries, help them to collect data and identify the losses.

4. CASE STUDY: MEASURING PRODUCTION EFFICIENCY OF A COMPANY

4.1. Introduction of Case Company

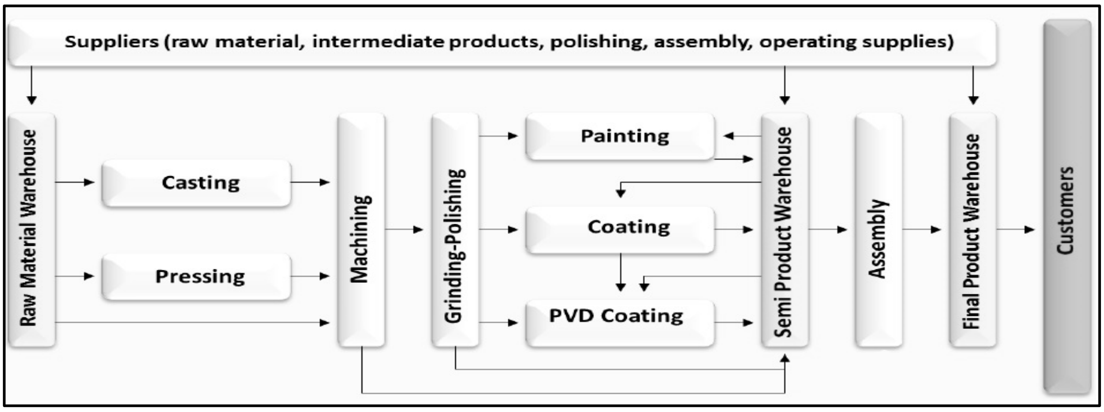

Figure 3. Production flow of facility

To compare OEE, TEEP and suggested metric, an application has been applied in a faucet production facility. The factory has roughly 480 employees and produces on a three-shift basis per day. 4 main product groups are produced as faucets, shower systems, bathroom accessories and concealed cisterns at the facility.

In company, production flow starts with supplying the raw material. Depending on the geometric shape of the product, it is processed in either the casting or pressing workshop. In the following process, machining operations are completed. Then surface operations are completed by the grinding and polishing workshop. After completing the surface operations, the product is ready for the coating processes. Products can be either painted, coated or PVD coated by the workshop. After that, the product is assembled with work-in-process materials and sent to the final product warehouse to send to the customer. The whole process is shown in Figure 3.

4.2. Data and Variables

All the productivity datas of company were collected for 12-month period in order to analyze and compare the different kinds of productivity metrics (OEE, TEEP and scoring based suggested method). In company, two systems are used to monitor and manage the OEE. These are barcode system and SAP as an ERP system. The barcode system consists of three main components: material flow forms, Data Transfer Terminals (DTT) and barcode software. The operators log the scorings of losses, production quantities, product codes etc. manually to the DTTs. The communication of barcode system and DTTs was provided by LAN connection inside the facility and the system is monitoring the production in real time. However, facility efficiencies are downloaded from barcode system and analyzed monthly.

4.3. Proposed Calculation Methodology and Comparison of Alternative Methods

To make it possible to monitor OEE in the barcode system; downtimes, losses and production were introduced to system by company. All these actions were named as a *scoring* on the barcode system. Moreover, each action has a scoring code. The scoring codes used in company are shown in Table 2.

Table 2. Scoring codes of case company

Scoring	*Code*	*Scoring*	*Code*
Adjustment	A	Revision	U
Intermediary Downtime	AD	Rework	T
Tool Unavailable	B	Pattern Waiting	Z
Operator Unavaible	C	Other Jaw Waitıng	IU
Die Heating / Idling	D	Workshop Testing	K
Energy Loss	E	Lunch Break	YY
Breakdown	F	Minor Stoppages	1F
Workbench Maintenance Cleaning	L	Oiling	Y
Material Unavailable	M	Material Loading / Unloading	1M
Production	R	Die Cleaning	H
Set Up	S	Quality Report Waiting	N

OEE calculation methodology works on loading time rather than total time. Hence, planned downtimes should be separated from the calculation. The scoring types used in company are shown in Table 3.

Table 3. Scoring types

Scoring Types	*Scoring Codes*
Production	R
Planned Downtimes	1M, C, J, L, Q, U, V, YY
Unplanned Downtimes	1F, A, AD, B, D, E, F, G, H, IU, K, M, N, S, T, X, Y, Z

The fundamental calculation structure of OEE was firstly determined by Nakajima (1989). However, applicable equations with the help of described scorings in the facility are given as Equations 13-16. OEE values are reached monthly by applying this structure to production cells, production workshops and finally throughout the facility.

$$\boldsymbol{OEE} = \frac{\boldsymbol{A\,x\,P\,x\,Q}}{\mathbf{10.000}} \tag{13}$$

$$\boldsymbol{A} = \frac{\boldsymbol{R\ Scoring}}{\boldsymbol{All\ the\ Scorings - Planned\ Downtimes}}\ \boldsymbol{x}\ \mathbf{100} \tag{14}$$

$$\boldsymbol{P} = \frac{\boldsymbol{Theorical\ Cycle\ Time\ \ x\ Processed\ Amount}}{\boldsymbol{R\ Scoring}}\ \boldsymbol{x}\ \mathbf{100} \tag{15}$$

$$\boldsymbol{Q} = \frac{\boldsymbol{Processed\ Amount - Defect\ Amount}}{\boldsymbol{Processed\ Amount}}\ \boldsymbol{x}\ \mathbf{100} \tag{16}$$

At this stage, the study implemented the TEEP in the company's efficiency forming process to include the planned downtimes in the calculation. Hence, the TEEP calculation method was harmonized with the scoring structure. Then all the company's annual efficiency outputs were organized for TEEP and recalculated. These calculations gave the opportunity to clearly observe the differences of the two methods on all annual efficiencies without using sampling. General overview of TEEP equations that customized with scorings are shown in Equations 17-20.

$$TEEP = \frac{Asset\ Utilization\ x\ Speed\ Rate\ x\ Quality\ Rate}{10.000} \tag{17}$$

$$Asset\ Utilization = \frac{R\ Scoring}{Total\ Time}\ x\ 100 \tag{18}$$

$$Speed\ Rate = \frac{Theorical\ Cycle\ Time\ \ x\ Processed\ Amount}{R\ Scoring}\ x\ 100 \tag{19}$$

$$Quality\ Rate = \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount}\ x\ 100 \tag{20}$$

TEEP aims to calculate efficiency over total time (7/24 calendar time) regardless of planned or unplanned downtime differences. However, OEE gives an opportunity to determine unplanned losses and grouped them to ensure a basis for improvement activities for inefficient units. To correct the deficiencies of both OEE and TEEP, designing the new performance measurement tool is essential for the company. The main objective of the recommended method involves using the pros of the OEE and TEEP methods and removing the cons. Hence, the first provision is to protect the focus on the losses structure of OEE. The second provision is to add planned downtimes to the calculation and broaden the scale of the method like TEEP. The new method is called *Scoring Based Overall Efficiency* (SBOE). SBOE equations are given below. (Equations 21-24).

$$SBOE = \frac{Capacity\ Utilization\ x\ Performance\ Rate\ x\ Quality\ Rate}{10.000} \quad (21)$$

$$Capacity\ U. = \frac{R\ Scoring}{R\ Scoring + Planned\ Downtimes + Unplanned\ Downtimes} x\ 100 \quad (22)$$

$$Performance\ Rate = \frac{Theorical\ Cycle\ Time\ \ x\ Processed\ Amount}{R\ Scoring}\ x\ 100 \quad (23)$$

$$Quality\ Rate = \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount}\ x\ 100 \quad (24)$$

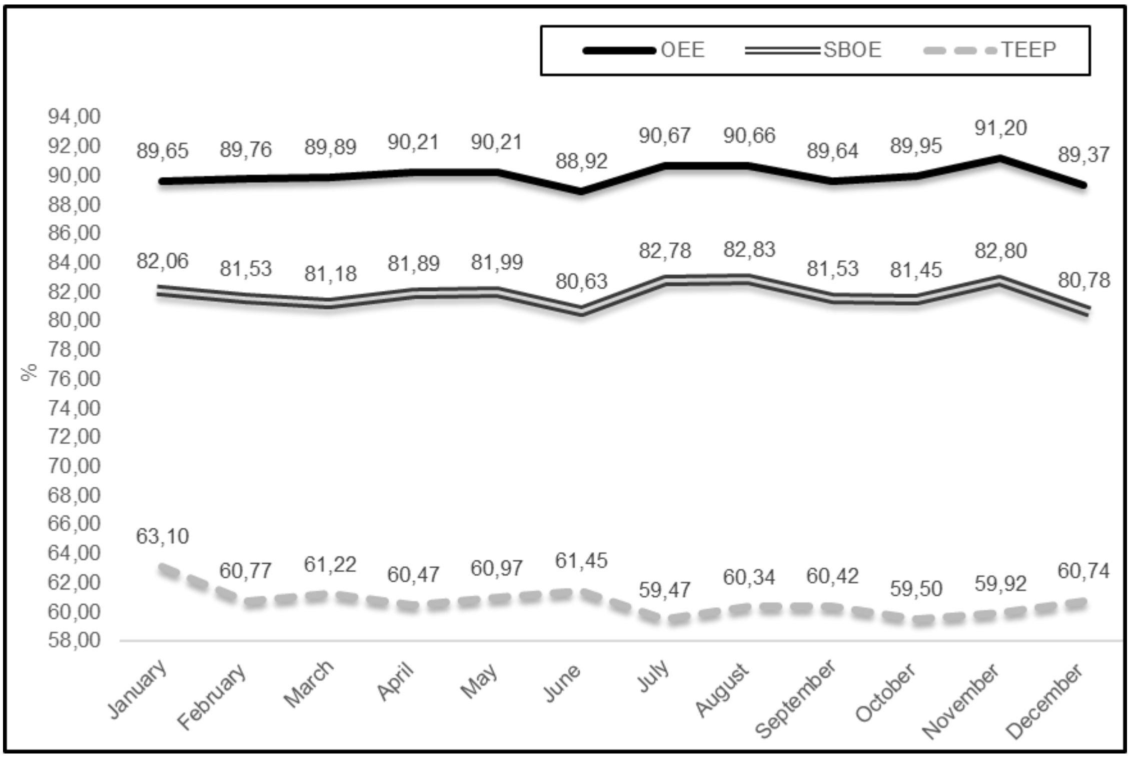

Figure 4. Comparison of productivity metrics

OEE, TEEP and SBOE metrics were calculated for every workshop in the company in a one-year period. According to these three methods, the facility-wide productivity results are compared in Figure 4. According to Figure 4, it is clear that the results of the TEEP metric are lower than the OEE metric. The main reason for this situation is that the OEE methodology ignores planned downtimes and is based on "loading time". Similarly, the SBOE metric also indicates lower efficiency results compared to OEE, as it also includes planned downtime losses. On the other hand, when SBOE and TEEP metrics are compared, although the SBOE metric contains planned downtimes, it is observed that efficiency outputs are lower in TEEP metric by based on the TEEP metric in “total time” (calendar time 7/24). However, the SBOE metric includes all planned and unplanned downtimes in the calculation, this indicates that there are deficiencies in the loss classification scheme used by the company and the existence of "undefined" losses.

5. CONCLUSION

TPM applications focus on the losses in the production environment and evaluate them under the topics of equipment failures, speed losses and quality defects. They also carry out improvement activities to increase the availability of the machines, decrease the costs and increase the efficiencies. Under TPM applications, controlling both losses and efficiencies are provided by the OEE metric. In case study, company’s currently used OEE metric was analyzed and try to suggest new metric in order to inspect the effectiveness of TPM applications. Therefore, both OEE and TEEP metrics were applied to the company’s efficiency forming processes and the results were compared in all annual efficiency outputs. After results were obtained, new alternative method was also applied to the one-year efficiency outputs and compared to other methods.

The proposed metric provides an opportunity to broaden the scale of the computation methodology of OEE and identify other factors that reduce capacity utilization. Therefore, practitioners can easily find out the hidden unproductive applications that comes from planned downtimes. As a result, the variety of improvement works can increase. On the other hand, using scorings instead of total time different from TEEP retains the true strength of OEE, which examines major losses or poor performance reasons, and allows to adjust improvement priorities and the beginning of root cause analysis. By the way, a serious issue was observed, while implementing the suggested metric. Although the SBOE metric includes all planned and unplanned downtime losses in the calculation, “unidentified” losses may still be encountered if there are deficiencies in the loss classification scheme used by companies. In order not to encounter such a situation, it is necessary to be sure that define all losses that may vary according to the sectors during the implementation phase. Taking everything into consideration, suggested alternative involve the pros of OEE and TEEP metrics, besides removing the cons of them.

In this study, different kinds of performance metrics were compared. Classical OEE method developed by Nakajima, TEEP method developed by Ivancic and suggested scoring based method were examined. It was also examined that how calculations can be performed with these three approaches in the faucet production company. It was tried to be determined whether there is difference between performance values among of them. Using one year of real data, it is believed that these three alternatives will make a significant contribution to both researchers and practitioners by enabling calculation and comparison of their results. On the other hand, lean production has gained a great importance under sustainable production. This is because lean production focuses on eliminating all kinds of waste and consume the natural resources in an effective way. TPM and OEE tools were evaluated under lean production and all the improvement works carried out in these tools directly contribute to protecting the balance of nature.

Finally, for the accuracy of performance metrics, collected data is very important. Without accurate data, measurement can lead to unreliability. Therefore, serious efforts should be made to improve data collection. Data collection can also be greatly improved by using new automated technologies.

Although the study makes important theoretical contributions to understanding the structure of the OEE and TEEP metrics, there are more several performance metrics exist in the literature (e.g., Overall Plant Effectiveness, Overall Factory Effectiveness, Overall Throughput Effectiveness, Overall Asset Effectiveness, Production Equipment Effectiveness). Accordingly, comparative studies can be carried out using other alternative performance metrics in future researches. Furthermore, developing new OEE calculation methods taking into account certain conditions can provide more accurate results. More general results will be reached and more definite results will reveal with application of OEE calculation methods in different firms and different sectors.

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