The effects of breakdown and delay times on TBM progress efficiency

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Based on the probability that an effective progress speed could be achieved with an efficient work plan as well as choosing the appropriate TBM (Tunnel Boring Machine) and optimum working conditions for the formation of the excavation site, the aim of this study was to determine the effects of breakdown and delay times on the progress efficiency of the TBM used in Konya Plain Irrigation Project. DEAP 2.1 (Data Envelopment Analysis Program) was employed in the efficiency measurements that adopted Data Envelopment Analysis (DEA). As a result of the analyses, inefficiency caused by delays was identified in approximately 73 % of the excavation weeks but it was also determined that the average working productivity could be increased from 24,43 % to 55,01 % by means of rehabilitation studies.

Key words: *TBM Performance, Data Envelopment Analysis, Breakdown and Delay Times*

Introduction

Human beings' needs are increasing and becoming diversified day by day due to the increase in world population and scientific and technological advancements. The significance of underground structures (e.g. tunnels, metro) has been recognized in seeking solutions to rehabilitate transportation and infrastructure facilities among multidimensional needs. Having been developed as an alternative to drilling-blasting method in building underground structures, TBM makes it possible to perform silent, non-vibrating, fast, safe and full-face tunneling.

The effective parameters in TBM performance are the technical specifications of TBM, the properties of the rock mass to be excavated and organization of the excavation site (Hassapour et al., 2009; Fuoco et al, 2009; Oraee, 2010). The primary factors in choosing the machinery and equipment to be used in a tunneling project are certainly the properties of the rock mass to be excavated and its excavability state. However, en effective progress speed can only be achieved through an efficient work plan in addition to the existing machinery specifications and working conditions. Like in all fields, despite the decreases in the efficient use of the present machinery, labor, capital, material and even time and information resources and excavation costs in this field, there could be increases in capacity utilization rates and profitability.

The mean progress speed of TBM is far lower than its net progress speed during excavation. Delays occurring during the progress of the machine, shift changes, maintenance, ground supporting and transportation are parameters that affect progress speed, and therefore performance, negatively.

Apparently, many studies conducted on TBM performances so far have only focused on the technical specifications of the machine and the properties of the rock mass to be excavated (Barton 1999, 2000; Sapigni et al., 2002; Ribachi and Lembo-Fazio, 2005; Ramezanzadeh et al., 2005; Yağız, 2007; Gong and Zhao, 2009; Hassanpour et al., 2009; Hamidi et al., 2010). On the other hand, stop and delay times due to breakdowns or the excavation process have negative impacts on the progress speed of TBM and may reduce the efficiency of the system with the potential time allocated for excavation.

Oraee (2010) states that time efficiency can be determined by dividing the time spent for all of the excavation processes by the total excavation time. However, determining efficiency/inefficiency here is just a determination of the existing state. What is required is coming up with suggestions so that efficiency can be achieved by determining the sources of inefficiency.

Efficiency analyses were carried out in this study in order to highlight the significance of TBM stop and delay times, determine their effects on the performance and come up with suggestions for rehabilitation studies. The analyses assessed the weekly data of the double shield TBM used in the excavation activities conducted between December 2008 and October 2010 to build a tunnel as a part of Konya Plain Irrigation Project (KPI).

Data Envelopment Analysis (DEA) was used in the efficiency measurements. DEA was chosen for this study because it allows for simultaneous evaluation of multiple variables and constraints together and interpreting predictive analyses and interpretations by means of a great deal of theory and methodology presented by mathematical-programming and it does not require production function (because the actual

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production function of the units subject to efficiency measurement could never be known and accurate results cannot be gained when the functional form to be established is inaccurate. Having been built on the ideas of Farrel (1957) and developed by Charnes et al. (1978), DEA is a relatively new concept in mining and tunneling sector despite its wide range of applications in many other sectors. DEAP 2.1 (Data Envelopment Analysis Program) was used in the analysis of DEA models (Coelli, 1996).

It was determined as a result of the analyses that the work performance was inefficient in 64 weeks out of the 88 weeks taken into consideration. It was concluded that by determining the sources of inefficiency breakdown and delay times could be decreased by an average of 84,533 % and working productivity could be increased from 24,43 % to 55,01 % on average.

Project description

Konya Plain Irrigation Project (KPI) is one of the biggest irrigation projects of Turkey. A yearly amount of 414,13 million m^3 water from Upper Göksu Basin normally flowing to the Mediterranean will be transferred to Konya closed basin by means of the three dams (Bağbaşı, Afşar and Bozkır) and a tunnel to be built as a part of the project. The water transferred is projected to support both the underground waters of Konya Plain and a total of 223410 hectares agricultural land. Also, a yearly energy production of 147,5 million kWh will be carried out by three hydroelectric power plants with 50,6 MW installed capacity power.

The tunnel to be bored in the project is 110 km from Konya and 25 km from Bozkır county center. Although tunnel-boring studies were launched in 6 July 2007, the first excavation activity with TBM started in December 2008. The length of the bored tunnel had reached 10132 meters by October 2010. The projected total length of the tunnel is 17034 m and the projected capacity is 36 m^3/sec.

A double shield TBM is used in this project (Fig. 1). The digging is performed by the flat rotating cutterhead equipped with 17≡ disc cutters. Technical specifications of the TBM are given in Table 1.

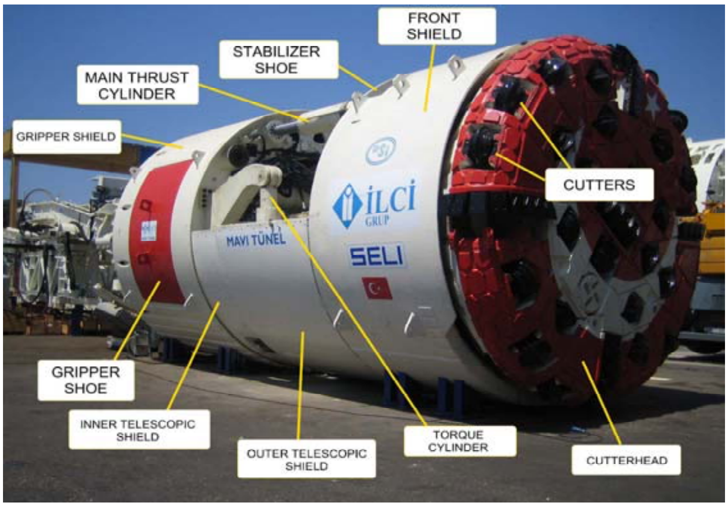

Fig. 1. Double shield TBM at the ET portal.

Problem formulation and mathematical model

In order to determine the effects of TBM breakdown and delay times on progress length, efficiency analysis was chosen among performance indicators. Efficiency can be defined as gaining maximum output with a certain input combination within the existing technology or producing an output combination with minimum input.

Parametric efficiency measurements (e.g. regression analysis) assume that the production functions of fully efficient units are known. On the other hand, since production function is never known in practice, (Farrell (1957) suggested estimating the function by using the data in the sample. The suggestion was first appreciated by Charnes et.al (1978) and this led to the emerge of a non-parametric efficiency measurement method called Data Envelopment Analysis.

DEA is a linear programming-based technique aimed at determining the relative level of efficiency of units (Decision Making Units = DMU) performing the same production activities when it is difficult to compare multiple inputs and outputs measured with different scales or those with different measurement units.

The first step in this analysis is to determine an enveloped surface (efficient frontier) that covers the linear combinations and efficient observations of the decision making units. Then the efficiency scores and radial distances of inefficient units within the enveloped surface from the center are calculated (Muniz, 2002). Unlike parametric methods involving an average technological application, this analysis method makes comparisons based on the best technological application (Grosskopf, 1986; Seiford, 1996).

The most significant advantage to this method is its capability of defining each decision-making unit's inefficiency amount and sources. This property of the method and could assist managers in deciding how much to decrease their inputs and/or increase their outputs so that inefficient units could become efficient.

Developed by Charnes et al (1978) and constituting the base of DEA, CCR model was developed under the assumption of constant return to scale and is used to determine Overall Technical Efficiency scores. In constant return to scale, any radial increase in input vector (an increase of all the input combinations by the same percentage) yields a radial increase in output vector by the same percentage. In other words, variations in production scale do not affect productivity.

Tab. 1. TBM technical specifications.

Machine	:	**Double Shield 0488 120**
Type	:	Telescopic double shielded TBM
Boring diameter	:	4880 mm
Minimum curve radius	:	400 m
Weight	:	Approx. 390 tons (570 with back-up)
Length	:	11.2 m (TBM); ~ 165 m (TBM + back-up)
Maximum penetration rate	:	10 m / hour (at reduced pressure)
Number of back-up decks	:	21

Cutterhead	:	**Flat design with 17" disc cutters and plates**
Maximum recommended thrust	:	8544 kN (32 x 267 kN)
Rotation speed	:	0 to 10.9 rpm (continuously variable)
Drive power	:	6 x 315 kW

In DEA, there are two alternative ways of calculating the relative efficiency of decision making units. The first one is "the output-oriented data envelopment analysis", which makes it possible to obtain a maximum amount of output with a certain combination of input. The second one, on the other hand, is "the input-oriented data envelopment analysis", which makes it possible to gain a certain amount of output with a minimum amount of input (Al-Shammari, 1999). Considering the fact that delay times during the excavation had negative effects on the TBM's progress, it was thought that keeping the amount of outputs constant and minimizing inputs would be appropriate and the study employed input-oriented CCR model.

The symbols used in the formulation of non-parametric linear programming model (DEA) are defined below:

n - number of decision making units where comparison is realized,
s - number of outputs gained from production,
m - number of inputs used in production,
$k = (1,2,\ldots,n)$ set of decision making unit considered,
$j = (1,2,\ldots,n)$ set of all decision making units,
$r = (1,2,\ldots,s)$ set of all outputs,
$I = (1,2,\ldots,m)$ set of all inputs,
θ_k - scaler variable (efficiency value) trying to increase all inputs of k DMU considered to gain the best frontier,
λ - the vector of density variables giving inputs-outputs weight averages = $k\times 1$,
λ_{jk} - the relative weight value (compared to other units, j) of "k" decision unit measured for efficiency in input-oriented,
Y_{rj} - the r^{th} output amount produced by j decision making unit,
Y_{rk} - the r^{th} output amount produced by k decision making unit,
Y_{rk}^* - the arranged r^{th} output amount of k decision making unit,
s_{rk}^- - slack value (the output not produced in sufficient amounts) of the r^{th} output of k decision making unit (which cannot be measured with DEA in "radial" terms but can be increased),
X_{ij} - the i^{th} input amount used by j decision making unit,
X_{ik} - the i^{th} input amount used by k decision making unit,
X_{ik}^* - the arranged i^{th} output amount of k decision making unit,
s_{ik}^+ - slack value (controllable input used in excess) of the i^{th} output of k decision making unit (which cannot be measured with DEA in "radial" terms but can be increased).

The following is the mathematical expression of input-oriented CCR model (Charnes et al., 1978):

Objective function

$$\min \theta_k \tag{1}$$

In models established for efficiency measurement to be performed under input minimization, the aim is to keep outputs constant but inputs at a minimum level.

Subject to

$$\sum_{j=1}^{n} \lambda_{jk} \cdot Y_{rj} - s_{rk}^{-} = Y_{rk} \qquad ; r = 1,2,...,s \tag{2}$$

$$\sum_{j=1}^{n} \lambda_{jk} \cdot X_{ij} + s_{ik}^{+} = \theta_k \cdot X_{ik} \qquad ; i = 1,2,..,m \tag{3}$$

$$\lambda_{jk}, s_{ik}^{+}, s_{rk}^{-} \geq 0 \qquad ; \forall i, r, j \tag{4}$$

Constraint (2) sets involve comparison of the outputs kept constant in DEA carried out under input minimization. With this constraint, r^{th} output of each j DMU will not be greater than the maximum linear combination of the units constituting the efficient frontier. The constraints where minimization is sought for the inputs in inefficient DMUs are shown in the equation (3). It will be possible to measure i^{th} input of each j DMU with a level of input lower than the one formed with weighted linear combination of the i^{th} input used by all of the units. Also, as stated in constraint (4), the weight value of each decision making unit and the slack variables of input and output sets should not be negative.

In order for a DMU to be considered efficient,

- optimal θ_k has to be equal to 1 and
- all slack variable scores have to be zero ($s_{ik}^{+}, s_{rk}^{-} = 0$).

Sensitivity analyses are used to determine how much to decrease inefficient units' inputs or increase their outputs so that these units, which are identified to be inefficient by analysis results, could become efficient.

By means of the sensitivity analyses conducted by the formula (5) below, it was possible to determine the breakdown and delay times that needed decreasing and the progress lengths that needed increasing despite the existing times.

$$X_{ik}^{*} = \theta_k \cdot X_{ik} - s_{ik}^{+} \tag{5}$$

Application

Data and Variables

In order to determine the effects of the time losses due to the TBM breakdowns and delay times caused by the excavation procedure on the excavation progress length, analyses assessed the weekly data of the TBM used in the excavation activities conducted between December 2008 and October 2010 as a part of Konya plain irrigation project. On the other hand, the weeks when the excavation activities couldn't be performed due to official holidays were excluded from the analysis.

The weekly Progress of the Excavation (meter/week) was taken into consideration as output. However, TBM Mechanic Breakdown, TBM Hydraulic Breakdown, TBM Electrical breakdown, Back-up Mechanic Breakdown, Back-up Hydraulic Breakdown, Back-up Electrical breakdown, Other Breakdown, No Train, No Electric Power, No Water +Ventilation, Tunnel Lines Extension, Cutterhead Care, Ring Erection Delay, Pea-gravel Injection Delay, External+Other Delay are input parameters. These parameters (hour/week) represent the weekly breakdowns and delays caused by other factors (Tab. 3).

A modern TBM's structure consists of cutterhead, thrust cylinders, steering cylinders, grippers, cutterhead motors, soil control and support systems, ring beam erectors, transportation of excavated material, ventilation and power supply units (Köse et al., 2007).

The back part of TBM, which is called back-up systems consists of stock of high-voltage electric cables, ventilation equipment, track laying equipment, water and drainage lines, segments and the lifting transport units, cabs jumbo, belt conveyors and wagons for the transport of excavated material. Back-up mechanic, back-up hydraulic and back-up electrical breakdowns refer to the breakdowns occurring in these systems. The factors causing the breakdown and delay times taken into consideration in the analyses are given in Tab. 2.

Sets and parameters

The following parameters were used:

n - the weeks of the excavation process between December 2008 and October 2010 (1, 2, 3, …, 87, 88),

s - the number of outputs used in analysis (weekly progress meters of TBM),

m - the number of inputs used in analysis (TBM Mechanic, TBM Hydraulic, TBM Electric, Back-up Mechanic, Back-up Electric, Back-up Hydraulic, Other Breakdown, No Train, No Electric Power, No Water

+Ventilation, Tunnel Lines Extension, Cutterhead Care, Ring Erection Delay, Pea-gravel Injection Delay, External+Other Delay),

k = (1,2,….,88) the set of decision-making units referred,
j = (1,2,….,88) the set of all decision-making units,
r = (1) the set of all outputs,
i = (1, 2, 3, 4….., 15) the set of all inputs.

Empirical Results

By means of DEAP, all inputs taken into consideration by keeping TBM progress lengths (outputs) constant were compared with each other and the weeks with the least time loss (caused by breakdown and delay times) and the weeks with the most progress (efficient weeks) were determined.

When the results presented in Tab. 4 were examined, it was found that these weeks were fully efficient because they achieved the longest excavation distance despite the breakdown and delay times occurring in weeks 11, 12, 22, 26, 27, 28, 35, 39, 40, 42, 44, 45, 48, 49, 50, 53, 54, 55, 61, 63, 64, 79, 85 and 87 ($\theta_k = 1{,}000$ and $s_{ik}^{+}, s_{rk}^{-} = 0$).

Week 2 was found to be the most inefficient week with an efficiency score of 1,3 %. The inefficiency in that week was caused by the fact that cutterhead care and ring erection took long while excavation progress distance was the least among other weeks. Sensitivity analyses were carried out in order to come up with recommendations for solution to eliminate the causes of inefficiency. The extent to which breakdown and delay times should be decreased so that inefficient weeks could become efficient was also determined.

Tab. 2. The factors that cause breakdowns and waiting times.

	Down-Time	Factors that Cause Down-Time
Breakdown	TBM Mechanic	Conveyor belt, segment erector, cutter head disc, cylinder and shield breakdown
	TBM Hydraulic	Erector hydraulic, lubrication system, gripper shield and cylinder, hydraulic system breakdown
	TBM Electric	Erector electrical, cable laying and breakdown, Lube electrical breakdown
	Back-up Mechanic	Rail and train, conveyor belt, power unit breakdown
	Back-up Electric	Segment crane electric cable breakdown, general electrical breakdown, conveyor belt electrical breakdown
	Back-up Hydraulic	Erector breakdown of hydraulic hose, hydraulic hose breakdown of the carrier segment, the TBM and Lube conveyor hydraulic breakdown
	Other Breakdown	Belt breakdown (rip, stopping, sliding, compression, cleanliness), wagon and rail breakdown (wagon and back-up car derailment, etc.).
Delay	No Train	Segment loading and unloading, evacuation of mud cars, derailment of wagons in California switch and roads, train maneuver (change in spring) waiting for
	No Electric Power	No electric power, adding medium-voltage cable
	No Water +Ventilation	Water supply interruption, water hose and pipe breakdown, cleaning the fan, filter change and breakdown
	Tunnel Lines Extension	Ray, electric cable and water pipe insertion
	Cutterhead Care	TBM cutterhead care
	Ring Erection Delay	The segment carrying crane failure, segment breakdown (breakage, incorrect position of segment), much excavation, etc.
	Pea-gravel Injection Delay	Pea-gravel pump and hose breakdown (clogging the hose, and change), pea-gravel injection in the installed rings
	External+Other Delay	Derailment of train and back-up system, etc. waiting due to breakdown conveyor belt

Tab. 3. Statistics for output and input data used in the analysis.

	Output [m]	**Inputs** [h]														
	Weekly Progress of the Excavation	**TBM Mechanic Breakdown**	**TBM Hydraulic Breakdown**	**TBM Electrical breakdown**	**Back-up Mechanic Breakdown**	**Back-up Hydraulic Breakdown**	**Back-up Electrical breakdown**	**Other Breakdown**	**No Train**	**No Electric Power**	**No Water +Ventilation**	**Tunnel Lines Extension**	**Cutterhead Care**	**Ring Erection Delay**	**Pea-gravel Injection Delay**	**External+Other Delay**
Max.	221,34	67,65	32,80	21,55	33,10	5,85	10,45	25,15	32,75	35,20	37,20	13,00	144,00	608,00	4,50	34,40
Min.	1,95	0,10	0,05	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
Standard Deviation	55,29	12,37	6,79	4,78	4,27	1,06	1,85	4,46	6,20	5,00	4,46	1,39	28,32	64,77	0,89	7,38
Average	115,14	7,12	3,93	4,45	1,89	0,53	1,05	2,34	2,29	2,35	1,95	0,28	9,50	7,35	0,54	3,48
TOTAL	9470,93	592,23	335,55	377,75	161,30	40,05	90,65	203,55	194,10	243,90	133,30	16,60	1982,40	38,45	40,55	286,25
		4736,63														

It was determined that the time spent for cutterhead care should be reduced from 3 hours to 0,001 hours by a decrease of 98,96 % and the procedure for ring erection should be reduced from 6,80 hours to 0,001 by a decrease of 99,98 % so that Week 2 could become efficient. In other words, in order for this week to be efficient, there should be no delay in this week in comparison with the progress distances taken in other excavation weeks.

The percentages by which all of the inefficient weeks should reduce their inputs to become efficient were determined but considering the fact that it wouldn't be possible to present all of these determinations in this article, the statistical scores of the results were given in Tab. 5. As can be seen in Tab. 5, inefficient weeks could become efficient by reducing breakdown and delay times by an average of 84,533 %.

As a result of the studies carried out by the company, it was found that the number of total working hours was 13094 but the number of net working hours was 3199. The hours when there was no work (13094-3199=9895) equals to the total of unavoidable delay times (standard duration spent for TBM care and so on) together with the total of time losses caused by breakdown and delays. According to Tab. 4, since the time loss caused by the total breakdown and delay was nearly 4737 hours, unavoidable delay would be 5158 hours (9895-4737). In light of these data, the working productivity was calculated as 24,43 % (3199 /13094).

Tab. 4. Efficiency values obtained from the analysis.

	DMU [Week]	Efficiency [θ]		DMU [Week]	Efficiency [θ]
2008 December	1	0,161		46	0,383
	2	0,013	**2009 December**	47	0,814
2009 January		-		48	1,000
		-		49	1,000
	3	0,047		50	1,000
	4	0,105	**2010 January**	51	0,949
	5	0,550		52	0,428
2009 February	6	0,499		53	1,000
	7	0,820		54	1,000
	8	0,559		55	1,000
	9	0,948	**2010 February**	56	0,960
2009 March	10	0,661		57	0,962
	11	1,000		58	0,940
	12	1,000		59	0,798
	13	0,707	**2010 March**	60	0,469
2009 April	14	0,756		61	1,000
	15	0,905		62	0,731
	16	0,847		63	1,000
	17	0,698	**2010 April**	64	1,000
	18	0,821		65	0,442
2009 May	19	0,578		66	0,038
	20	0,517			-
	21	0,588	**2010 May**	67	0,068
	22	1,000			-
2009 June	23	0,821			-
	24	0,468			-
	25	0,732		68	0,066
	26	1,000	**2010 June**		-
2009 July	27	1,000		69	0,311
	28	1,000		70	0,752
	29	0,946		71	0,054
	30	0,339	**2010 July**	72	0,537
		-		73	0,225
2009 August		-		74	0,210
	31	0,169		75	0,399
	32	0,878		76	0,435
	33	0,745	**2010 August**	77	0,738
2009 September	34	0,831		78	0,682
	35	1,000		79	1,000
	36	0,736		80	0,390
	37	0,555	**2010 September**	81	0,396
2009 October	38	0,623			-
	39	1,000		82	0,544
	40	1,000		83	0,622
	41	0,910	**2010 October**	84	0,582
	42	1,000		85	1,000
2009 November	43	0,944		86	0,907
	44	1,000		87	1,000
	45	1,000		88	0,581

(θ=1,000 value refer to efficient weeks).

It was found as a result of the analysis that 4737 hours were reduced to 733 hours approximately because the breakdown and delay times decreased by 84,533 % on average. The number of the hours when there was no work would be 5891 (5158+733) in this case. The new net working hours, on the other hand, could be estimated as 7203 (13094-5891). As a result, it was determined that the new working productivity reached 55,01 % (7203/13094) by reducing the breakdown and delay times by the determined percentage. In order to increase working productivity even more, it is required that a study be conducted on unavoidable delay times and these times be improved.

In addition, the reduction percentages of the breakdown and delay times that were taken into consideration were examined based on all of the efficient and inefficient weeks and the sources of inefficiency were analyzed. The most effective ones among the factors influencing the weekly efficiency of the TBM were delay times caused by hydraulic breakdowns (47,651 %) and lack of water+ventilation (40,997 %) followed by those caused by TBM mechanic breakdowns, TBM electrical breakdowns, external+other delays and back-up mechanic breakdowns. On the other hand, it was determined that the time spent for tunnel lines extensions had the minimum impact on the inefficiency by 3,299 % (Fig. 2).

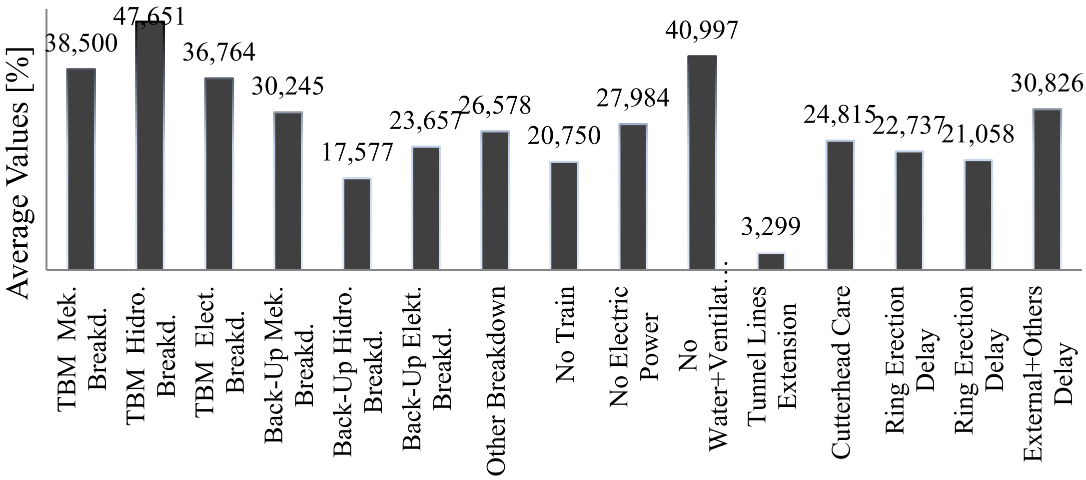

Fig. 1. The average values of sources inefficiency.

Conclusion

This study was conducted in order to determine the impacts of breakdown and delay times on the progress efficiency of the TBM used in the tunneling activities of Konya plain irrigation project. The study identified inefficiency based on time loss in 64 weeks out of 88 excavation weeks.

It was concluded that through sensitivity analyses breakdown and delay times could be decreased by an average of 84,533 % and by means of the average decrease rate, working productivity determined by the company could be increased from 24,43 % to 55,01 % on average. It was also found that in order to increase working productivity even more, it is required that a study be conducted on unavoidable delay times and these times be improved.

As a result of the analysis based on the reduction percentages of the breakdown and delay times of all of the efficient and inefficient weeks, it was found that the efficiency was caused by TBM hydraulic breakdowns and lack of water+ventilation most while the times spent for water +drainage lines had the minimum impact on the inefficiency by 3,299 % (Fig. 2).

In order to eliminate inefficiency state, the machinery and equipment used in excavation should be serviced in proper intervals and possible breakdowns should be detected and prevented in advance. Also, in order to repair the breakdowns that might occur despite the precautions as soon as possible, it is vital that enough spare parts and qualified personnel are present in the site.

An effective working organization is required to minimize unavoidable delay times when there is no work due to procedures. Therefore, there will be reductions in excavations costs while capacity utilization rates and profitability will increase. Despite the efforts to obtain information about the properties of the rock masses to be excavated, a sufficient number of preparations may not be made due to financial factors and there may be unexpected situations during the excavation. A detailed initial study should be carried out to avoid this type of problems or, if they cannot be avoided, to solve those problems as soon as possible and with minimum cost. Finally, the probability of external factors not caused by the system such as electricity and water cuts should be examined and necessary precautions should be taken.

Tab. 5. Recommended reduction rate statistics of breakdown and delay times based on sensitivity.

	Proposed Reduction of Rates [%]															AVERAGE
	TBM Mechanic Breakdown	**TBM Hydraulic Breakdown**	**TBM Electrical breakdown**	**Back-up Mechanic Breakdown**	**Back-up Hydraulic Breakdown**	**Back-up Electrical breakdown**	**Other Breakdown**	**No Train**	**No Electric Power**	**No Water +Ventilation**	**Tunnel Lines Extension**	**Cutterhead Care**	**Ring Erection Delay**	**Pea-gravel Injection Delay**	**External+Other Delay**	
Max.	99,900	99,830	99,590	99,680	99,040	99,660	99,590	99,870	99,980	99,420	99,570	99,990	99,980	98,260	99,850	
Min.	5,200	20,000	9,090	5,400	45,200	4,000	4,000	37,860	9,600	5,625	93,880	44,610	41,780	16,860	24,500	
Standard Deviation	27,631	16,612	25,873	21,977	13,188	24,394	29,797	16,282	26,885	23,965	2,846	16,552	14,530	19,271	20,363	
Coefficient of Variance	34,252	18,224	35,988	26,423	14,494	29,295	40,768	17,833	33,844	29,892	2,941	18,191	16,702	23,919	23,270	
Average	80,670	91,159	71,895	83,173	90,989	83,272	73,090	91,301	79,438	80,171	96,773	90,989	86,995	80,568	87,506	84,533

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