Influence Of Bulldozer Delays On Effective Time Of Work In Surface Mining

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***Abstract*—Aim of this paper is to show existing or non linear correlation between individual delays of a bulldozer and years of using as well as a total effective time of the bulldozer work. Also, it will be determined major and minor delays which have influence on the effective time of work. For that purpose it was used measured data at the pit mines Banovici Bosnia and Herzegovina for period from 2006 to 2012. Waiting for repair of machinery, rest and reserve are changeable delays trough years of using the bulldozer KAM-1. Delays because of reserve, conditions and oil show the linear correlation trough years of using. Major delays are waiting for repair of machinery, machine repair, rest and reserve. The linear correlation between delays and effective time of work show next delays: service, machinery repair, rest and technical overview. All these parameters will be helpful in process decision making for selection proper equipment, modality of equipment repair, etc. It is possible to improve productivity and cost efficiency as well as correctly decision making.**

Keywords—surface mining, delays, bulldozer, statistical analysis, correlation, regression coefficient, cost efficiency, productivity

I. Introduction

Statistical analysis is a very powerful tool for engineering calculations (Lewis, E.E.; Gijbels, I. and Prosdocimi, I., 2010) and process decision making (Cebesoy et al., 1995; Saty,T.L., 1990; Bascetin, A., 2009; Massawe, A. and Baruti, K., 2011a, 2011b). According to many authors from the field of mining industry, correct statistical analysis can help in all process of exploitation of mineral raw materials (Massawe et al., 2011a, 2011b; Karacan, C.Ö. and Goodman, G.V., 2011; Wei, G., 2011; Wen-bing, G., 2008; Dougherty et al., 2010; Toraño et al., 2000; Hawkins, J.W., 2004; Kapageridis et al., 2009; Ortiz, R. and Silva, R.M., 2009; Coleman, P.J. and Kerkering, J.C., 2007; Chadwick, J., 2008; Williams, A.; Jambrik, R., 2006; Tatiya, R.R., 2005). One of an important process in surface mining is auxiliary works with huge participation in an overall cost of production of raw material (Scott et al., 2010; Çetin, N., 2004; Nuric, S. and Nuric, A., 2004; Nuric et al., 2005; Nuric et al., 2006; Nuric et al., 2007; Nuric et al., 2009; Ta et al., 2005; Tatiya, R.R., 2005). Any kind of increasing these costs get to decreasing productivity and economical cost effectiveness of the pit mine. Because of that, it is interesting to research delays in process of the exploitation.

Surface mining is complex of many mining operations like drilling, blasting, loading, hauling, transportation, separation, etc (Nuric et al., 2008; Scott et al., 2010; Jambrik, R., 2006; Bascetin, A., 2004). Transportation is one of the most expensive processes at surface mining. Analysis of the auxiliary equipment (bulldozer KAM-1) delays for surface mining can help in process of decision making for better work and cost effectiveness at the pit mines (Rajesh et al., 2005). Whatever, statistical analysis can be useful tool in process of selection optimal equipments for exploitation at the pit mine (Cebesoy et al., 1995; Bascetin, A., 2009; Massawe, A. and Baruti, K., 2011; Bascetin, A., 2004; Michiotis et al., 1998; Burt et al.; Komljenovic, D. and Kecojevic, V., 2009; Project documentation from Brown Coal Mine (BCM) Banovici).

II. Research Design

For analysis used the operational measured data set from field of observation at Banovici BCM in Banovici [41]. Delays for bulldozer KAM-1 trough years of observation (2006-2012) are presented in Table 1. Statistical data set was grouped into 9 columns depending on type of the delay and 7 rows depending on year of observation. Linear correlations and regression analysis with relationship data delays-years and delays-total effective time of bulldozer work were performed. The equations with r-square are given for all correlation relations.

The first hypothesis:

H1: Major impacts on total time of delays have delays because of waiting on repair of equipment and repair of equipment.

TABLE I. DELAYS FOR BULLDOZER KAM-1

DELAYS (h) KAM-1													
Year	Year of production	Service	Oil	Waiting for repair of machinery	Machinery repair	Technical overview	Conditions	Reserve	Holiday	Rest	**Total delays h**	**Total Eh**
2012	2003	8	0	1912,5	3597,5	8,5	2	226,5	0	213	9983	1518,5
2011		77,5	30,5	638	2188	71,5	28	1322	24	661	7051,5	3200,5
2010		52	23,5	1039,5	1799,5	57,5	55	857,5	48	851	4802	3958
2009		70,5	7,5	344	921	52,5	21	1411	24	1028	4045	4715
2008		74	34,5	327,5	1800	49,5	10,5	735	8	1058,5	4097,5	4686,5
2007		57	43	1785	2392,5	37,5	16,5	56,5	72	644	5114	3646
2006		158,5	52,5	341,5	433,5	113,5	3,5	92,5	48	1257,5	2501	6259
Total		497,5	191,5	6388	13132	390,5	136,5	4701	224	5713	37594	27983,5
Mean		71,07	27,36	912,57	1876	55,78	19,5	671,6	32	816,14	5370,57	3997,64
s (standard deviation)		45,15	18,69	688,5	1027,3	32,15	18,19	565,7	25,29	345,75		

The second hypothesis:

H2: Values of delays do not change through years of using equipment.

The third hypothesis:

H3: Total effective time of work of equipment at pit mine grows with reduction of the delays.

III. RESULTS AND DISCUSSION

A. Data Analysis for Relation Delays-Years

In this chapter have been presenting the results of statistical analysis. The hypothesis H1: Major impacts on total time of delays have delays because of waiting on repair of equipment and repair of equipment was tested. Figure 1 presents distribution of delays trough years of observation. It can be seen that the most significant influences have delays because of machine repair (repair of equipment KAM-1), waiting for the repair of machinery and rest for all years except for 2006.

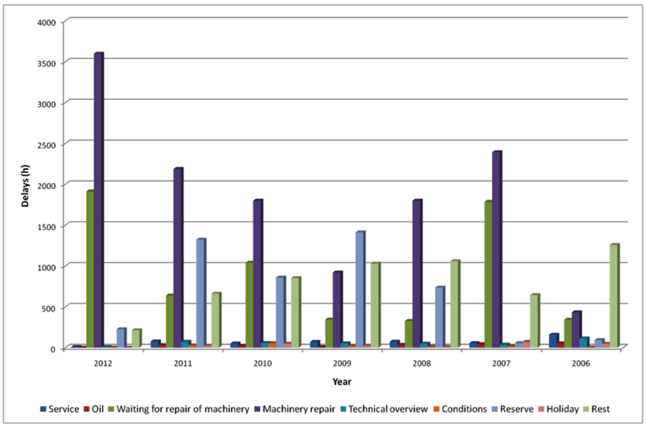

Fig. 1. *Distribution of delays trough years for bulldozer KAM-1*

Estimation was performed for proving second hypothesis: H2: Values of delays do not change through years of using equipment. Fig. 2 presents distribution of averaged values of separate delays with per cent in total time of delay.

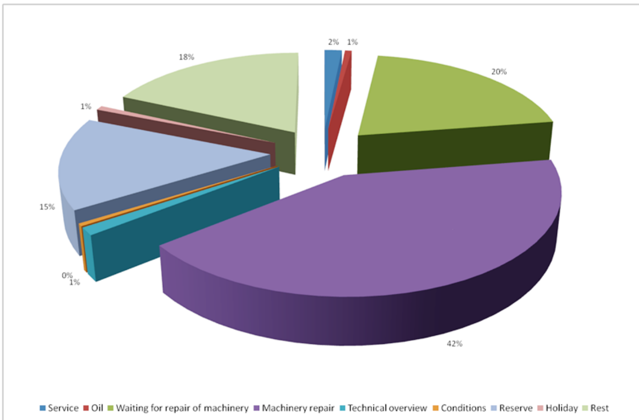

Fig. 2. *Distribution of averaged values of separate delays in total time of delay*

Fig. 3 shows change of all delays trough years of observation. It is evident that the extreme values and changes in the hours following a deadlock delays are: waiting for repair of machinery, reserve and rest. Other time of delays do not significantly differ over the years of exploitation.

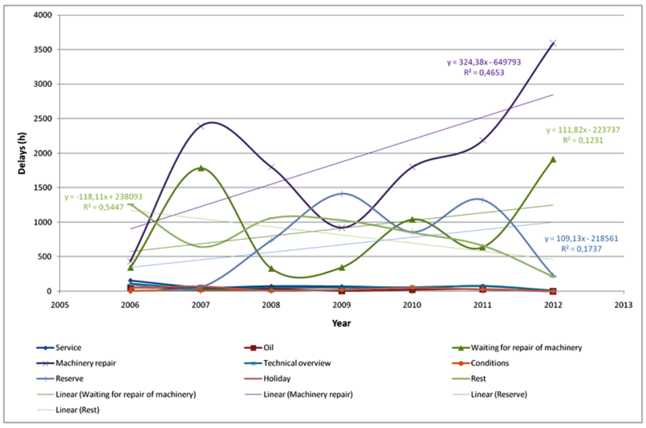

Fig. 3. *Linear correlation between all delays and year for bulldozer KAM-1*

The correlation coefficients and the corresponding equations were obtained by correlation analysis for each of these delays. From Table 2, Fig. 4 and Fig. 6 are evident that strong linear relationships have been generated because of delays due to waiting on oil, working conditions and reserve. Times of delays because of these parameters are established regardless of the using machine. Other delays do not show linear dependence of the changes through time, i.e. prove that during the operation affects these delays.

TABLE II. VALUES OF CORRELATION COEFFICIENT FOR LINEAR RELATION DELAYS-YEAR

Delays	Service	Oil	Waiting on machinery repair	Machinery repair	Technical review	Conditions	Reserve	Holiday	Rest
r^2	0,55	0,64	0,12	0,47	0,33	0,07	0,17	0,37	0,55

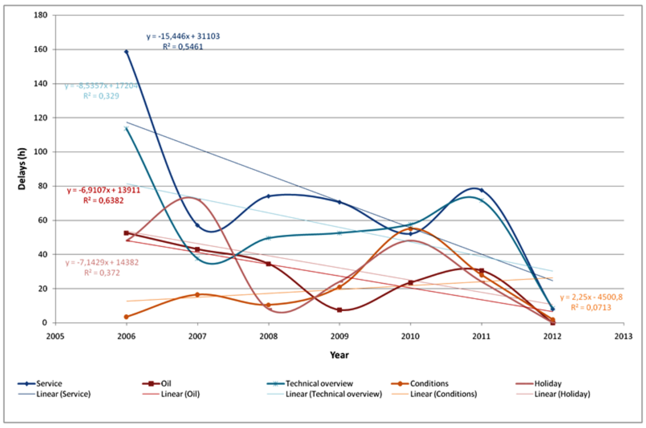

Fig. 4. *Linear correlation between minor delays and year for bulldozer KAM-1*

Selected delays of major impact were analyzed with polynomial regression (Fig. 5), where it is possible to see that the correlation coefficient increases with higher degree of polynomial functions (Fig.6). For more accurate analysis would be necessary to take into consideration some of the factors that could affect on these delays to determine the optimal, i.e. those factors with the greatest influence on delay. Thus, we could make corrections trough defined factors and reduce delays during the total operating time of machines at the pit mine.

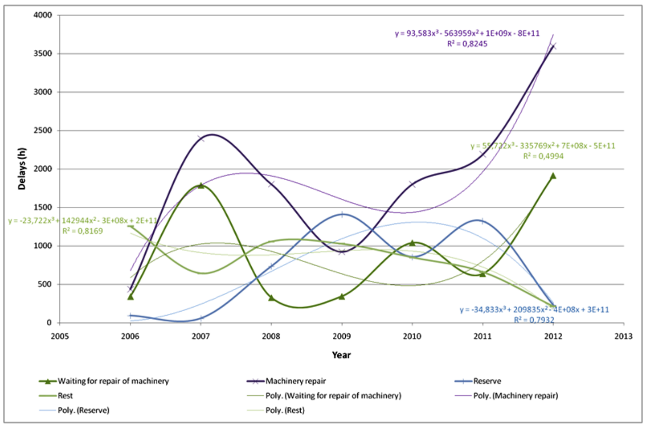

Fig. 5. *Polynomial correlation between mayor delays and year for bulldozer KAM-1*

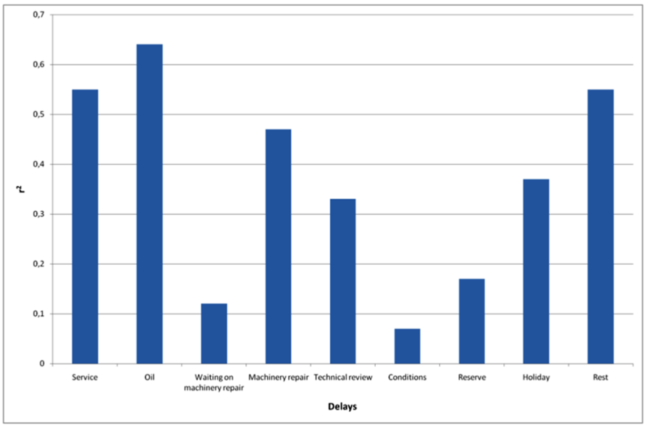

Fig. 6. *Values of correlation coefficient for bulldozer KAM-1*

B. Data Analysis for Relation Delays-Effective Time of Work

Upon the same principle determining factor of smaller and greater importance were made individual dependency diagrams delays vs. the effective time of work. They give the impact of certain delays in the effective time of machines, as well as the strength of this influence for testing third hypothesis: H3: Total effective time of work of equipment at pit mine grows with reduction of the delays. Linear dependence indicates that delays because of waiting for service and rest are in positive relation to the total effective time, i.e. with increasing delay there is increasing effective time of work, while the other modes are not (Fig. 7).

Linear correlation between the major important delays and the effective operation time was showed that there is negative strong correlation for delays due to repairs of machinery (Fig. 7). The affect of delays due to reserve, condition, holidays and waiting on oil have not interpreted with the linear relationship i.e. there are additional factors affecting on the effective operating time associated with these delays (Table 3, Fig. 7 and Fig. 8).

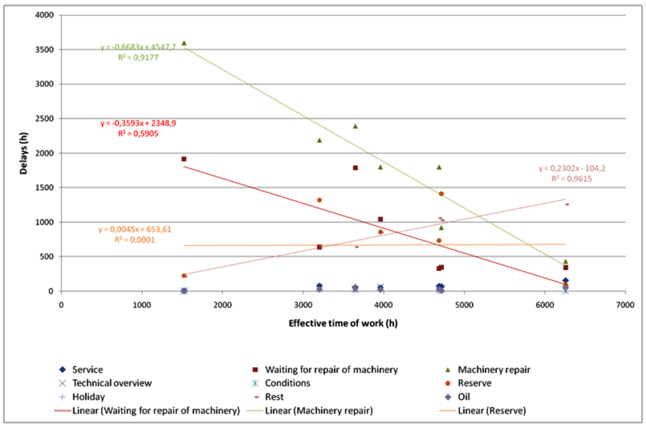

Fig. 7. *Linear correlation between delays and effective time of work*

TABLE III. VALUES OF CORRELATION COEFFICIENT FOR LINEAR RELATION DELAYS-EFFECTIVE TIME OF WORK

Delays	Service	Oil	Waiting on machinery repair	Machinery repair	Technical review	Conditions	Reserve	Holiday	Rest
r^2	0,8	0,42	0,59	0,92	0,68	0,001	0,0001	0,14	0,96

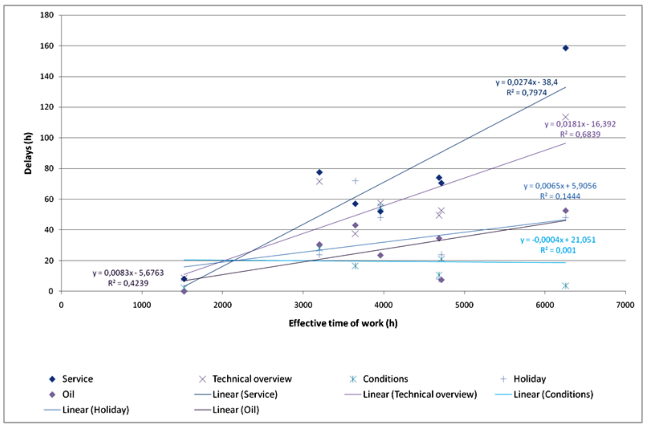

Fig. 8. *Linear correlation between effective time of work and delays minor values*

IV. Conclusion

With this paper is showed that is possible to make decision about factors of major and minor influence on total delays of transportation equipment and effective time of work these equipments at the open pit mine. For that purpose it was used Microsoft Excel software, although it is possible to use any other software for statistical estimation [12, 14]. Which of these factors have strong linear correlation and which have polynomial correlation? Based on performed statistical analysis it can be concluded following:

1. Observing the relationship of individual delays through years of observations: a) Significant participation of some delays in the total delays through years of using bulldozer have the following delays: waiting for the machine repair, machine repair, reserve and rest.

b) It is evident that the extreme values and changes in hours of delays through years of using bulldozer have the following delays: waiting machines on repair, reserve and rest.

c) Observing delays through years of work the bulldozer KAM-1 and their linear correlation relationship can be established that a strong linear relationship achieved: delays due to waiting on oil, working conditions, reserve and service. Specifically this means that these parameters are established regardless of the time delays due to machine of using.

d) Linear weak relationship shows delays due to waiting for the repair of machinery, machine delays due to repairs, delays due to breaks and rest as well as delays due to holidays.

e) A polynomial regression with third order polynomial provides a satisfy R^2 for these delays (those with weak linear relationship). It is obvious that two more factors influencing on their delays during the years of observation. The discovery of these unknown factors would significantly affect the total downtime bulldozer mark KAM-1.

2. Observing relationship between the individual delays and the effective time of work for the bulldozer follow:

a) The biggest change in the relationship between delays and the total effective time of work through years of observation showed delays due to: waiting on machine repair, machine repair, rest and reserve. Linear relationship for this case shows: repair of machinery as well as rest.

b) Less significant delays to the total effective time of bulldozer work have delays due to: service, oil, technical review, conditions and holidays. Linear relationship for this case shows the following delays: waiting for the technical review and waiting for service.

Finally, performed estimations showed that hypothesis 1 'Major impacts on total time of delays have delays because of waiting on repair of equipment and repair of equipment.' is supported, except for year 2006.

Hypothesis 2 'Values of delays do not change through years of using equipment.' Analyses are showed extremely changes of some delays trough years of observation like waiting for repair of machinery, reserve and rest. Other time of delays do not significantly differ over the years of exploitation. This is expected and has logical explanation; since the equipment is older it has more ageing faults and there are needs for supply reserve parts so there are big value of delays because of waiting on repair, and reserve. Also, age-factor has influence on the bigger time of rest and other undefined factors for delays.

Testing third hypothesis H3: 'Total effective time of work of equipment at pit mine grows with reduction of the delays.' showed that it is proven only for delays owing to waiting for repair of machinery, machinery repair, reserve, conditions and holidays. Other delays have not expected influence on effective time of operational bulldozer work KAM-1. That can be explained with facts that with quality made service and technical overview it is possible to improve quality of bulldozer work. Although, with effective planned time of loading with oil in bulldozer and operator rest it is possible to increase effective time of work.

To improve research in this field it is necessary to obtain more quantities of measured data, to apply multi-variant correlation analysis with polynomial relationship between correlated data and investigate other currently unknown factors of influence on correlation, like time conditions (high and low temperature, rain, snow etc.), trained truck operators and personal on repair of equipment, quality of reserve parts etc.

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