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EXCAVATOR DOWNTIME'S DIFFERENCES BETWEEN TYPES AND COMPARISON WITH OTHER MINING EQUIPMENT

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Original Scientific Paper

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Mining equipment working time is critical for ensuring output and fulfilling mining project deadlines. In order to find trends and possible downtime minimization measures, this article analyses numerous types of excavators, dump trucks, loaders, backhoe loaders, bucket wheel excavators, and surface-top hammer drill rigs in Serbian mining sites. The study collects data on mechanical, electrical, technological, organizational, abuse and meteorological downtimes types with the aim to highlight efficient ways for minimizing non-operational periods, hence improving the overall productivity and safety of mining operations in the industry. Special emphasis is put on excavators whose role in the mining industry is pivotal, directly impacting project timelines and financial outcomes. The methodology includes analysing the duration and implications of different downtime categories. Collected data showed non-parametric features, according to the descriptive statistics. To compare the data, the non-parametric Mann-Whitney U-test is implemented. The results of the research showed that, in most cases, there is a difference in the duration of downtimes between different categories of excavators` downtimes. However, a comparison between excavator downtimes and other machinery downtimes has not shown any statistically significant differences. This analysis aims to contribute to the optimisation of mining equipment usage, offering valuable insights for mining industry stakeholders.

Keywords: Mann-Whitney U-test; Excavator; Downtime; Mining equipment

INTRODUCTION

Companies nowadays need to increase their efficiency and reduce costs in order to compete in the market (Bakator et al., 2019; Barauskaite & Streimikiene, 2021). The demand for innovative organizational and technical solutions as well as efficient resource management are directly tied to these processes. Changes have an impact on the mining sector as well as the global economy. The mining sector also has to deal with the challenging environmental conditions in which this raw material is extracted underground as well as mounting social demand to protect the environment (Herrington, 2021). Owing to these circumstances, the mining industry is becoming increasingly committed to finding solutions into place that lower production costs and maximize resource utilization, hence increasing efficiency (Brodny & Tutak, 2022; Watson et al., 2014).

Open-cast mines provide the majority of Serbia's electrical power output in terms of energy balance (Brkic et al., 2014). The rising cost of electricity and society's growing reliance on energy sources necessitates constant observation of machinery and

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equipment used in opencast mining operations, as well as enhanced availability, efficiency, and regular maintenance (Brkic et al., 2014).

Accordingly, the operational efficiency of mining operations is crucial, both due to productivity, safety and ecological compliance (Chattopadhyay & Chattopadhyay, 2020; Fourie, 2016; Hilson & Murck, 2000; Komljenovic et al., 2017; Oliveira et al., 2017).

The operational efficiency of excavators in the mining industry is pivotal, directly impacting project timelines and financial outcomes (Kassem et al., 2021). One of the critical factors influencing this efficiency is excavator downtime, a period during which the excavator is non-operational due to various reasons. Understanding and comparing the duration of different types of excavator downtime is essential for developing strategies to minimise these interruptions, thus enhancing overall productivity (Spasojević Brkić et al., 2023).

Excavator downtime can be categorized into several types, including mechanical, electrical, technological, organizational, and meteorological, each with unique causes and impacts on operations (Spasojevic Brkic et al., 2022). Recent studies, such as those by Lee et al. (2019) and Pałęga and Rydz (2018), have delved into aspects influencing excavator efficiency, from ergonomic cabin designs to innovative unmanned excavation systems, shedding light on potential areas to mitigate downtime.

This paper aims to compare different types of excavator downtime, drawing on existing literature to offer a nuanced understanding of each category's characteristics and implications. By synthesising these insights, we aim to contribute to the ongoing discourse on improving excavator efficiency, ultimately benefiting industries reliant on these crucial machines. Also, we compare the downtimes of excavators and other mining machinery. The paper is divided into several sections, starting with a review of the existing literature. It then goes on to discuss the methodology and present the research findings. Finally, the overall findings are summarised in the conclusion.

LITERATURE REVIEW

There are numerous literature sources which examine the safety, ecology and productivity issues of mining industry equipment, but they are rarely focused on the working and/or downtime of mining machinery.

There are a few publications that offer a thorough examination of the variables influencing mining industry safety. Knights and Scanlan's (2019) paper examines the relationship between coal prices and deaths in Queensland coal mines. It finds that when coal prices fall below a particular threshold, economic downturns may jeopardize safety and raise the likelihood of multiple-fatality accidents. In a different study, Mirzaei Aliabadi et al. (2020) highlighted the necessity of comprehensive safety management by using a Bayesian network technique to identify important organizational and human elements that contribute to mining accidents, such as skill-based errors and environmental factors. Using lost workdays as a novel metric to evaluate safety performance, this approach highlights the significance of safety and offers a more nuanced knowledge of the impact of injuries across various mining industries (Coleman & Kerkering, 2007). In order to improve safety efficiency, Ma (2020) examines the limitations in coal mining safety management and offers solutions for locating and resolving them. In their analysis of coal mine safety trends, Li et al. (2020) highlight the necessity of ongoing safety standard development. A mathematical model for mining safety analysis is introduced by Mondal et al. (2023), emphasizing the model's potential in risk assessment. Verma et al. (2023) use ARIMA models to anticipate mishaps and enhance safety standards as they explore safety in the steel industry. Together, these studies demonstrate how crucial it is for high-risk businesses to employ creative thinking and make ongoing improvements in safety management. The significance of ergonomics in excavator cabin design is emphasized by Pałęga and Rydz (2018), who establish a link between operator safety and comfort and decreased downtime. Pałęga and Rydz (2018) propose that optimal cabin design might enhance operational efficiency by mitigating fatigue and absenteeism due to health issues. Based on an evaluation of safety performance and climate in transportation and mining firms, Alsharif et al. (2024) present a novel conceptual framework for organizational resilience assessment at various organizational levels. Factor and reliability analysis are included in the framework, and it goes on by using the SMART approach—account for, monitor, respond, and learn—from the resilience corners perspective. Alsharif et al. (2024) study outcomes are reported to middle management issues.

The mining sector has both positive and negative effects on the three main tenets of sustainable development—society, economy, and environment—due to its strong relationship to sustainable development. The primary drivers behind the topic of sustainable development are the depletion of mineral resources, the possibility of their exhaustion, and worries about their availability for future generations. On the other hand, mining-related social, economic, and environmental issues have a negative impact on neighbouring communities (Asr et al., 2019). The mining sector is focused on lowering operational risks and preserving social permission for resource extraction, according to McCullough and Lund (2006).

In order to improve safety performance in mining, Komljenovic et al. (2017) propose incorporating organizational elements into mine safety management by emulating nuclear sector practices. Stemn et al. (2019) place a strong emphasis on systematic review and improvement as they evaluate and advance the maturity of safety culture inside mining organizations. Verster and colleagues (2023) investigate the application of simulation methodologies with both synthetic and real-world data to enhance vehicle safety and traffic management in mining operations. When taken as a whole, these studies show how important it is to tackle mining safety from all angles, incorporating advanced operational tactics and organizational culture.

According to Rakhmangulov et al. (2021), sustainability is one of the primary goals of open pit mining, especially in light of the constantly changing internal and external environmental conditions. All mining equipment must cooperate in order to do this. The structure of the mining system is composed of several subsystems and components, all of which are evaluated using a wide range of indicators. Evaluating the system in detail for each possible signal is a challenging and time-consuming task. However, each part and a subsystem have a different effect on how sustainable the system is. Despite the urgent need for sustainable mining, Gastaure et al. (2018) point out that revegetation and restoration of areas impacted by mining activities remain challenging.

Studies regarding downtimes of mining equipment are rare. Research by Edwards et al. (2002) and Spasojević Brkić et al. (2022) emphasize risk management and cost prediction when examining the effects of excavator downtime in the mining sector. According to Spasojević Brkić et al. (2022), mechanical problems are the main causes of downtime, and they recommend proactive maintenance methods. A model for estimating downtime costs is introduced by Edwards et al. (2002), improving operational and financial decision-making. In order to increase productivity and cut expenses, both studies stress how critical it is to incorporate downtime analysis into mining equipment management. Together, these publications highlight the need for an integrated approach to mining safety that takes organizational dynamics, human behaviour, and economic forces into account in order to raise operational safety standards and increase worker safety. In their examination of electrical system malfunctions in mining, Pontt et al. (2006) make the case for better engineering techniques that will increase dependability and safety. In order to minimize downtime linked to health and safety, Lee et al. (2019) describe an autonomous excavator system that uses 3D scanning and remote controls to operate safely in hazardous locations. Misita et al. (2022) first analyse the efficiency of the dumper and deal with the input/output ratio, i.e. the amount of fuel poured/number of working hours as an indicator of the efficiency of work. The second part of Misita et al. (2022) research refers to the analysis of dumper downtime during the analysed time period with basic ideas to determine the most common causes of downtime and assess their level of danger so that they can determine and classify potential risks and propose measures mitigation thereof.

Studies focused on excavators are even more rare, and one of them is based on the examination of maintenance data from hydraulic excavators. The study by Spasojevic Brkic et al. (2023) suggests a three-dimensional risk assessment matrix for auxiliary machinery risk mitigation in open-pit mines.

Previous research shows that enough attention until now has not been paid to mining equipment working time optimization although its importance for the efficiency and effectiveness of mining is evident.

METHODOLOGY

The methodology of this survey contains two parts for testing differences between downtimes on mining equipment based on data collected at Serbian mining sites.

Firstly, this study examines the duration of various types of downtime of excavators, including technological, electrical, mechanical, third-party, organisational, and meteorological factors. In addition, these periods of inactivity can be further classified into two categories: planned and unplanned. Table 1 provides the labels utilised for different types of downtime.

Secondly, this study compares excavators and mining machinery downtimes by categories of technological, electrical, mechanical, abuse-caused, organisational, third-party caused downtime and the total downtime for certain mining equipment types.

Nomenclature of examined factors is given in Table 1.

Table 1: Nomenclature

Label	Meaning	Label	Meaning
BA - TEH UP	Unplanned technological downtime of excavator	DA-T	Technological downtime of dump truck
BA - The P	Planned technological downtime of excavator	DA-S	Electrical downtime of dump truck
BA - El UP	Unplanned electrical downtime of excavator	DA-M	Mechanical downtime of dump truck
BA - Mech UP	Unplanned mechanical downtime of excavator	DA-Z	Abuse downtime of dump truck
BA - TP UP	Unplanned third-party downtime of excavator	DA-O	Organizational downtime of dump truck
BA - Org UP	Unplanned organisational downtime of excavator	DA-E	Third-party downtime of dump truck
BA - Org P	Planned organisational downtime of excavator	DA-V	Total downtime of dump truck
BA - Met UP	Unplanned meteorological downtime of excavator		
		KO-T	Technological downtime of backhoe loader
BA-T	Technological downtime of excavator	KO-S	Electrical downtime of the backhoe loader
BA-S	Electrical downtime of excavator	KO-M	Mechanical downtime of the backhoe loader
BA-M	Mechanical downtime of excavator	KO-Z	Abuse downtime of backhoe loader
BA-Z	Abuse downtime of excavator	KO-O	Organizational downtime of backhoe loader
BA-O	Organisational downtime of excavator	KO-E	Third-party downtime of backhoe loader
BA-E	Third-party downtime of excavator	KO-V	Total downtime of backhoe loader
BA-V	Total downtime of excavator		
		RB-T	Technological downtime of bucket wheel excavator
BU-T	Technological downtime of bulldozer	RB-S	Electrical downtime of bucket wheel excavator
BU-S	Electrical downtime of bulldozer	RB-M	Mechanical downtime of bucket wheel excavator
BU-M	Mechanical downtime of bulldozer	RB-Z	Abuse downtime of bucket wheel excavator
BU-Z	Abuse downtime of bulldozer	RB-O	Organizational downtime of bucket wheel excavator
BU-O	Organizational downtime of bulldozer	RB-E	Third-party downtime of bucket wheel excavator
BU-E	Third-party downtime of bulldozer	RB-V	Total downtime of bucket wheel excavator
BU-V	Total downtime of bulldozer		
		UT-T	Technological downtime of loader
BS-T	Technological downtime of surface top hammer drill rig	UT-S	Electrical downtime of loader
BS-S	Electrical downtime of surface top hammer drill rig	UT-M	Mechanical downtime of the loader
BS-M	Mechanical downtime of surface top hammer drill rig	UT-Z	Abuse downtime of loader
BS-Z	Abuse downtime of surface top hammer drill rig	UT-O	Organizational downtime of loader
BS-O	Organisational downtime of surface top hammer drill rig	UT-E	Third-party downtime of loader
BS-E	Third-party downtime of surface top hammer drill rig	UT-V	Total downtime of loader
BS-V	Total downtime of surface top hammer drill rig		

RESULTS

The observed data descriptive statistics regarding excavators' downtimes are presented in Table 2. The data was found to be non-parametric or to not follow a normal distribution, based on the analysis done by using the Kolmogorov test of normality.

The planned and unplanned excavators` downtime groups on technological, electrical, mechanical, meteorological, organisational, and third-party-caused downtime were compared using the Mann-Whitney U-test because the data does not show parametric behaviour.

The obtained results are shown in Tables 3 and 4. Table 3 shows the Mann-Whitney U-test for excavator downtimes where differences are found, together with the level of significance. Table 4 presents the Mann-Whitney U-test for excavator downtimes where differences are not found.

Histograms on downtimes collected data of different mining equipment are shown in Figures 1-7.

Table 2: Descriptive Statistics on excavators' data collected

	BA - TEH UP	BA – The P	BA - El UP	BA – Mech UP	BA - TP UP	BA - Org UP	BA – Org P	BA - Met UP
N	2919	39	121	1044	35	31	589	70
Mean	6,948270	5,923077	6,851240	6,939655	7,171429	6,967742	6,212224	7,428571
Median	7,000000	6,000000	7,000000	7,000000	7,000000	7,000000	6,000000	8,000000
Minimum	5,000000	0,000000	0,000000	0,000000	6,000000	6,000000	6,000000	6,000000
Maximum	9,000000	8,000000	9,000000	9,000000	8,000000	9,000000	8,000000	8,000000
Range	4,000000	8,000000	9,000000	9,000000	2,000000	3,000000	2,000000	2,000000
Standard deviation	0,470220	2,168975	1,130348	1,001053	0,746983	0,546740	0,612334	0,693059
Coefficient of variation	6,76743	36,61906	16,49844	14,42512	10,41609	7,84673	9,85691	9,32965

Table 3: Mann-Whitney U-test for excavator downtimes where differences are found

Variables			Mann - Whitney U	p-value
BA - TEH UP	vs	BA - TEH P	34107,50	<0,01
BA - TEH UP	vs	BA - El UP	199194,00	<0,01
BA - TEH UP	vs	BA - Mech UP	1575393,50	0,05
BA - TEH UP	vs	BA - TP UP	60690,50	0,00
BA - TEH UP	vs	BA - Org P	1449468,50	0,00
BA - TEH UP	vs	BA - Met UP	59351,00	0,00
BA - TEH P	vs	BA - El UP	1752,00	0,01
BA - Teh P	vs	BA - Mech UP	14377,00	0,01
BA - Teh P	vs	BA - TP UP	374,50	<0,01
BA - Teh P	vs	BA - Org UP	364,00	0,02
BA - Teh P	vs	BA - Met UP	581,00	<0,01
BA - El UP	vs	BA - TP UP	2577,00	0,04
BA - El UP	vs	BA - Org P	19824,00	0,00
BA - El UP	vs	BA - Met UP	5796,00	<0,001
BA - Mech UP	vs	BA - Org P	165428,00	0,00
BA - Mech UP	vs	BA - Met UP	47649,00	<0,001
BA - TP UP	vs	BA - Org P	16995,50	0,00
BA - Org UP	vs	BA - Org P	2899,00	0,00
BA - Org UP	vs	BA - Met UP	637,00	<0,001
BA - Org P	vs	BA - Met UP	5271,00	0,00

Table 4: Mann-Whitney U-test for excavator downtimes where differences had not been found

Variables			Mann - Whitney U	p-value
BA - TEH UP	vs	BA - Org UP	45996,50	0,81
BA - Teh P	vs	BA - Org P	13107,50	0,11
BA - El UP	vs	BA - Mech UP	66201,00	0,36
BA - El UP	vs	BA - Org UP	2107,50	0,25
BA - Mech UP	vs	BA - TP UP	21009,00	0,11
BA - Mech UP	vs	BA - Org UP	16728,50	0,74
BA - TP UP	vs	BA - Org UP	645,00	0,13
BA - TP UP	vs	BA - Met UP	991,00	0,08

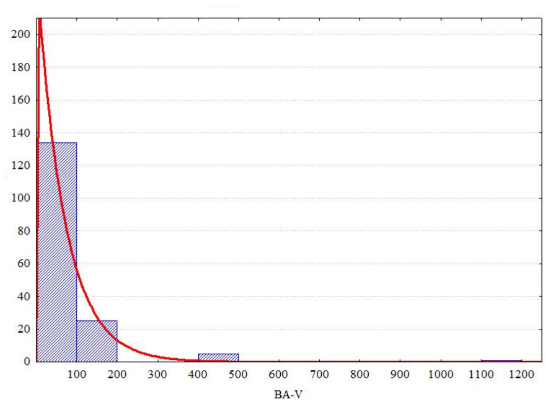

Figure 1. Histogram on downtimes of excavators

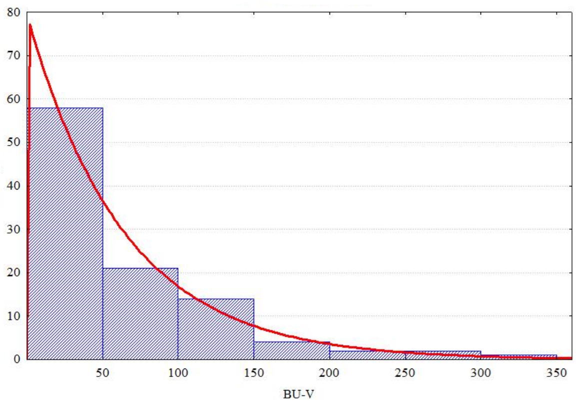

Figure 2. Histogram on downtimes of bulldozers

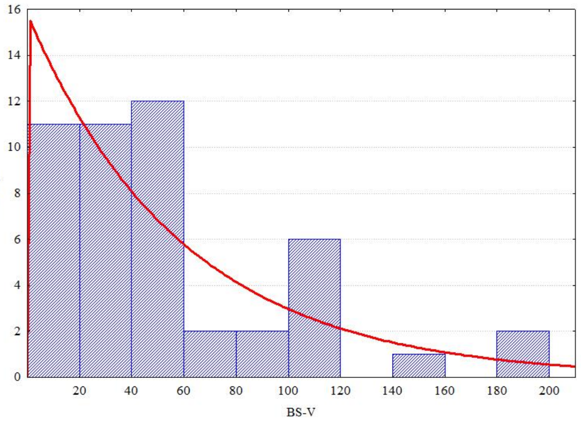

Figure 3. Histogram on downtimes of surface top hammer drill rig

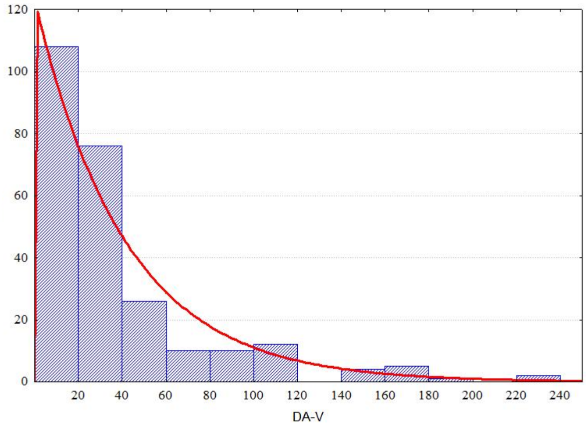

Figure 4. Histogram on downtimes of dump trucks

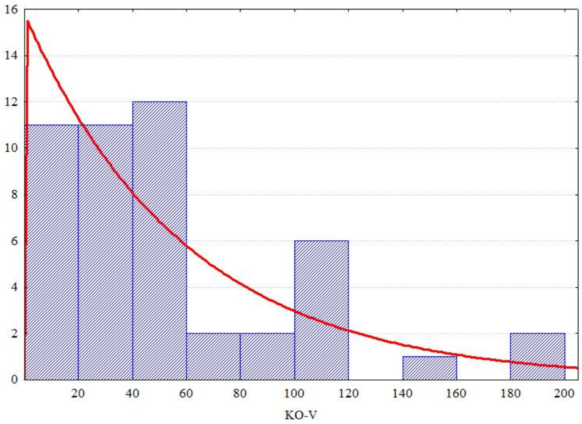

Figure 5. Histogram on downtimes of backhoe loader

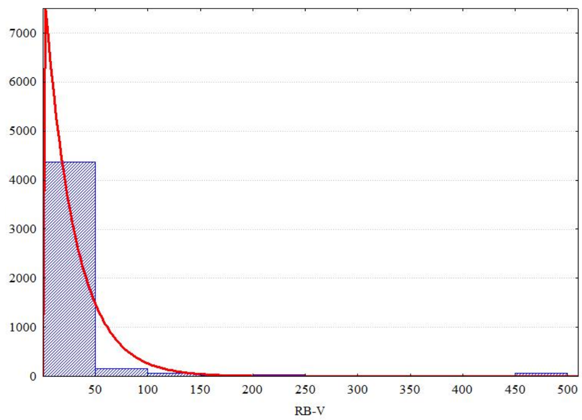

Figure 6. Histogram on downtimes of bucket wheel excavator

Data regarding other mining equipment shows that almost all coefficients of variation are far greater than 30% (Adegoke et al., 2022), so the comparison was made again by using the Mann-Whitney U* test.

The results of the comparison of downtimes of different mining equipment are shown in Table 5, where can be seen that differences have not been found.

Testing via the standardized normal distribution can only be performed for technological downtime between the top hammer drill rig and the backhoe loader, as given in Table 6.

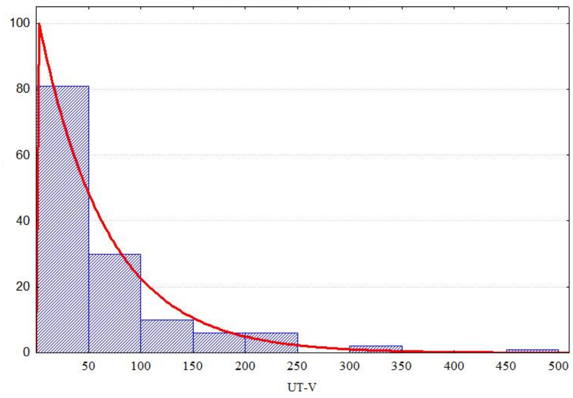

Figure 7. Histogram on downtimes of loader

Table 5: Mann-Whitney U-test for downtimes of different mining equipment

Variables			Z*	p-value	difference
BA-T	vs	BU-T	0.00	1.000000	n.s.
BA-T	vs	BS-T	0.130558	0.896125	n.s.
BA-T	vs	DA-T	0.00	1.000000	n.s.
BA-T	vs	KO-T	0.130558	0.896125	n.s.
BA-T	vs	RB-T	0.525619	0.599153	n.s.
BA-T	vs	UT-T	0.455383	0.648834	n.s.
BU-T	vs	BS-T	0.913908	0.360766	n.s.
BU-T	vs	DA-T	0.00	1.000000	n.s.
BU-T	vs	KO-T	0.913908	0.360766	n.s.
BU-T	vs	RB-T	0.840168	0.400815	n.s.
BU-T	vs	UT-T	0.00	1.000000	n.s.
BS-T	vs	DA-T	0.00	1.000000	n.s.
BS-T	vs	RB-T	-0.102062	0.918707	n.s.
BS-T	vs	UT-T	0.00	1.000000	n.s.
DA-T	vs	KO-T	0.522233	0.601509	n.s.
DA-T	vs	RB-T	-0.129004	0.897355	n.s.
DA-T	vs	UT-T	0.182153	0.855463	n.s.
KO-T	vs	RB-T	-0.102062	0.918707	n.s.
KO-T	vs	UT-T	0.00	1.000000	n.s.
RB-T	vs	UT-T	1.548301	0.121551	n.s.
BA-M	vs	BU-M	0.00	1.000000	n.s.
BA-M	vs	BS-M	0.00	1.000000	n.s.
BA-M	vs	DA-M	0.00	1.000000	n.s.
BA-M	vs	KO-M	0.00	1.000000	n.s.
BA-M	vs	RB-M	0.00	1.000000	n.s.
BA-M	vs	UT-M	0.00	1.000000	n.s.
BU-M	vs	BS-M	0.00	1.000000	n.s.
BU-M	vs	DA-M	0.00	1.000000	n.s.
BU-M	vs	KO-M	0.00	1.000000	n.s.
BU-M	vs	RB-M	0.00	1.000000	n.s.
BU-M	vs	UT-M	0.00	1.000000	n.s.

Table 5: Mann-Whitney U-test for downtimes of different mining equipment ***(continued)***

Variables			Z*	p-value	difference
BS-M	vs	DA-M	0.00	1.000000	n.s.
BS-M	vs	KO-M	0.00	1.000000	n.s.
BS-M	vs	RB-M	0.00	1.000000	n.s.
BS-M	vs	UT-M	0.00	1.000000	n.s.
DA-M	vs	KO-M	0.00	1.000000	n.s.
DA-M	vs	RB-M	0.533114	0.593955	n.s.
DA-M	vs	UT-M	0.00	1.000000	n.s.
KO-M	vs	RB-M	0.00	1.000000	n.s.
KO-M	vs	UT-M	0.00	1.000000	n.s.
RB-M	vs	UT-M	0.00	1.000000	n.s.
BA-V	vs	BU-V	0.00	1.000000	n.s.
BA-V	vs	BS-V	0.00	1.000000	n.s.
BA-V	vs	DA-V	0.00	1.000000	n.s.
BA-V	vs	KO-V	0.00	1.000000	n.s.
BA-V	vs	RB-V	-0.906776	0.364526	n.s.
BA-V	vs	UT-V	0.00	1.000000	n.s.
BU-V	vs	BS-V	0.00	1.000000	n.s.
BU-V	vs	DA-V	0.00	1.000000	n.s.
BU-V	vs	KO-V	0.00	1.000000	n.s.
BU-V	vs	RB-V	-1.10129	0.270772	n.s.
BU-V	vs	UT-V	0.00	1.000000	n.s.
BS-V	vs	DA-V	0.00	1.000000	n.s.
BS-V	vs	KO-V	0.00	1.000000	n.s.
BS-V	vs	RB-V	1.446501	0.148038	n.s.
BS-V	vs	UT-V	0.00	1.000000	n.s.
DA-V	vs	KO-V	0.00	1.000000	n.s.
DA-V	vs	RB-V	-0.593557	0.552809	n.s.
DA-V	vs	UT-V	0.00	1.000000	n.s.
KO-V	vs	RB-V	0.745356	0.456057	n.s.
KO-V	vs	UT-V	1.446501	0.148038	n.s.
RB-V	vs	UT-V	0.00	1.000000	n.s.

Table 6. Comparison with the Z distribution

Variables			Z	p-level	difference
BS-T	=	KO-T	0	1	n.s.

DISCUSSION

Operational periods of excavators are essential in the mining processes to meet project deadlines and guarantee desired output. Namely, the length of non-operational times, or downtime, has a significant impact on a project's costs and quality. The mining processes also require the use of other mining equipment. This article examines many different types of excavators, dump trucks, loaders, backhoe loaders, bucket wheel excavators, and surface top hammer drill rigs downtime, including mechanical, electrical, technological, organizational, abuse, and meteorological, in an effort to identify trends and potential mitigation strategies and in that manner fulfilled evidenced research gap.

Our results have shown that between different types of excavators, significant differences had not been found between unplanned technological and organizational downtime, between unplanned electrical and mechanical downtime, between unplanned electrical and organizational downtime, between unplanned mechanical and third-party downtime, between unplanned mechanical and organizational downtime, between unplanned third-party and organisational downtime and between unplanned third-party and meteorological downtime. Also, there were no statistically significant differences in the downtime of excavators and bulldozers, surface top hammer drill rigs, loaders, backhoe loaders, bucket wheel excavators, and dump trucks.

CONCLUSION

The study's results showed that there were significant differences in the length of excavators' downtime among different examined categories. There is no statistically significant difference between unanticipated downtime caused by organizations and technology when it comes to excavators. While there is no statistically significant difference between technological and organizational scheduled downtimes, there is a difference between mechanical and electrical unplanned downtimes as well as weather-related unplanned downtimes. Third-party-caused unscheduled downtime is not substantially different from mechanical unplanned downtime in this scenario. Comparing the category of unplanned downtimes induced by third parties to the downtimes caused by organizational unplanned downtimes, i.e., to meteorological unplanned downtimes, does not reveal any statistically significant differences. It was found that there was a statistically significant difference in all other examined downtimes.

It is interesting to note that there were no statistically significant differences in the downtime of excavators and other mining machines (bulldozers, surface top hammer drill rigs, loaders, backhoe loaders, bucket wheel excavators, and dump trucks).

This analysis contributes to the optimisation of mining machinery usage, offering valuable insights for industry stakeholders. Anyhow, further research is recommended and it would be beneficial to enlarge sample sizes and check out our conclusions. Expanding the database of excavator downtime and creating a model that utilizes machine learning methods to forecast downtime duration depending on the particular kind of downtime would be helpful research initiatives.

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MEĐUSOBNO POREĐENJE RAZLIČITIH TIPOVA ZASTOJA/ OTKAZA BAGERA I POREĐENJE ZASTOJA/ OTKAZA BAGERA SA OSTALIM RUDARSKIM MAŠINAMA

Vreme u radu rudarske opreme je ključno za obezbeđivanje rezultata i ispunjavanje rokova rudarskih projekata. U cilju utvrđivanja trendova i mogućih mera za minimiziranje zastoja/ otkaza, u ovom radu analiziramo različite tipove otkaza kako bagera, tako i dampera, utovarivača, kombinirki, rotornih bagera i površinskih bušilica u srpskim rudarskim kompanijama. U radu su najpre prikupljeni podaci o mehaničkim, električnim, tehnološkim, organizacionim, zloupotrebama i meteorološkim vrstama otkaza i zastoja u cilju da se istraže efikasni načini za minimiziranje neoperativnih perioda, a samim tim, i za poboljšanje ukupne produktivnosti i bezbednosti rudarskih operacija. Poseban naglasak je stavljen na bagere čija je uloga u rudarskoj industriji ključna, jer imaju najveći uticaj na vremenske rokove i finansijske rezultate projekata. Metodologija dalje uključuje analizu trajanja i implikacija različitih kategorija zastoja. Prikupljeni podaci pokazuju neparametarske karakteristike, prema deskriptivnoj statistici. Za upoređivanje podataka implementiran je neparametarski Mann-Whitney U-test. Rezultati istraživanja su pokazali da u većini slučajeva postoji razlika u trajanju zastoja između različitih kategorija zastoja kod bagera. Međutim, poređenje između zastoja bagera i zastoja drugih mašina nije pokazalo nikakve statistički značajne razlike. Konačno, sprovedene analize doprinose optimizaciji korišćenja rudarske opreme, nudeći vredne uvide za sve zainteresovane strane u rudarskoj industriji.

Keywords: Mann-Whitney U-test; Bager ; Zastoj/Otkaz; Rudarske mašine