

## Determination of Performance Analysis for an Underground Colliery Utilizing Mechanized Production System

Ali Ekrem Arıtan<sup>1</sup>, Cem Şensöğüt<sup>2\*</sup>

<sup>1</sup>Afyon Kocatepe University, Mining Engineering Department, Afyonkarahisar, Turkey

<sup>2</sup>Kütahya Dumlupınar University, Mining Engineering Department, Kütahya, Turkey

\*Email: [cem.sensogut@dpu.edu.tr](mailto:cem.sensogut@dpu.edu.tr)

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**Abstract:** Performance is one of the most important parameters for today's business organizations. An organization that is low on performance, no matter how much high quality products they have, cannot take the share they desire from the market. It is the inevitable result for organizations with low performances to lose money and get closed down. Nowadays performance is measured in many ways. In this work; the production performance of Ömerler Colliery, which is the only government controlled mechanized lignite mine authorized under the Western Lignite Corporation (WLC) and the factors that caused performance decrease has been determined. In order to gain performance measurements; effectiveness, efficiency and productivity criteria have been used and performance indexes have been acquired. As the result of the performance analysis, it is understood that there has been malfunctions with; in order; belt conveyor, chain conveyor, shearer and fortification that has been effective in the decrease of performance. Performance indexes, which are barely derived from the multiplication of performance parameters, are examined and it is deduced that the highest relation is achieved for the efficiency parameter with a correlation constant ( $r$ ) of 0.9489 and a certainty constant ( $R^2$ ) of 0.9005 while the lowest relation is obtained for the efficiency parameter with a correlation constant ( $r$ ) of 0.4621 and certainty constant ( $R^2$ ) 0.2135. With this acquired result it has been determined that by only measuring effectiveness, performance detection cannot be made.

**Keywords:** Mechanized production, performance analysis, Western Lignite Corporation, productivity, efficiency.

### Introduction

In literature it can be seen that there are varying definitions for performance. Kenger has identified performance as a work done on a certain period of time and with a certain deal of operating speed (Kenger, 1986). According to Bas and Artar; it is defined as an individual, a group or enterprise doing a certain work and measuring how far they could get to their intended goal, in other words it is the expression of what it could provide in terms of quantity and quality (Bas and Artar, 1991; Songur, 1995). The definition of performance according to Turkish Language Society is the limit of success or strength (Turkish Dictionary, 1992). Akal defines organisation performance as the result obtained in a certain period of time, the coverage ratio of the organisation target or mission (Akal, 1998). Again according to Akal performance in organisations, a performance of a business system is the outcome as a result of a certain time or operation (Akal, 2005). This result should be perceived as the rating of the work fulfilment. In this case, performance can be identified as the evaluation of the efforts made in order to realize its purposes. Performance, by Bozkurt et al. (1998) has been defined as 'work performance' and the degree of success on any kind of work. Elitas and Agca, (2006) have defined performance as the output and the measurement of output that have been used for the funds which have been utilised for performance; the degree of being successful in reaching a goal; productivity and effectiveness of an intentioned activity (Bozkurt et al., 1998; Elitas and Agca, 2006).

They have also defined performance through some indicators such as effectiveness, productivity, and quality, quality of work life, innovation, and profitability with their mutual and complicated relation between each other. The performance is the expression of an individual, a group or an organisation's capability to achieve their goal in terms of quality and quantity (Falay, 2000). Barutcugil has defined an organisation's performance as; in the process of the realization of strategic, tactical and operational objectives and the quality and the work of employees to fulfil the requirements for a certain work as well as its evaluation (Barutcugil, 2002). Bilgin has defined performance as; it determines what happens after an intentional and planned activity (Bilgin, 2004). Lawson (1995) on the other hand has a different approach to the term performance and says that the term performance has varying initiatives, sometimes it focuses on financial performance and sometimes on political performance. Some are interested in the process of the work's performance. Customer's performance concept takes shape mostly by product and service quality. However, it is necessary to view the performance in general containing all the parts of the organization and operation (Lawson, 1995; Celep, 2010).

As it will be clearly understood from the above definitions that, although there is no similar concept understanding in the literature, performance is in general defined as, what is the importance of all the work done to reach the target, and whether the target

was reached or not. To be able to talk about performance, previously there must be a determined target. If reaching the target means to be successful, it can be said that performance concept and success are in the same direction (Oyman, 2010; Atakus, 2006; Peru, 2010).

In this study, the performance analyses were performed with the data taken from M7 panel of the Ömerler Colliery. Since the demand is always higher than the production, demand analysis was not performed.

The system performance which is used in coal production, affects the profitability of the production in the mine directly. For this reason, it was tried that the main reasons of the decrease in performance of the mechanized system are determined. At this point, to increase the performance of the system, it is necessary to determine all the parameters which clearly explain the performance, to measure and control these parameters continuously and later improvements will be put into practice.

Performance analysis is performed by the system which uses performance parameters. For this, efficiency, productivity and effectiveness values, and related to these values system, performance indexes are determined. The results of these performance examinations were compared in themselves and with each other. Related to the results taken, mechanized system's working performance and the problems were dealt comprehensively and systematically (Aritan, 2011; Hosenie et al., 2012; Dey and Sharkel, 2015).

## Materials and Methods

In this study, examinations were made in Turkish Coal Enterprise, Western Lignite Corporation (WLC) and Ömerler underground colliery. Aforementioned mine is in Tavşanlı/Kütahya, Turkey (Fig. 1).



Fig. 1 Map showing the study area.

Coal produced from the colliery together with the coal extracted by open pit mining in other state owned

mines in the same region are evaluated in three ways which are for the electricity production in power plant, for domestic heating purpose or to donate for poor people. Ömerler Colliery's planned annual production rate is about 350.000 tons.

Coal production has been practised since 1940 in the region and the first mechanized production trials started in the middle of 1987 using parallel (to the face) drum shearers. In the first trial, it was not efficient enough and the production was continued by the conventional methods.

Mechanized production started again in June of 1997 and the mechanized production technique has still been continued since then. In mechanized production system, following equipments are utilized.

### Double Ended Drum Shearer (EICKHOFF DW-150-2L)

The shearer which is used in cutting up and loading face coal has a double ended drum, face conveyor mounted, and unchained pulling system. Since the drum has a water spraying system while working, it is designed as not to cause a problem of dust.

### Chain Armored Conveyor

The chain armored conveyor, which is used for coal transportation, has a double ended drive and is a twin chained conveyor. This conveyor's reduction gear is designed as water cooled. Chain conveyor, which is 40 m long, transfers the loaded coal onto the belt conveyor by a collecting conveyor.

### Face Supporting System

In long walls, hydraulic support equipment are used. On the mechanized panel, different types of supporting systems are utilized such as end of face supports, transition supports and the supports used in the face.

### Belt Conveyor

Designed as mounted in front of collecting conveyor, 100 cm wide, having a capacity of 800 tons/hour and a belt storage of up to 50 meters. As the face proceeds, by disassembling the console units from the tail part of the belt conveyor, it is possible to shorten the belt conveyor by removing it up to 50 meters.

### Performance Measuring Method Selection and Determining Performance Criteria

#### Selection Method

The most general and the most known performance analysis method is the productivity calculation and is carried out by input/output calculation. Nowadays, in production facilities/plants not only the produced product quantity is important but also factors like quality, customer satisfaction are becoming prominent.

Therefore, this measuring method is counted as narrow-scoped.

In another performance evaluation system, which is used for establishing the performances of machinery used in mines, the productivities are analyzed. In this method, evaluating the performances of machines is possible by machines' employment rates calculation. Although this system is not sufficient enough, on the other hand comparing with the other systems gives satisfactory information. However, it must be kept in mind that, a satisfactory performance measurement is only possible when the performance criteria are correctly determined in the establishment to be examined and when the criteria are completely covered.

By using performance criteria, in the generation of performance indexes, up to date works are included in the literature. The performance criteria used in these exercises are;

- Effectiveness,
- Efficiency,
- Productivity,
- Profitability.

Rose has formulized the performance of the company's sales performance as follows (<http://hosteddocs.ittoolbox.com/MRose62706.pdf>);

Performance = State of readiness x Productivity x Efficiency x Effectiveness.

In another study Once et al. (2007), performance is formulized as below;

Performance = Productivity x Efficiency x Effectiveness

As it can be seen in both formulas, productivity, efficiency and effectiveness are used in common. While determining the performance criteria, the priorities of the system or the machinery to be analyzed should be taken into consideration.

**Selection Criteria**

While investigating a machine's or a system's performance, if the correct criteria is not taken into consideration, the result would not be reliable. Moreover, it was decided that while making a study, if the performance analysis is performed by only considering one dimension it was thought that the result would not be satisfactory because reliable performance analysis is carried out considering three dimensions (productivity, efficiency and effectiveness).

While calculating the performance criteria, care was taken in selecting the data that will give correct results and that will present the system. While making selections, the human factor, is negligible because

engineers and others working in the mine are experienced and specialized.

In the scope of this study, in Ömerler underground mine, during 18 months on the panel where mechanized production is performed, studies and measurements were conducted. For continuous data flow, at the end of each month, data were taken from the mine.

In the present study, besides productivity, efficiency and effectiveness, the performance index of mechanized system which was calculated by the multiplication of productivity, efficiency and effectiveness is used. By this way, it was thought that the correct judgment about the system would be provided. Moreover, in case even where efficiency rate is maximum, for the mechanized system, the performance is not so high. Even if the system is working on 100% efficiency, within the considered period, the system may be working continuously, but it may be possible that there is not enough production. For this reason, with efficiency, effectiveness and productivity rates, it is useful to take into consideration the interpretation of performance indexes.

Therefore, in the study performed, the theoretical general definitions and definitions which are adapted to the system of performance parameters (productivity, efficiency and effectiveness) considered while determining system's performance index can be seen at Table 1.

Table 1 Performance parameters adapted for theoretical and mechanized system.

Performance Parameter	Theoretical General Definition	Adaptation to Mechanized System
Effectiveness	Realized output / Expected output	Foot progression / Planned foot progression
Efficiency	Consumed input (source) / Potential input(source)	Mechanized system's working hours / Useable (planned) mechanized system working hours
Productivity	Output / Input	Productivity's physical (ton) value/ Mechanized system's total working hours

Here theoretically, effectiveness is the degree of attainment to the aims, at the result of studies conducted to reach to the defined aims. In the description concerning the system performance, the defined purpose is considered as useable or planned capacity. In addition, the question is about how well the capacity was used. Effectiveness was used as an expression of this term.

Second parameter, the efficiency, is a concept related to consumption of resources. It is most likely oriented to tools. In other words, it determines whether the works are performed correctly or not. Although a production factor is active, output level can be low, or vice versa. When it is considered as system based, it is

an expression of how much the system works despite the planned working hours.

Third parameter, the effectiveness, is determined by considering input/output concepts as well as interaction of many sources (for example, quality). When the system is considered, it is the system's total working hours versus production's physical value's (ton) expression.

In the Table 1, planned face progression and planned mechanized system working hours is valid when all the cases are suitable or production conditions are 100%. However, in underground mining production conditions, such a case is nearly impossible. Failures, congestion of the supports, irregular water flow, electricity cut offs, geological factors, mechanical factors etc. can restrain planned progression, and timing and production may stop. In other words, planned progression and working time are the concepts to be stated when all the parameters listed are considered.

**Performance Measurements**

**Effectiveness**

In determining effectiveness values, the measurements of face advancement rate and planned face propagation values (Table 1) are used. These values are monthly based and the unit is in meters. Planned face progression rate, is the theoretical expected length while calculating the annual production yield.

Face advancing rate, on the other hand, is the real progression figure that shows up in the production face during the measurements taken at the end of the month (Fig. 2).

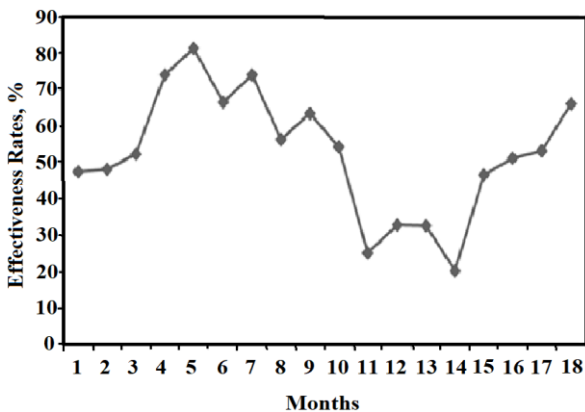


Fig. 2. Effectiveness rates (%).

In Figure 1, there is an increase in effectiveness rates beginning from the first month where the production started. While the mechanized system's effectiveness increases between the first and the fifth months, it can be seen that it starts decreasing later. The reason of decrease is that face advancement cannot be realized as planned. After the repairs and maintenance, the increase in face progress can be clearly seen starting

from the 14<sup>th</sup> month. By thorough examination of the Figure 2, it may be pointed out that 100% of effectiveness rate could not be reached for the last 18 months meaning that the system is not used effectively for this period.

**Efficiency**

In efficiency rate calculation, the mechanized system's working period and planned mechanized system working period (Table 1) values are used. Here again, planned mechanized system working time is the theoretical value in calculating annual production yield. Mechanized system's working time is also the realized working time. Results are given in Figure 3.

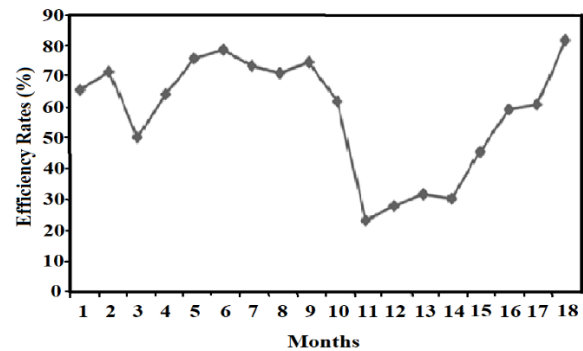


Fig. 3. Efficiency rates (%).

When the efficiency rate is taken as "100%" it means that standard efficiency level and sources are used in an optimum way. In Figure 3, it can be illustrated that from the production starting date to production ending date, the efficiency rate of 78.6% could not be exceeded. It means that the system is insufficient in using the sources in an optimum way.

**Productivity**

The productivity is calculated by comparing the value of produced coal per ton and the mechanized systems' total working period. Computational results are given in Figure 4.

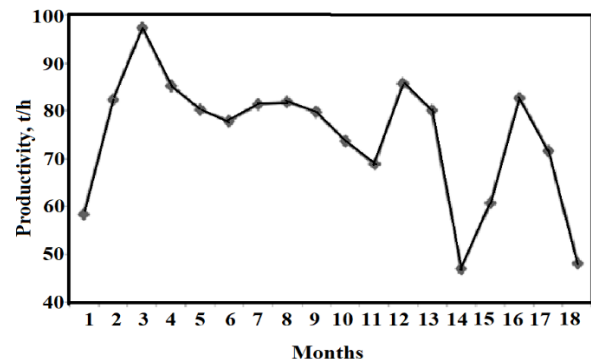


Fig. 4. Productivity (t/h).

When productivity is examined, it can be seen that the production is at the lowest levels on the 14<sup>th</sup> month of production. The reason is that, although monthly 30,000 tones production was planned, 10,000 tons

were produced. On the 3<sup>rd</sup> month of the production, the level was at the highest point. The reason for that is, on the 3<sup>rd</sup> month although the production was 2.7 times of 14<sup>th</sup> month, this production was realized within the same working period.

### Performance Index Calculation

Performance index calculation is the result of multiplication of productivity, efficiency and effectiveness. The reason to calculate the performance index is not to see the performance change between months but is to analyze the performance of production for all the periods. Therefore, by the results obtained, the reasons in the performance variation would be determined and the measures to increase the performance would be taken.

Performance index values which are the result of multiplication of productivity, efficiency and effectiveness are given in Figure 5.

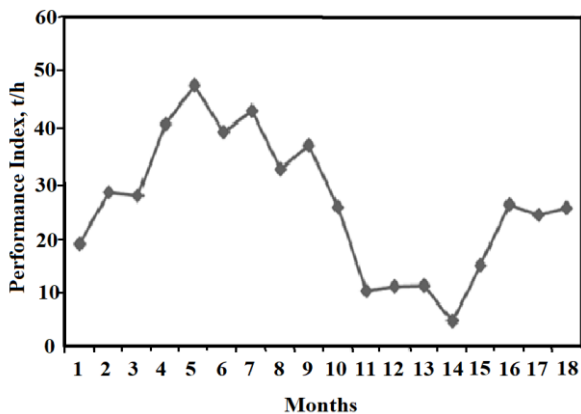


Fig.5. Performance Index (t/h).

As production progresses, more system problems arise and performance index may fall down. In fact, when the indexes here are carefully analyzed, it can clearly be seen that the mechanized system is unable to finish one panel's production without fault and when the planned working time is exceeded the performance is decreased. In Figure 5, it can clearly be stated that the performance index values have no standard. Persistently, there is inconstancy. The reason for that is, since there are cessations in the mine, production cannot be performed uninterruptedly.

5<sup>th</sup> month of the production has the highest performance index value. Since, this month is the month where the failures are minimum. From this result, it can undoubtedly be said that, as the number of failures decreases the performance increases. But when all the months are analyzed as a whole, it can be seen that there are lots of failures and the performance is low.

### Performance Analyses

The first of the results which are taken from performance index calculations is that the production

in the mine is not stable. The main reason of not being stable is that the cessations in the mine cannot be eliminated. The second result is that, without taking into consideration the first month of production, until the 5<sup>th</sup> month there is an increased tendency in production, but later there is a decrease. Especially, at the 9<sup>th</sup> and 10<sup>th</sup> months there is a sharp decrease in the production performance curve. The decrease stopped between 11<sup>th</sup> and 13<sup>th</sup> months and at the 14<sup>th</sup> month, the decrease reached at the minimum level. After this date, by the help of the revisions made in the system, the production increased but the performance at the 5<sup>th</sup> month could never be reached again. The increases and decreases at the 3<sup>rd</sup> to 6<sup>th</sup> month of the performance curve show clearly the problems in mechanized system. It can clearly be seen that, mechanized system's life, which was installed on 1997 and was determined to have a life cycle of 10 years by the installation company, has completed its life.

The relation between performance parameters which consisted of productivity, efficiency and effectiveness- and performance parameters which are obtained from performance analysis may be explained as given below.

When the performance analysis results are analyzed, a stable status was not observed in the index. Because of the mining sector's own problems and the failures arising in the system, the stability could not be reached. When the status of the performance index of the first months is analyzed, there is an increasing curve. Longwall's most critical and most difficult period is the beginning of the production at the face. As the face progresses, critical period ends and the face production carries on at a normal rate (Kose and Tatar, 2003). Critical period started to overpass at the 2nd month of the production and when compared with the 1st month, a performance increase of 54% was observed. Although this increase was expected to continue in the later months, the data obtained says it does not. Especially, until the 10<sup>th</sup> month, the index is around 30 to 50, from that month it started to decrease and only in the last month the index could climb to 25.

When the analysis results are evaluated, 14<sup>th</sup> month has the lowest index value. The reason for this is that, in this month there were lots of cessations, the decrease in face advancement caused a decrease in production performance in index value.

In this study, if only the production amounts were analyzed, in the 6<sup>th</sup> month, the production should have the highest performance value. If solely productivity is considered as a criterion, 14<sup>th</sup> month would not have the lowest performance. Here is a stunning case. According to classical performance determination systems, in performance analysis, in other words, in performance evaluations based on productivity, while 14<sup>th</sup> month would have an average value, when evaluated by the system using performance criteria, it has lowest performance values. The reason for this is



that, because of the failures, the cessations affected the results.

The relations between the performance indexes which are obtained by the multiplication of the parameters are shown in Figure 5. While correlation coefficient having a value of 0.9489 and determination coefficient ( $R^2$ ) having a value of 0.9005 are the highest relation effectivity parameters, correlation coefficient having a value of ( $r$ ) 0,4621 and determination coefficient ( $R^2$ ) having a value of 0,2135 are the lowest relation effectivity parameters.

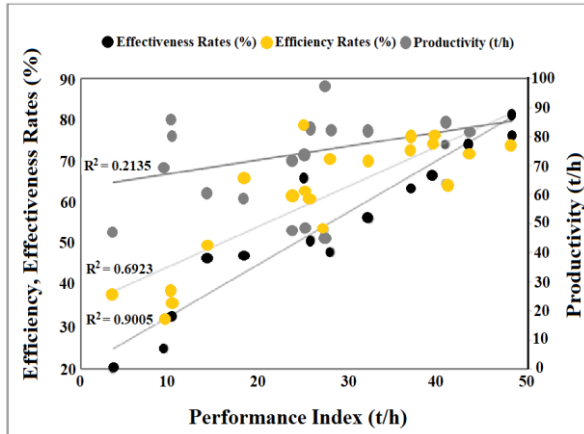


Fig. 6 Performance index relations.

As a result of this linking, it was decided that, without evaluating cessation periods and face progression which is the main criterion in face work, only evaluating the performance regarding production amount (tons) would not be reliable. Achieving the target of monthly planned tonnages, does not clearly show the system's performance. Without considering the failures and cessations of the system, the real performance cannot be calculated. To be able to judge the success of the production, it is necessary to examine more than one dimensions of the performance.

## Results and Discussion

In mechanized system production, performance is directly affected by the performance of the equipment, conveyors and supports. The system which is used for many years after many revisions, says that it needs now a whole change or essential changes.

In analysis where only the productivity parameter is considered, since only input/output calculation is done, only the production amount per hour/per year etc. is considered. However, if performance criteria are considered, the working time of the system and the progression amount are also considered and thus the performance results change. The results in this study show that, while examining a system's or a machine's performance, it is necessary to evaluate all the criteria, instead of only productivity.

The result of the relationship between the performance index and the multipliers is that effectiveness is the most important multiplier. Progression amount which constitutes effectiveness coefficient shows that in mechanized systems, while making performance analysis, like making in classical performance analysis, it came out that not only evaluating production amounts but also monthly progression amounts as a result of the production at face is necessary.

In underground mining, it is decided again that it is necessary to make production by holding the face advancement rates at optimum levels. Increasing speed by more than the optimum level will result in quick failure of the equipment in use and as a result the decrease in performance. In this study, this thought is supported by the value of the relationship between face advancing rate -which was taken as the effectiveness parameter- and performance index and the value was found to be 90.05%.

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