Measuring The Performances of the Machines Via Preference Selection Index (PSI) Method and Comparing Them with Values of Overall Equipment Efficiency (OEE)

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Abstract

Manufacturing enterprises give importance to determining machine performances in order to manage their operations and prioritize improvement activities. Overall Equipment Efficiency (OEE) is a tool that is frequently used by production managers to examine machine performances and is calculated by considering performance, quality and availability values. However, there are many different criteria that affect the performance of the machines. In this case, a multi-criteria decision-making (MCDM) approach is appropriate for handling machine performance values. The Preference Selection Index (PSI) is a MCDM method that is used for the evaluation of alternatives while weighting the criteria determined. This study was carried out to purpose of using the PSI method to generate the performance index of the machines. In addition to factors used in OEE calculation, MCDM problem with multiple criteria that supported by the literature was developed. The performance ranking of the machines was performed by PSI method with these criteria. The findings of this study suggest that when the more criteria are included in the studies for performance evaluation, the differences in the value of the results can be seen in the closer range and sensitivity. So, it would be useful to implement models that consider different criteria from OEE for machine performance evaluation.

Keywords: Preference Selection Index, PSI, Overall Equipment Efficiency, OEE, MCDM
Jel Codes: M10

Makinelerin Performanslarının Tercih Seçim Endeksi Yöntemi ile Ölçülmesi ve Toplam Ekipman Etkinliği Değerleri ile Karşılaştırılması

Özet

İmalat işletmeleri operasyonlarını yönetmek ve iyileştirme faaliyetlerini önceliklendirmek amacıyla makine/ekipman performanslarının belirlenmesine önem vermektedir. Toplam Ekipman Etkinliği (OEE), üretim yöneticilerinin makine performanslarını incelemelerinde sıklıkla kullanılan bir araç olup, performans, kalite ve kullanılabilirlik değerleri göz önünde bulundurularak hesaplanmaktadır. Ancak makinelerin performanslarının etkilendiği farklı ölçütler de mevcuttur. Bu durumda makine performans değerlerinin ele alınması konusunda çok kriterli karar verme problemleri yaklaşımı uygun olmakta ve çözüm sunmaktadır. Tercih Seçim Endeksi (Preference Selection Index / PSI) yöntemi, alternatiflerin değerlendirilmesi için belirlenen kriterleri kendi içinde ağırlıklandıran bir yöntemdir. Bu çalışma, PSI yönteminin makinelerin performans endeksini oluşturmasında kullanılması amacıyla yapılmıştır. OEE hesaplaması sırasında kullanılan, ölçütlerin yanında, literatürce desteklenen faktörler de göz önünde bulundurularak ÇKKV problemi oluşturulmuştur, PSI yöntemi ile makinelerin performans sıralaması yapılmıştır. Bu çalışmanın bulguları, performans değerlendirme çalışmalarına daha fazla kriter dahil edildiğinde, sonuçların değerindeki farklılıkların daha yakın aralıkta ve hassasiyette görülebileceğini göstermektedir. Bu nedenle, makine performansı değerlendirmesi için OEE'den farklı kriterleri de göz önünde bulunduran modelleri uygulamak faydalı olacaktır.

Anahtar Kelimeler: PSI, Toplam Ekipman Etkinliği, OEE, ÇKKV.
Jel Kodu: M10

1. INTRODUCTION

In parallel of developing technology, the efforts of the enterprises to increase the production performance are continuing in the current competitive environment. The determination of competition priorities of enterprises causes the necessity of providing higher quality, lower cost and more innovative products. The performance and competitiveness of production enterprises depend on the reliability and efficiency of the production facilities (Madu, 2000: 937; Muchiri, et al., 2011: 295). The performance of production

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system can be improved by highlighted the maintenance function (Madu, 1999: 694; Cooke, 2000: 1003 - 1004). Although the production performance of the enterprise is directly related to the rate of equipment use, this is necessary for the production of better quality and lower cost products.

Determination of equipment performance is a process based on many criteria. Overall Equipment Efficiency (OEE) is a frequently used value that makes the performance of the machines clearly understandable. OEE which used to measure the efficiency of equipment in the production area, identifies and measures losses in important aspects of production such as availability, performance and quality ratio (Muchiri, and Pintelon, 2008: 3518). On the other hand, there are many criteria in the literature that can be used to determine and rank equipment (Wang et al., 2000; Samanta et al., 2002; Dağdeviren, 2008; Nguyen, et al., 2016; Ghorabaee, et al., 2018). Since there are many criteria affecting the performance evaluation, multi-criteria decision-making methods can be used to examine machine efficiencies. The Preference Selection Index (PSI) is a multi-criteria decision-making method used by firstly Maniya and Bhatt (2010). PSI provides systematic evaluation without the need for the additional weighting of the criteria.

In this study, it is aimed to calculate machine performances by the PSI method and to compare the results with OEE values of machines. For this purpose, machine performance measurement and especially OEE are explained in the second part of this paper. In addition, literature is given about the other criteria affecting machine performance. In the third part, the PSI method is explained with the application steps. The fourth part of the study is the case study.

2. MACHINE PERFORMANCE MEASUREMENT

Production performance of machines in manufacturing enterprises is measured primarily with output unit (Jain et al, 2011:

617). In addition to output, machine performance is also affected by variables such as failure rate and processing time which indicate the result of maintenance (Yan, et al., 2004: 796 - 797). Breakdowns and unrecognized losses in the machines during production cause different negativities, which affects the production performance of them. The method of equipment efficiency improves production performance and provides a smooth working plant.

Overall Equipment Efficiency (OEE) is an efficient method that allows equipment performance measurement (Yaşin & Daş, 2017: 46). OEE is calculated using the following formula (Muchiri, and Pintelon, 2008: 3520).

OEE = Performance Rate x Quality Rate x Availibility Rate

The calculated OEE value can be used at various levels in managing the operations of the enterprise (Dal et al., 2000: 1490). It can be applied to compare the performance of different machines or to compare the previous values of the same machine. The OEE value can also be calculated for the production line, so that line performance can be compared (Sucu et al. 2010: 50). OEE is concerned with the availability of equipment, which is a function of planned and unplanned downtime, and is supported by planning management.

Table 1: Criteria of Equipment Performance

Criteria / Indicator	Unit	Description
Number of Failures	Number	Number of operational or safety failures
Failure / Downtime frequency	Number / unit time	Number of failures per unit time (Reliability indicator)
MTBF	Hours	Mean Time Between Failures (Reliability indicator)
Availability	%	MTBF / (MTBF+MTTR)
OEE	%	Availability, Performance Ratio, Quality Ratio

Note: (Mean Time to Repair / MTTR)
Source: Muchiri, et al., (2011:300)

Muchiri, et al., (2011: 300) describes the key elements such as the mean time between failures (MTBF) and the number of unplanned maintenance, that should be monitored and

controlled after maintenance planning in order to manage equipment performance. The measurement of these performance elements within the OEE framework, the availability of equipment and the development of reliability are considered important. Indicators for equipment performance are shown in Table 1.

To determine of equipment performance in addition to OEE, the use of a different indicators results in the evaluation of this issue as a multi-criteria decision making (MCDM) problem and the use of comparing the alternative equipment. In the literature, the studies on this subject are examined; Wang et al., (2000) in the study of the flexible production cell machine selection problem by using the fuzzy MCDM method. In the application for ten alternative machines, the total cost of purchase, total floor area, total number of machines and efficiency criteria were presented. Samanta et al. (2002) used the Analytic Hierarchy Process (AHP) method to make a selection based on seven criteria among five different alternatives. Parida, and Chattopadhyay, (2007) have developed a multi-criteria hierarchical framework for performance measurement in their study. They also explained the availability, performance ratio, quality ratio, number of failures, downtime, and reprocessing rate as equipment performance indicators (Parida, and Chattopadhyay, 2007: 250). Dağdeviren (2008) has implemented an application that integrates AHP and PROMETHEE methods for equipment selection. Nguyen, et al. (2016) evaluated and made selection of conveyor equipment by using the fuzzy AHP and Fuzzy ARAS methods. Ghorabaee et al., (2018) used fuzzy MCDM to evaluate the construction equipment on sustainability.

The PSI method has not previously been used in a study of machine performance. First of all, it is aimed to contribute to the literature by using this method. In addition, the comparison of PSI results with the OEE values commonly used in practice will also contribute to those who want to examine different criteria as well as the OEE value. In this study, the indicators supported in the literature are taken into consideration for multi-criteria machine performance evaluation. And also, to make different view of previous studies, PSI method, which is providing ease of calculation, is used. Previously, the use of the method will be explained and then the case study on this subject is shared.

3. PREFERENCE SELECTION INDEX (PSI) METHOD

The Preference Selection Index (PSI) is developed by Maniya and Bhatt (2010) and it is used for multi-criteria decision making (MCDM) the problems. The PSI is explained as a method that stands out due to its feature that determines the weight of the criteria and which does not require relative weighting.

In the PSI method, the overall preference value calculated for each criteria and the preference index (I_j) are calculated for each alternative, and the height of the preference index value allows the alternative to be determined as the best (Maniya and Bhatt, 2010: 1786). The use of the PSI method arises in situations where it is difficult to decide the criteria weight (Attri and Grover, 2015: 209).

In the literature, the PSI method is used for ranking or selection of alternatives, and the validity of the method is tested by comparing with the other commonly used methods. Firstly, Maniya and Bhatt (2010) applied the PSI for material selection problem and the results were compared with the outputs obtained by TOPSIS and GTMA methods. Sawant, et al., (2011) in their study used the PSI method for the problem of automatic-oriented vehicle selection, sixteen different vehicle models were ranked based on nine criteria. In the study, for used criteria were desired the maximum and minimum values and the results were compared with the TOPSIS method. Akyüz and Aka (2015) applied PSI method to measure manufacturing performance and evaluated the results using AHP and TOPSIS methods. Mufazzal and Muzakkir (2018) and Noryani et al., (2018), in their studies; PSI was discussed

with AHP, ANP, DEA, ELECTRE, GRA, GTMA, MAUT, PROMETHEE, SAW, TOPSIS, VIKOR.

Advantage of the PSI method; it is the direct implementation of the alternative to assess the performance of the alternative and to calculate the rating score. On the other hand, the disadvantage is the method that does not allow the user to consider the qualitative factors (Noryani et al., 2018: 3336). This is related to the method based on calculations that determine the weight of criteria within its own systematic.

The steps taken by the Maniya and Bhatt (2010) in PSI method are as follows:

Step-1: Defining the problem and determining the criteria.

Step-2: Rows are the *alternatives* A=[A_i, i=1, 2, … , n], columns are the *criteria* C=[C_j, j=1, 2, … ,m], and the value of cells X_{ij}, represent the decision matrix.

Step-3: Normalization of the decision matrix is the standardization of the *criteria* measured by different units.

The normalization of the *criteria* in different units is 0 - 1, and the reinterpretation of the data to show if the *maximum* value of the criterion is better, 1 is the best, 0 is the worst, if the *minimum* value of the criterion is better, 0 is the best, 1 is the worst.

$$N_{ij} = \frac{X_{ij}}{X_{ij\ max}}; \quad \forall\ i,j \quad \rightarrow \quad \text{if the } \textit{great value}$$
represents better (1)

$$N_{ij} = 1 - \frac{X_{ij}}{X_{ij\ max}} \quad \forall\ i,j \quad \rightarrow \text{if the } \textit{small value}$$
represents better (2)

Step-4: Calculating *preference variation value* (PV$_j$).

$$PV_j = \sum_{i=1}^{n}[N_{ij} - \overline{N_j}]^2 \tag{3}$$

$\overline{N_j}$: is the average of the *normalized values* of the alternative j

$$\overline{N_j} = \frac{1}{n}\sum_{i=1}^{n} N_{ij} \tag{4}$$

Step-5: Determining the *overall preference value* ψ_j for each criteria. For each criteria, the *overall preference value deviation* θ_j is found. (Quantitative Weighting).

$$\theta_j = 1 - PV_j \tag{5}$$

$$\psi_j = \frac{\theta_j}{\sum_{j=1}^{m}\theta_j} \tag{6}$$

$\rightarrow$ Sum of the *overall preference values* of the criteria equals the one ($\sum \psi_j = 1$)

Step-6: Calculating the *index value.*

$$I_i = \sum_{j=1}^{m}(N_{ij}\ x\ \psi_j) \tag{7}$$

The results are accepted as *Preference Selection Index* (PSI) and are shown as I_i. PSI values are used for alternative selecting, sorting, and comparing, with the highest value showing better.

4. CASE STUDY

In this section, the proposed approach is implemented in a manufacturing company operating in Izmir. The company produces a speed of 200pcs/min (machine speed depending on the part form) on multi-station machines that make mass production with cold forming method. The data regarding the equipment performances of the enterprises which produce at such a speed is obtained by examining the OEE values of the machines. However, the maintenance and production managers of the enterprise have found that there are different indicators effective in determining machine performances other than

OEE values. In order to manage the performance improvement studies on the machines, it is required to compare the machines. In this case, there is a need for a MCDM method to compare machines. For this purpose, the calculation of preference index values of machines by using PSI method is studied.

Data Source

In implementation, it is necessary to identify the equipment for performance comparison. In this direction, the enterprise provided 10 alternative machines. Then the criteria for equipment comparison are determined as supported by literature and provided by the manufacturing. From the performance measurement literature, equipment related performance indicators are listed as; availability, production rate, quality, number of stops, number of downtime and rework rate (Kutucuoglu, et al., 2001: 181; Parida, and Chattopadhyay, 2007: 250). This study aims to measure the equipment performance and also compare it with the OEE values so, OEE indicators are taken account as criteria near the literature supported and there are no rework data gathering by company in cold forming manufacturing type so that this indicator is not seen as a criterion.

Table 2: Decision Matrix

Criterion / Alternative	Availability (OEE Indicator)	Performance (OEE Indicator)	Quality (OEE Indicator)	Capacity Utilization %)	Total Produced (monthly unit)	Failure / Breakdown Time (Monthly min.)	Set-up Time (Monthly min.)
Goal	max	max	max	max	max	min	min
M1	90.5	100.0	100.0	27.5	1.750.068	11	1000
M2	85.2	100.0	100.0	22.6	1.222.914	43	1234
M3	80.9	97.0	100.0	54.1	2.922.654	137	4232
M4	76.6	97.4	100.0	48.4	2.033.653	141	4526
M5	70.8	99.8	100.0	48.3	2.136.516	483	5129
M6	69.4	99.1	100.0	7.9	320.290	30	913
M7	76.9	86.3	100.0	54.4	1.553.541	1097	3755
M8	67.3	96.1	100.0	60.2	2.700.152	167	7826
M9	62.2	97.8	100.0	45.7	1.819.885	295	6765
M10	58.5	99.7	100.0	53.8	2.113.653	185	9000

Table 3: Normalized Decision Matrix

Criterion / Alternative	Availability (OEE Indicator)	Performance (OEE Indicator)	Quality (OEE Indicator)	Capacity Utilization %)	Total Produced (monthly unit)	Failure / Breakdown Time (Monthly min.)	Set-up Time (Monthly min.)
M1	1.000	1.000	1.000	0.457	0.599	0.990	0.889
M2	0.941	1.000	1.000	0.375	0.418	0.961	0.863
M3	0.894	0.970	1.000	0.899	1.000	0.875	0.530
M4	0.846	0.974	1.000	0.804	0.696	0.871	0.497
M5	0.782	0.998	1.000	0.802	0.731	0.560	0.430
M6	0.767	0.991	1.000	0.131	0.110	0.973	0.899
M7	0.850	0.863	1.000	0.904	0.532	0.000	0.583
M8	0.744	0.961	1.000	1.000	0.924	0.848	0.130
M9	0.687	0.978	1.000	0.759	0.623	0.731	0.248
M10	0.646	0.997	1.000	0.894	0.723	0.831	0.000
$\overline{N_j}$	0.816	0.973	1.000	0.702	0.635	0.764	0.507

Table 4: Overall Preference Value

Criterion / Alternative	Availability (OEE Indicator)	Performance (OEE Indicator	Quality (OEE Indicator	Capacity Utilization %)	Total Produced (monthly unit)	Failure / Breakdown Time (Monthly min)	Set-up Time (Monthly min.)
M1	0.034	0.001	0.000	0.060	0.001	0.051	0.146
M2	0.016	0.001	0.000	0.107	0.047	0.039	0.127
M3	0.006	0.000	0.000	0.038	0.133	0.012	0.001
M4	0.001	0.000	0.000	0.010	0.004	0.012	0.000
M5	0.001	0.001	0.000	0.010	0.009	0.042	0.006
M6	0.002	0.000	0.000	0.326	0.277	0.044	0.153
M7	0.001	0.012	0.000	0.040	0.011	0.584	0.006
M8	0.005	0.000	0.000	0.089	0.083	0.007	0.142
M9	0.017	0.000	0.000	0.003	0.000	0.001	0.067
M10	0.029	0.001	0.000	0.037	0.008	0.005	0.257
PV_j	0.112	0.015	0.000	0.721	0.572	0.795	0.904
Q_j	0.888	0.985	1.000	0.279	0.428	0.205	0.096
ψ_j	0.229	0.254	0.258	0.072	0.110	0.053	0.025

There are seven criteria that are taken into consideration in the comparison of equipment, so that three of these criteria are the values used in OEE calculation. The decision matrix created with the alternative equipment and criteria determined are given in Table 2.

In this study, the quality criteria are 100 for all the alternatives, and this criterion is not change the PSI ranking. The reason of being a criterion in the decision matrix is that the quality criterion is an OEE indicator and the PSI results will be compared with the OEE values at the end of the application.

PSI Calculations

After the decision matrix is formed in the PSI method, a normalized decision matrix is formed to standardize the values. Table 3 shows the normalized decision matrix and shows the values.

Following the creation of a normalized decision matrix, it is necessary to find the preference variance and to determine the overall preference value. Overall preference value can be considered as benchmark weights. Table 4 shows the overall preference value calculation step.

When the overall preference values that determined for each criterion, were examined, the highest weight was given to the Quality indicator with a value of 0.222. The second most significant weight is given to the Performance indicator with a value of 0.207. These two criteria with the highest weight are the values used for the OEE calculation. As a result of the overall preference value for each criterion, the values accepted as the PSI for each alternative are calculated. Table 5 shows the calculation of PSI values.

When the preference index values calculated by PSI method are examined, it is seen that M3 machine has the highest value and M1 and M4 machines are followed. After comparing the performance of machines with OEE values, to investigate whether the effect highest criteria weights of quality and performance, PSI method was applied over the remaining four criteria, without including OEE indicators. Performance ranking of the 10 machines considered as an alternative was calculated by taking into consideration the capacity utilization, total

produced, breakdown time and set-up time. Table 6 was established to compare the PSI

preference values and the monthly OEE values of the machines.

Table 5: Calculation of the PSI Values

Criterion / Alternative	Availability (OEE Indicator)	Performance (OEE Indicator	Quality (OEE Indicator	Capacity Utilization %)	Total Produced (monthly unit)	Failure / Breakdown Time (Monthly	Set-up Time (Monthly min.)	PSI
M1	0.229	0.254	0.258	0.033	0.066	0.052	0.022	0.913
M2	0.215	0.254	0.258	0.027	0.046	0.051	0.021	0.872
M3	0.205	0.246	0.258	0.065	0.110	0.046	0.013	0.943
M4	0.194	0.247	0.258	0.058	0.077	0.046	0.012	0.891
M5	0.179	0.253	0.258	0.058	0.081	0.030	0.011	0.868
M6	0.176	0.252	0.258	0.009	0.012	0.051	0.022	0.780
M7	0.195	0.219	0.258	0.065	0.059	0.000	0.014	0.809
M8	0.170	0.244	0.258	0.072	0.102	0.045	0.003	0.893
M9	0.157	0.248	0.258	0.055	0.069	0.039	0.006	0.831
M10	0.148	0.253	0.258	0.064	0.080	0.044	0.000	0.846

Table 6: Comparison of OEE Values of Machines with PSI Values

Machine	OEE	PSI I	PSI II
M1	90.4 %	91.3%	66.7%
M2	85.2 %	87.2%	55.9%
M3	78.4 %	94.3%	90.2%
M4	74.6 %	89.1%	74.2%
M5	70.6 %	86.8%	68.7%
M6	68.8 %	78.0%	36.6%
M7	66.4 %	80.9%	53.1%
M8	64.7 %	89.3%	85.4%
M9	60.9 %	83.1%	64.7%
M10	58.3 %	84.6%	72.3%

As seen in Table 6, M1 has the highest OEE value with 90.4%, while the PSI method based on seven criteria (PSI I) is in the second preference and PSI method based on four criteria (PSI II) is in the sixth preference. On the other hand, M3, which has the highest preference value according to the indices as PSI I and PSI II, ranks third in terms of OEE value. Further, the preference values of the alternatives for the seven criteria ranged from 0.943 to 0.780, while the preference values of the alternatives for the four criteria ranged from 0.902 to 0.366. The increase in openness between these values shows that the differences between the

machines become more evident as the results move away from the OEE indicators.

5. CONCLUSION

Changing in customer requirements, increasing competition conditions and low-cost demand, force the businesses to review the efficiency of their operations. Businesses follow machine performances in order to eliminate production losses and to manage improvement works correctly. OEE is a frequently used measurement instrument in the industry for machine accomplishment. However, there are many different indicators to evaluate machine performances. In this instance, the MCDM methods can be used to estimate the performance of the machines. The PSI is a method which is based on the variance of preference with its systematic calculation steps. In this study, machine performance values were found by the PSI method and compared with monthly OEE values of machines.

During the implementation of the PSI method, seven criteria for the ranking of ten alternative machines were discussed. Three of these criteria are availability, performance and quality ratios used in the calculation of OEE value. These OEE included criteria are thought as they will play a

decisive role. But there is no any proof for other criteria for comparison with OEE values. For that reason, there are two scenarios in implementation. First of them is all seven criteria which are included in OEE is also is taken account and the preference values of machines reached as a result of application were named as PSI I. For other scenario, another MCDM model was established in which the indicators used in the calculation of the OEE value were not included and PSI II are reached. PSI II values were first compared with OEE values of machines and then with PSI I results.

In the PSI I application, the range of preference values of alternatives varies with narrow range of preference values of alternatives in the PSI II application. The difference between these values shows that the differences in preference are more pronounced in measurements based on fewer criteria. As the number of criteria increases, the selection values of the alternatives

approach each other, but also small changes become more decisive. In the comparison of the results with the OEE values, it was observed that the results obtained by PSI I method, which included the OEE indicators, were more similar to the OEE values ranking, but not exactly the same.

This study closes a literature gap in terms of using the PSI method for the first time in evaluating machine performance. In addition, this study differs from other studies which applied PSI method and compared with the other MCDM methods, while comparing the results obtained by the PSI method with the OEE values of the machines. In order to improve this study, the criteria weights that are inherent in the PSI method can be calculated by using with the other MCDM methods. And it could be compared with weights found by other weighting methods.

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