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Transport and Mining Machinery Foot Controls: Safety and Human Factors View

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ABSTRACT

There are rare studies carried regarding the assessment of the anthropometric convenience of transport and mining machinery. The first aim of this paper is to examine if there are differences between transport and mining machinery operators from the aspect of foot controls, the second aim is to compare the most common causes of downtime and failure and the third aim is to compare if there are differences in the field of injuries at work of both machinery types. Samples of 31 transport and 65 mining machinery operators were examined. Analysis is done by using descriptive statistics, the Kolmogorov test for normality, Mann–Whitney U test, and Pareto analysis. Comparison of operators' height and weight, vibrations feeling through the foot controls and its easiness to be reached and used/controlled and injuries rates have not shown statistically significant differences found between transport and mining machinery. Pareto analysis on failures and stoppages of both types of machinery found completely different causes in the field of "vital few". Anyhow, since statistically proved facts show that there are no differences regarding safety and human factors issues it could be indicated to designers that there is the possibility of applying the same innovative solutions to both types of mechanization in the field of foot controls.

Keywords: Transport machinery, Mining machinery, Foot controls, Statistical analysis, Pareto analysis

INTRODUCTION

The assessment of anthropometric convenience of transport and mining machinery cabins and its human-centred design are rarely examined. The importance of studying this problem largely exceeds the number of published works. Despite today's the risk awareness, incidents in heavy machinery operations have not substantially decreased (Duarte et al. 2021).

Transport and mining machinery operators' job is very demanding since high precision is needed and they remain in cabins during almost the whole shift (Brkic et al. 2015; Apud 2012). Inadequate shape and dimensions of control devices, their inadequate arrangement in the cabin, as well as mismatch of the forces required to activate the control devices with the anthropometric characteristics of the operator, have an impact on the quality of the performance of the work task and overall safety. In the Swedish mining industry, in the period from 1980 to 2010, progress has been noted when it comes to safety, in accordance with the development of technologies, while at the beginning of the 2000s, the focus shifted to the organizational aspect of safety (Lööw et al. 2019). In Chile, more than 50% of health reason absenteeism was linked with musculoskeletal disorders caused by poor ergonomic workplace (Apud 2012). Also, in the South Africa, non-ergonomically adapted workplaces in examined industries are related with musculoskeletal disorder (Schutte 2005). Study conducted on the data from Mine Safety and Health Administration (MSHA) has showed that 32% of total incidents were caused due to operator's foot slipping (Santos et al. 2010). When it comes to the transport machines, accidents occurred during the material transport and handling proved to be the most dangerous with extremely high risk (Jeon et al. 2013; Jiang, 2020). Study conducted in the Hong Kong construction industry, showed that human factors have significant impact on safety (Tam et al. 2011). From the ergonomics aspect work posture has an important role in the occurrence of injuries at work (Suseno 2021). Crane cabins' space do not suits to the most operators from the ergonomic point of view (Zunjic et al. 2015). A non-ergonomic environment affects accidents caused by the human factor, and it is necessary to provide an ergonomic environment in order to reduce the number of these accidents (Lee and Jung 2021). As well as mining machines operators, transport machinery operators are facing numerous health issues such as back and lower limb disorders, due to non-ergonomic working positions (Vander Molen et al. 2004; Spasojevic Brkic et al. 2015). The recent study in Serbia showed that there is no significant difference between transport and mining operator's attitudes, number of injuries and absenteeism due to poor working conditions (Spasojević-Brkić et al. 2022).

The aim of this paper is to compare data related to foot controls and injuries both for transport and mining operators and to show whether there are differences between them, together with analysis of failures and stoppages by Pareto diagram for both type of machineries.

STATISTICAL EXAMINATION OF FOOT CONTROLS ERGONOMIC CONVENIENCE

The study conducted samples of 31 transport and 65 mining machinery operators working in Serbian and Montenegrin companies. Data on operators' height and weight were collected and the following three questions related to foot controls ergonomic convenience were examined:

Q1- Do you feel vibrations from the equipment through the foot controls?
Q2 - Can you easily reach the foot controls?
Q3 - Can you easily/adequately use the foot controls?

Results of descriptive statistics for operator's height and weight are given in Table 1. Since for all categories significance level p is lower than 0.05, the non-parametric test is required because the data are not following normal contribution (Montgomery & Runger 2013). Descriptive statistics included

Table 1. Descriptive statistics for operator's height and weight.

	N	Mean	Med	Min	Max	R	SD	Cv (%)	d	p	var
Transport machinery operator's height	31	174.032	176.000	165.000	182.000	17.000	5.862	3.37	0.24434	< 0.05	Non-parametric
Transport machinery operator's weight	31	87.161	83.000	70.000	102.000	32.000	11.112	12.75	0.23088	< 0.05	Non-parametric
Mining machinery operator's height	65	179.415	180.000	166.000	190.000	24.000	5.687	3.17	0.10499	1.000	Non-parametric
Mining machinery operator's weight	65	91.092	90.000	60.000	150.000	90.000	16.778	18.42	0.16176	< 0.10	Non-parametric

sample sizes, mean values, median, minimum and maximum, range, standard deviation and coefficient of variation expressed in percentages. In cases when the coefficient of variation is greater than 30%, the variable is inhomogeneous, thus non-parametric statistics is used. Otherwise, the Kolmogorov test for normality was additionally conducted, where the d test values and p values for the Kolmogorov test were given.

After descriptive statistics and normality test, the non-parametric Mann–Whitney U* test was performed. Table 2 shows the results of Mann–Whitney U* test that compares operator's height and weight for both transport and mining machinery.

It has been shown that there are no significant differences (n.s.) on both types of machinery operator's height and weight.

Table 3 shows descriptive statistics for both transport and mining machinery operators with the results of normality test and Table 4 shows descriptive statistics for average values for the same questions both for transport and mining operators with the results of the normality test.

Comparison between foot control related question between transport and mining machinery operators is given in Table 5.

Finally, the comparison for foot control related questions group is given in Table 6.

It has been shown that there are no statistically significant differences regarding vibrations feeling through the foot controls and its easiness to be reached and used/controlled of both transport and mining machinery.

Table 2. Mann–Whitney U* test for transport and mining machinery operator's general data comparison.

Transport machinery		Mining machinery	U*	Z*	p	Significance
Operator's height	=	Operator's height	3.500000	0.833333	0.404657	n.s.
Operator's weight	=	Operator's weight	4.500000	0.193649	0.846451	n.s.

Table 3. Descriptive statistics for transport and mining machinery operators by individual foot control related questions.

	N	Mean	Med	Min	Max	R	SD	Cv (%)	d	p	var
Transport machinery operators											
Q1	31	4.097	5.00	1.00	5.00	4.00	1.274	31.10	0.26127	< 0.05	Non-parametric
Q2	31	4.065	4.00	3.00	5.00	2.00	0.929	22.85			Non-parametric
Q3	31	4.065	4.00	2.00	5.00	3.00	0.929	22.85	0.20518	< 0.15	Parametric
Mining machinery operators											
Q1	65	3.308	4.00	1.00	5.00	4.00	1.580	47.78	0.31169	< 0.01	Non-parametric
Q2	65	4.215	5.00	1.00	5.00	4.00	1.205	28.59			Non-parametric
Q3	65	4.077	4.00	1.00	5.00	4.00	1.229	30.14			Non-parametric

Table 4. Descriptive statistics for mean values of foot control related questions for transport and mining operators.

N	Mean	Med	Min	Max	R	SD	Cv (%)	d	p	var
Transport machinery operators										
31	4.075	4.333	2.333	5.000	2.667	0.889	21.82	0.14914	n.s.	Parametric
Mining machinery operators										
65	3.867	4.000	1.000	5.000	4.000	0.862	22.28	0.13521	n.s.	Parametric

Table 5. Comparison of foot controls related questions between transport and mining machinery operators.

Transport machinery		Mining machinery	U*	Z*	p	Significance
Q1	=	Q1	15.000	−1.414	0.157	n.s.
Q2	=	Q2	31.000	−0.924	0.356	n.s.
Q3	=	Q3	52.500	1.083	0.279	n.s.

Table 6. Comparison of all foot control related questions of transport and mining machinery operators.

Transport machinery		Mining machinery	Z	p	Significance
Foot control related questions group	=	Foot control related questions group	1.082	0.1395	n.s.

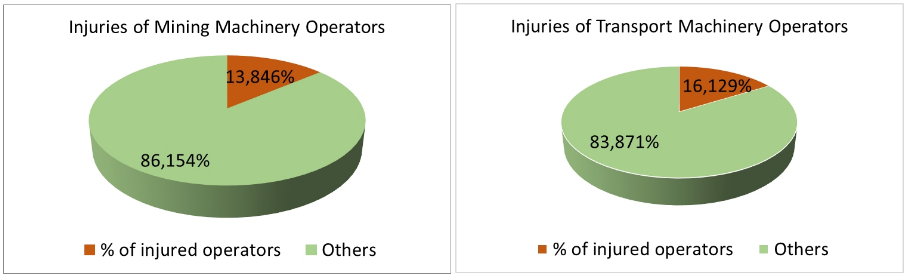

Figure 1: Percentages of injured operators of mining and transport machinery.

The last data that was compared by testing the difference in two population proportions, namely if between operators of transport and mining machinery are equal proportions of injuries, and those data is shown on Figure 1. The comparison again showed that this difference is not statistically significant, given that the p-level of the test is 0.7205.

PARETO ANALYSIS OF FAILURES AND STOPPAGES

Finally, failures and stoppages of both types of machinery are collected and analysed and Pareto diagrams constructed. As it can be seen on Figure 2 and Figure 3, all failures and stoppages for transport and mining machinery can be divided in three groups. The first, group A is group with the most influence on failures and stoppages. For the transport machinery, the most common cause of failures and stoppages are crane travel drive switch,

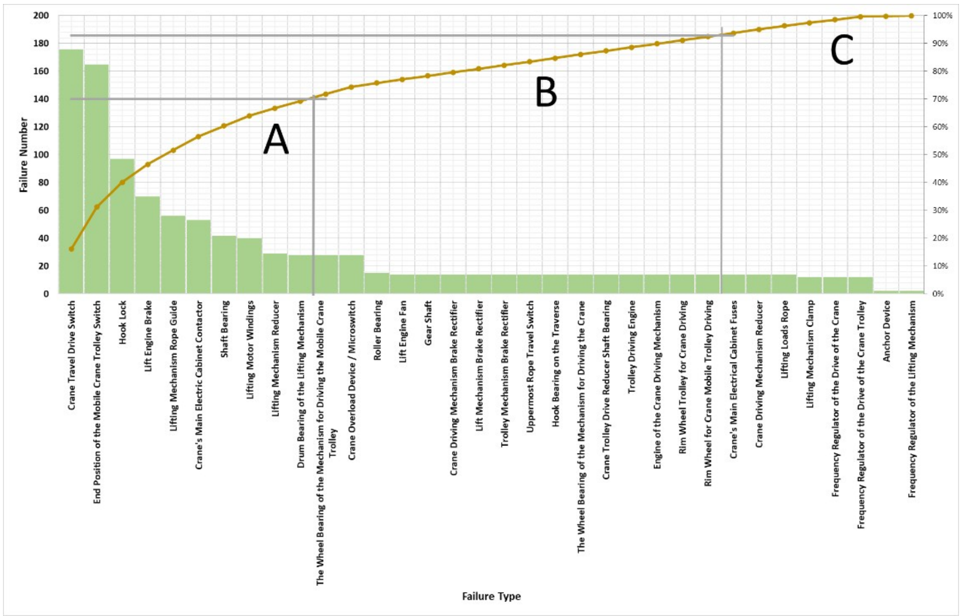

Figure 2: Pareto diagram of failures and stoppages for transport machinery.

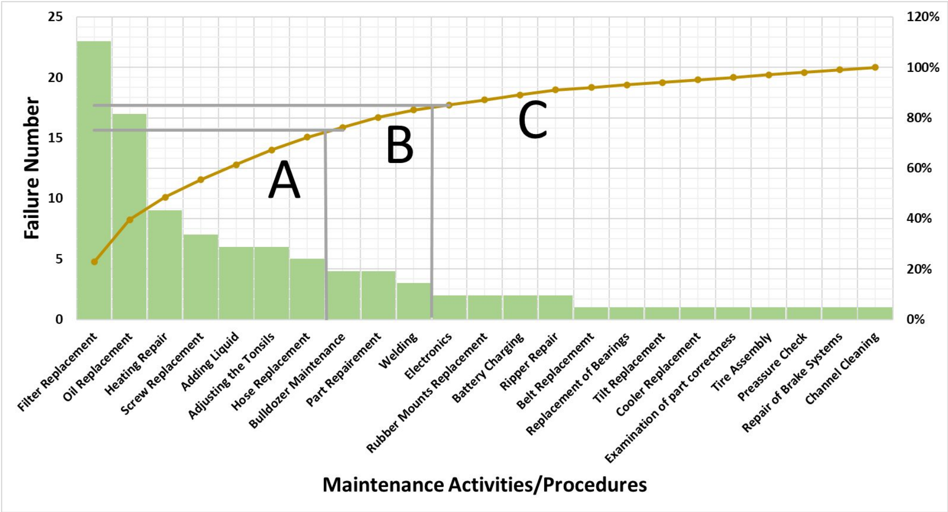

Figure 3: Pareto diagram of failures and stoppages for mining machinery.

end position of the mobile crane trolley switch, hook lock, lift engine brake, lifting mechanism rope guide, crane's, main electric cabinet contactor, shaft bearing, lifting motor windings, lifting, mechanism reducer and drum bearing of the lifting mechanism while for mining machinery it is filter replacement, oil replacement, heating repair, screw replacement, adding liquid, adjusting the tonsils, hose replacement, bulldozer maintenance, part repairment and welding.

CONCLUSION

The aim of this paper was to examine and compare transport and mining machinery operators' height and weight and foot controls ergonomics convenience. Comparison of operators' height and weight have not shown differences found between transport and mining machinery. Descriptive statistics regarding vibrations feeling through the foot controls and its easiness to be reached and used/controlled of both transport and mining machinery has been done and although slightly lower values are obtained from mining machinery operators, statistically significant differences have not been found, too. The last data that was compared between operators of transport and mining machinery are injuries at work, for which proportions were used, where it was shown that 16.129% of operators of transport machinery had injuries, while that number among operators of mining machinery was 13.846%. The comparison again showed that this difference is not statistically significant, given that the p-level of the test is 0.7205. Later on, failures and stoppages of both types of machinery are collected and analysed and Pareto diagrams are given, where completely different causes are evident in the field of "vital few" causes. Pareto analysis of transport machines failures and stoppages showed that the most of them are caused by crane travel drive switch, end position of the mobile crane trolley switch and hook lock and for the mining machines, they are filter replacement, oil replacement and heating repair.

Anyhow, since statistically proved facts show that there are no differences regarding safety and human factors issues it could be indicated to designers that there is the possibility of applying the same innovative solutions to both types of mechanization in the field of foot controls.

Further collection and analysis of anthropometric dimensions is recommended as the future research avenue.

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