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Evaluation of the Performance of Drilling Machines in the Aegean Lignite Corporation (Türkiye) by Analytical Hierarchy Process (AHS) and TOPSIS Method

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Abstract: Multi-criteria decision making techniques are designed to enable better selection when it comes to complex decisions involving various parameters. When a complex problem is mentioned, statements with immeasurable and contradictory criteria such as efficiency, performance, safety, reliability, cost, and economy are understood. One of the known purposes of the multi-criteria decision analysis approach is to assist the people who are responsible for organizing and synthesizing such information that makes them feel confident in taking a decision, and to minimize potential decision after regret by ensuring satisfaction when all criteria and factors are considered. Analytical Hierarchy Process (AHS) is widely used in solving complex problems involving more than one criterion. The AHP method is based on a hierarchical system consisting of many goals, criteria and alternatives. TOPSIS method can be applied directly on the data without making a qualitative conversion.

There are a total of 21 hole drilling machines in the Aegean Lignite Corporation (Türkiye), which is affiliated to the General Directorate of Turkish Coal Board. 12 of these machines are INGERSOL DM50, 7 of them are REEDRIL/SK50C and 2 of them are BUCYRUS/35HR models. A total of 103,332 meters of holes were drilled with 15 machines in one year. 11 of the machines were used in the "Soma" field and 4 of them were used in the "Deniş" field. The criteria used as a basis for the examination of hole drilling machine performances are working hours, number of holes, hole size, maintenance times, downtime, hourly fuel consumption and engine oil consumption. Among these criteria, working hours, number of holes, hole length were accepted as positive effect criteria, while maintenance times, downtime, hourly fuel consumption and engine oil consumption were accepted as negative effect criteria. With this study, performance ranking of 15 hole drilling machines was carried out by AHP and TOPSIS methods according to the determined criteria.

Keywords: Open pit mining, drilling machinery, analytical hierarchy process, TOPSIS

Introduction

The choices we make in our lives determine our lifestyles. Every choice made also means at least one alternative that is given up. While the right choices provide benefits, the incorrect choices appear as a cost or cost in different ways. Decision analysis is then used to assess alternatives. Multi-criteria decision-making techniques are designed to enable better selection when it comes to making complicated decisions covering different dimensions (Lin et al., 2013). A complicated problem is often explained by interminable and contradictory criteria such as efficiency, performance, safety, reliability, cost, and economy (Achillas et al., 2013). One of the known purposes of the multi-criteria decision analysis approach is to assist the people who are responsible for organizing and synthesizing such information that makes them feel confident in taking a decision. In addition, considering all criteria and factors, it aims to minimize potential regrets after a decision by ensuring satisfaction. In this analysis, classically, it is tried to make a simple choice from a set of options. These types of problems encountered in the literature care for being either discrete selection or specialization of mathematical programming problems. However, comprehensive multi-criteria decision analysis pays attention to both (Belton & Shewart, 2002). Multi-criteria decision making is explained as aimed at defining the optimum alternative among multiple, contradictory and interactive criteria (Demirel & Yücenur, 2011). The theory and method of multi-criteria decision making is used in sorting out complex problems encountered in many fields such as business, engineering and other fields of activity of human beings (Achillas et al., 2013).

Analytical Hierarchy Process (AHS) Method

The Analytical Hierarchy Process is a method developed by Thomas Saaty (1977). This method is useful in solving complex problems involving more than one criterion. The AHP method is based on a hierarchical system consisting of many objectives, criteria and alternatives. This hierarchical method works based on expert judgment with the help of pairwise comparisons of different criteria (Hillerman et al., 2017).

AHP is preferred because of the use of qualitative and quantitative data. The fact that the method is easy to apply helps the managers to find out the advantages of the criteria and sub-criteria, to choose the best supplier and to compare the efficiency of the systems

(Dağdeviren and Eren, 2001). The most obvious advantage of AHP is that complex problems can be decomposed into components and transformed into a simple structure, since a hierarchical structure is created in the application of the method. The disadvantage is that when new decision components are added to the problem, it may cause changes in the order of preference of the alternatives. It has been stated that the use of the AHP method is avoided in the case of a large number of provisions (Aydın et al., 2009).

The most important factor in the decision-making process and on the result is the modeling of the problem. Therefore, determining the decision hierarchy is critical in using the AHP method.

Creating a hierarchical structure makes it easier to solve a complex problem. Figure 1 shows the hierarchical structure of the AHP. At the highest level of the hierarchy, the goal is to establish the macro target to make the best decision. At the second level of the hierarchical structure, there are criteria that contribute to the purpose, and at the lowest level, there are decision alternatives. Alternatives help to explain the criteria, and the criteria help to explain the purpose (İbicioğlu and Ünal, 2014).

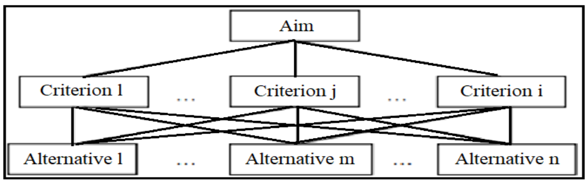

Fig. 1 Hierarchical structure

Technique for Order Preference by Similarity to An Ideal Solution (TOPSIS)

The TOPSIS method can be utilized directly on the data without making a qualitative conversion (Eleren and Karagül, 2008). The TOPSIS technique was offered by Chen and Hwang with reference to Hwang and Yoon (Wei, 2010). Although the TOPSIS method determines a solution closest to the best solution and the farthest from the negative best solution, it does not consider the relative importance of these distances (Cristóbal, 2012). The agreed solution can be accepted as the preferred solution at the shortest Euclidean distance from the best solution and the farthest Euclidean distance from the negative best solution (Tzeng and Huang, 2011). The TOPSIS literature is used mainly due to its advantages such as rationality and easy understanding, simplicity in calculation and weighting of evaluation criteria (Çakır and Perçin, 2013). The application actions of the TOPSIS method are explained below.

Step 1: Forming the Decision Matrix (A)
Step 2: Forming the Standard Decision Matrix (R)
Step 3: Forming the Weighted Standard Decision Matrix (V)
Step 4: Forming the Positive Best (A+) and Negative Best (A-) Solution Sets
Step 5: Calculating Discrimination Measures

Determination of Performance of Drilling Machines of Aegean Lignite Corporation

There are a total of 21 hole drilling machines in the Aegean Lignite Corporation, which is affiliated to the General Directorate of Turkish Coal Enterprises. 12 of these machines are INGERSOL DM50, 7 of them are REEDRIL/SK50C and 2 of them are BUCYRUS/35HR models. A total of 103,332 meters of holes were drilled with 15 machines in one year. 11 of the machines were used in Soma field and 4 of them were used in Denis field.
The criteria taken as a basis for the examination of hole drilling machine performances are working hours, number of holes, hole size, maintenance times, downtime, hourly fuel consumption and engine oil consumption. Among these criteria, working hours, number of holes, hole length were accepted as positive effect criteria, while maintenance times, downtime, hourly fuel consumption and engine oil consumption were accepted as negative effect criteria.

Determination of Performances with the Analytical Hierarchy Process

The parameters affecting the performance of a hole drilling machine have been determined by expert engineers and the most effective criteria have been put forward. As important as the total hole length of a hole drilling machine is downtime which is also negatively important in order to keep the actual working time of this machine at the maximum level. In this context, the criteria determined were evaluated within the scope of the AHP (Figure 2).

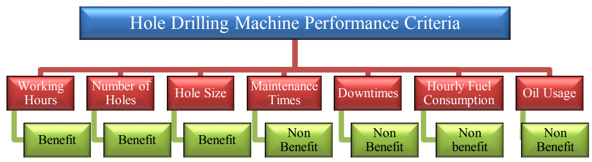

Fig. 2 Drilling machine performance criteria

Working hours, number of holes and hole length were determined as the positive performance criteria of the hole drilling machine, while maintenance times (h), downtime (h), fuel consumption (l/h) and oil usage (kg) were determined as negative impact criteria.

As a result of the evaluation made by 3 engineers who are experts in their fields, the pairwise comparison matrix was formed as in Table 1.

Table 1 Pairwise comparison matrix

	Working Hours (h)	Number of Holes	Hole Length	Mainten. Periods	Downtime	Hourly fuel consump.	Oil usage (engine)
Working Hours (h)	1.00	2.33	0.78	7.00	0.78	1.40	7.00
Number of Holes	0.43	1.00	0.33	3.00	0.33	0.60	3.00
Hole Size (m)	1.29	3.00	1.00	9.00	1.00	1.80	9.00
Maintenance Times (h)	0.14	0.33	0.11	1.00	0.11	0.20	1.00
Downtimes (h)	1.29	3.00	1.00	9.00	1.00	1.80	9.00
Hourly fuel consumption (l/h)	0.71	1.67	0.56	5.00	0.56	1.00	5.00
Oil usage (engine) (kg)	0.14	0.33	0.11	1.00	0.11	0.20	1.00

As a result of the pairwise comparison, weights were determined against the criteria (Table 2).

Table 2 Hole Drilling Machine performance criteria weights

	Weights (w)
Working hour (h)	0.20
Number of holes	0.09
Length of hole (m)	0.26
Maintenance times (h)	0.03
Downtimes (h)	0.26
Hourly fuel consumption (l/h)	0.14
Oil consumption (motor) (kg)	0.03

With the pairwise comparison made after the analytical hierarchy process evaluation, it has been revealed that hole length and downtime are the most important criteria for hole drilling machine performance, working hours are the important criteria, and maintenance times and oil usage amount criteria are the least important criteria.

Determination of Performances by TOPSIS Method

The criterion weights used in the evaluation of hole drilling machine performances were obtained from the AHS method and used in the TOPSIS method.

Step 1: Creating the Decision Matrix

A decision matrix was created for the performance of drilling machines by using the working information in question (Table 3)

Table 3 Drilling machines decision matrix (Turkish Coal Board, 2019)

	Brand-Model-Door No	Working Hours (h)	Number of Holes	Hole length (m)	Maintenance Times (h)	Downtimes (h)	Hourly fuel consumption (l/h)	Oil consumption (engine) (kg)
SOMA	Ingersoll DM50-201	531	665	9467	14	555.5	52.8	320
	Ingersoll DM50-202	215	372	5031	3.5	2212.5	53.6	148
	Ingersoll DM50-204	186	165	1775	2.5	2435	39.2	131
	Ingersoll DM50-205	231	394	3994	3	101	48.3	106
	Ingersoll DM50-209	144	485	3771	2	2484.5	38.6	152
	Reedrill SK-50-214	26	58	808	0.5	3902.5	41.6	68
	Reedrill SK-50-215	285	1342	10075	5	369	65.5	100
	Reedrill SK-50-216	275	589	7370	3.5	1102.5	60.8	45
	Reedrill SK-50-217	141	548	4249	2.5	1871	28.6	45
	Reedrill SK-50-223	533	1209	18405	9.5	587.5	71.9	226
	İngersoll DM50-224	483	935	12230	8	472	20.5	173
DENİŞ	İngersoll DM50-207	246	692	5566	6.5	837	33	45
	İngersoll DM50-208	228	499	4419	4.5	946	46.8	90
	İngersoll DM50-210	463	929	10904	6	632	37.4	90
	İngersoll DM50-211	214	513	5268	4	752	31.1	45

Step 2 Establishing the Standard Decision Matrix (Normalized)

Table 4 Normalized decision matrix

	Brand-Model-Door No	Working Hours (h)	Number of Holes	Hole length (m)	Maintenance Times (h)	Downtimes (h)	Hourly fuel consumption (l/h)	Oil consumption (engine) (kg)
SOMA	İngersoll DM50-201	0.432935	0.240591	0.298144	0.602464	0.087260	0.291580	0.588436
	İngersoll DM50-202	0.175294	0.134586	0.158441	0.150616	0.347549	0.295998	0.272152
	İngersoll DM50-204	0.151650	0.059696	0.055900	0.107583	0.382500	0.216476	0.240891
	İngersoll DM50-205	0.188339	0.142546	0.125783	0.129099	0.015866	0.266730	0.194919
	İngersoll DM50-209	0.117406	0.175469	0.118760	0.086066	0.390276	0.213163	0.279507
	Reedrill SK-50-214	0.021198	0.020984	0.025446	0.021517	0.613021	0.229730	0.125043
	Reedrill SK-50-215	0.232366	0.485524	0.317292	0.215166	0.057964	0.361714	0.183886
	Reedrill SK-50-216	0.224213	0.213095	0.232103	0.150616	0.173185	0.335759	0.082749
	Reedrill SK-50-217	0.114960	0.198262	0.133814	0.107583	0.293905	0.157939	0.082749
	Reedrill SK-50-223	0.434566	0.437406	0.579628	0.408815	0.092287	0.397057	0.415583
	İngersoll DM50-224	0.393800	0.338275	0.385159	0.344265	0.074144	0.113208	0.318123
DENİŞ	İngersoll DM50-207	0.200569	0.250360	0.175290	0.279715	0.131480	0.182238	0.082749
	İngersoll DM50-208	0.185893	0.180534	0.139167	0.193649	0.148602	0.258446	0.165498
	İngersoll DM50-210	0.377494	0.336104	0.343399	0.258199	0.099277	0.206536	0.165498
	İngersoll DM50-211	0.174479	0.185599	0.165905	0.172133	0.118127	0.171745	0.082749

Step 3 Creating the Weighted Standard Decision Matrix

It is obtained as in Table 5 by multiplying the weights obtained by the Analytical Hierarchy Process with the Normalized decision matrix.

Table 5 Weighted Decision Matrix

	Brand-Model-Door No	Working Hours (h)	Number of Holes	Hole length (m)	Maintenance Times (h)	Downtimes (h)	Hourly fuel consumption (l/h)	Oil consumption (motor) (kg)
SOMA	İngersoll DM50-201	0.086587	0.020622	0.076666	0.017213	0.0224384	0.0416543	0.016812
	İngersoll DM50-202	0.035059	0.011536	0.040742	0.0043033	0.0893697	0.0422854	0.0077758
	İngersoll DM50-204	0.030330	0.005117	0.014374	0.0030738	0.0983572	0.0309252	0.0068826
	İngersoll DM50-205	0.037668	0.012218	0.032344	0.0036886	0.0040797	0.0381042	0.0055691
	İngersoll DM50-209	0.023481	0.015040	0.030538	0.0024590	0.1003567	0.0304518	0.0079859
	Reedrill SK-50-214	0.004240	0.001799	0.006543	0.000615	0.157634	0.0328186	0.0035726
	Reedrill SK-50-215	0.046473	0.041616	0.081589	0.0061476	0.0149051	0.0516734	0.0052539
	Reedrill SK-50-216	0.044843	0.018265	0.059684	0.0043033	0.0445334	0.0479656	0.0023643
	Reedrill SK-50-217	0.022992	0.016994	0.034409	0.0030738	0.0755755	0.0225628	0.0023643
	Reedrill SK-50-223	0.086913	0.037492	0.149047	0.0116804	0.0237309	0.056722	0.0118738
	İngersoll DM50-224	0.078760	0.028995	0.099041	0.0098361	0.0190655	0.016173	0.0090892
DENİŞ	İngersoll DM50-207	0.040114	0.021460	0.045075	0.0079919	0.0338090	0.0260340	0.0023643
	İngersoll DM50-208	0.037179	0.015474	0.035786	0.0055328	0.0382119	0.0369209	0.0047285
	İngersoll DM50-210	0.075499	0.028809	0.088303	0.0073771	0.0255284	0.0295051	0.0047285
	İngersoll DM50-211	0.034896	0.015909	0.0426613	0.0049181	0.0303756	0.0245350	0.0023643

Step 4 Establishing Positive Ideal A+ and Negative Ideal A- Solutions

While determining the A+ values, the maximum values of the criteria (working hours, hole length, number of holes) that positively affect the performance of the drilling machine, and the minimum values of the criteria that negatively affect the performance of the drilling machine were selected.

A+	0.0869132	0.0416163	0.1490472	0.0006148	0.0040797	0.0161726	0.0023643
A-	0.0042397	0.0017986	0.0065433	0.0172133	0.1576341	0.0567225	0.0168125

Step 5: Calculating Discrimination Measures and Relative Closeness to the Ideal Solution

Table 5 Relative closeness to the ideal solution

	Brand-Model-Door No	S+	S-	Ci
SOMA	Ingersoll DM50-201	0.083582479	0.178878736	0.68154
	Ingersoll DM50-202	0.126682831	0.161806253	0.56087
	Ingersoll DM50-204	0.151379597	0.160018577	0.51387
	Ingersoll DM50-205	0.131946263	0.162008909	0.55113
	Ingersoll DM50-209	0.137897758	0.161822032	0.53991
	Reedrill SK-50-214	0.170347467	0.16024128	0.48471
	Reedrill SK-50-215	0.086541927	0.179529158	0.67474
	Reedrill SK-50-216	0.106421283	0.169428663	0.61421
	Reedrill SK-50-217	0.133832807	0.163390354	0.54972
	Reedrill SK-50-223	0.043953985	0.22310029	0.83541
	Ingersoll DM50-224	0.053756868	0.196090037	0.78484
DENİŞ	Ingersoll DM50-207	0.116506532	0.163665855	0.58416
	Ingersoll DM50-208	0.128247521	0.161048053	0.55669
	Ingersoll DM50-210	0.064993576	0.189875501	0.74499
	Ingersoll DM50-211	0.12154762	0.164807523	0.57554

Results and Discussion

The rankings of the hole drilling machines performed with the analytical hierarchy process and the TOPSIS method according to their performance evaluations were formed as in Table 6. In order to make an evaluation, the order of the machines according to the working hours and hole length is shown in the same table.

Table 6 Drilling machines performance ranking

	Brand-Model-Door No	Sorting by TOPSIS Method	Sorting by Working Hour	Sorting by Hole Length
SOMA	Ingersoll DM50-201	4	2	5
	Ingersoll DM50-202	9	10	9
	Ingersoll DM50-204	14	12	14
	Ingersoll DM50-205	11	8	12
	Ingersoll DM50-209	13	13	13
	Reedrill SK-50-214	15	15	15
	Reedrill SK-50-215	5	5	4
	Reedrill SK-50-216	6	6	6
	Reedrill SK-50-217	12	14	11
	Reedrill SK-50-223	1	1	1
	Ingersoll DM50-224	2	3	2
DENİŞ	Ingersoll DM50-207	7	7	7
	Ingersoll DM50-208	10	9	10
	Ingersoll DM50-210	3	4	3
	Ingersoll DM50-211	8	11	8

- Reedrill SK-50-223 hole drilling machine working in the Soma field is in the first place with the highest score.

Ingersoll DM50-224 and Ingersoll DM50-210 came 2nd and 3rd, respectively. The worst performance was machine numbered Reedrill SK-50-214.

- When the decision matrix of drilling machines (Table 6) is examined, Reedrill SK-50-223 with the highest performance is the machine with the highest working hours, the highest number of holes and the highest hole length, and Reedrill SK-50-214 with the worst performance it is seen that the machine has the least working hours, the least number of holes and the least hole length.

- When the ranking of drilling machines according to working hours is compared with the ranking made by the TOPSIS method, it is seen that most of them overlap, except for a few deviations.

- It has been determined that the ranking of the machines according to the hole length is much more compatible with the TOPSIS, therefore, when evaluating the performances of the machines, the comparison of the hole sizes will be sufficient in terms of preliminary information.

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