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Study on Fatigue Risk Management Heavy Equipment Driver in the Mining Industry

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ABSTRACT
Work fatigue problems occur in various industrial sectors, including the mining industry. The research location is in a mining company at East Borneo. The research population is the 43 operator of the Komatsu HD785 Dump Truck. Measurement of subjective fatigue was measured by the Karolinska Sleepiness Scale and Fatigue-Visual Analogue Scale. Data analysis techniques are descriptive analysis and multiple linear regression. The results of the study show that in general, based on the graph of the KSS and F-VAS values, over time the level of employee fatigue will increase and reach the peak of fatigue just before rest time (12:00). After resting the level of fatigue will decrease and over time until the end of the shift, the level of fatigue will increase. This model of the relationship between Speed and Productivity with KSS and F-VAS can be negative or positive for different times of the day.
Keywords - Work fatigue, Karolinska Sleepiness Scale (KSS), Fatigue-Visual Analogue Scale (F-VAS), fatigue risk mitigation, Operator Dump Truck

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1. Introduction

The mining industry sector is a sector with a high risk of work. Every year there are quite a lot of accidents in mining activities in Indonesia. Activities in mining companies are dominated by driving heavy equipment, which is the main activity of mining companies. From the activity has a high history of serious accidents, some of which have even resulted in the death of workers or drivers of heavy equipment. From data released by the National Safety Council in 2020, the mining industry sector is the sector with the 2nd highest fatality rate in the world in 2018 as shown in Figure 1.

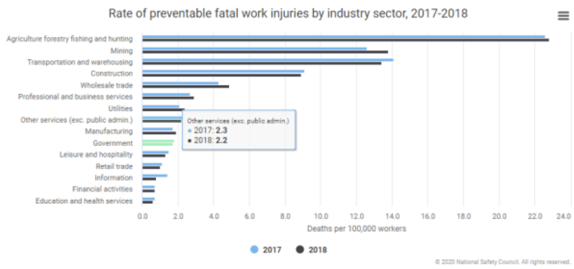

Figure 1 The ratio of preventable deaths from various industrial sectors

In the industrial world, especially coal mining, there are many aspects of the problems that occur, one of which is work accidents that often occur (Compass, 2016). Work accidents in the mining sector continue to increase, including coal mining industry, during 2019 the occurrence of 24 cases of work accidents that killed 24 workers (antaranews.com, 2020). Work accidents are caused by dangerous actions or as a result of dangerous conditions (Irzal, 2016 [5]). There is two causes of work accidents namely dangerous work behavior (unsafe human act) and dangerous conditions (unsafe conditions). From statistical data 80%-85% of work accidents are caused by behavior or human error itself. International Labor Office statistics show that 1.1 million deaths each year are caused by occupational diseases or accidents (ILO, 2013). Of the 147,000 cases of accidents, 2,575 of them resulted in death (Detik News, 2018 [3]) and 4,678 others were disabled.

Fatigue is a biological drive to rest in order to recuperate (Williamson, 2011 [15]). Fatigue or work fatigue results in a decrease in capacity and endurance at work. The cause of fatigue is caused by monotonous and repetitive things, the presence of excessive work intensity or duration, the environment around the workplace; including lighting and noise, mental problems such as responsibilities, worries and conflicts on and off the job, and illness or poor nutrition. Fatigue or general fatigue is characterized by a reduced willingness to work which is a psychological requirement. Work fatigue is characterized by a decrease in alertness and a feeling of tiredness which is a subjective symptom. The term fatigue refers to conditions that vary from individual to individual. but it all boils down to a loss of efficiency and a decrease in work capacity and endurance. The causes of general fatigue are the monotony, intensity and duration of mental and physical work, environmental conditions (Tarwaka, 2014 [14]).

2. Materials and Methods

2.1 Population and Sample

The population in this study is 43 operators who work at Mining Company in the Bengalon-East Kutai-East Kalimantan area. The sample used in this study were respondents from the age group of 20-40 years. The selected respondents are Heavy Equipment Operators who work in the Bengalon-East Kutai-East Kalimantan area.

2.2 Research design

Each respondent will observe by Karolinska sleepiness survey (KSS), Fatigue-visual analogue scale (F-VAS), will be measured with their respective times at the beginning of shift (7:00), before rest time (9:00-12:00), after rest time (13:00), before mid break 2 (15:00-17:00), and end of shift (18:00). In this research, there are several equipments prepared, namely the KSS Form and the F-VAS Form

2.3 Analysis Unit

Unit of analysis refers to the level of aggregation of data collected during the data analysis stage. The unit of analysis can be at the individual level, the dyads level, namely the interaction between two people, such as superior-subordinate interactions, or the organizational level (Sekaran & Bougie, 2016: 102 [11]).

3. Results and Discussion

The regression model is used to test the hypothesis using Ordinary Least Square (OLS) or the classical linear method, it is necessary to test the classical assumptions to ensure that the model meets the Best Linear Unbiased Estimator (BLUE) criteria (Widarjono, 2015: 59 [19]). The following are the results of the classical assumption test including normality test, linearity test, multicollinearity test, heteroscedasticity test, and autocorrelation test.

3.1 Results of Regression and Hypothesis Testing

Hypothesis testing was carried out on four hypotheses in this study shown in table 1, 2, 3 & 4, and result of figures of research shown in Figure 2.

Table 1 Effect of Speed (X1) on KSS (Y1)

Time	Model	R2	T	P	Conclusion
Beginning of shift	X11-->Y11	0.003	0.355	0.725	Positive effect, but not significant
Before rest time 1	X12-->Y12	0.003	-0.360	0.720	Positive effect, but not significant
Rest	X13-->Y13	0.118	2,346	0.024	Positive influence and not signific
Mid rest time 2	X14-->Y14	0.000	-0.142	0.888	Positive effect, but not significant
End of shift	X15-->Y15	0.033	-1,192	0.240	Positive effect, but not significant

Table 2 Effect of Speed (X1) on F-VAS (Y2)

Time	Model	R2	T	P	Conclusion
Beginning of shift	X11-->Y21	0.260	1.045	0.302	Positive effect, but not significa
Before rest time 1	X12-->Y22	0.007	0.540	0.592	Positive effect, but not significa
Rest	X13-->Y23	0.031	-1,146	0.258	Positive and insignificant effec
Mid rest time 2	X14-->Y24	0.029	1.114	0.272	Positive effect, but not significa
End of shift	X15-->Y25	0.004	-0.382	0.704	Positive effect, but not significa

Table 3 Effect of Productivity (X2) on KSS (Y1)

Time	Model	R2	T	P	Conclusion
Beginning of shift	X21-->Y11	0.014	-0.118	0.452	Positive effect, but not significa
Before rest time 1	X22-->Y12	0.065	-1,682	0.100	Positive effect, but not significa
Rest	X23-->Y13	0.058	1,594	0.119	Positive and insignificant effect
Mid rest time 2	X24-->Y14	0.033	-1,177	0.246	Positive effect, but not significa
End of shift	X25-->Y15	0.000	-0.064	0.949	Positive effect, but not significa

Table 4 Effect of Productivity (X2) on F-VAS (Y2)

Time	Model	R2	T	P	Conclusion
Beginning of shift	X21-->Y21	0.008	0.593	0.557	Positive effect, but not significar
Before rest time 1	X22-->Y22	0.002	-0.255	0.800	Positive effect, but not significar
Rest	X23-->Y23	0.006	-0.493	0.625	Positive and insignificant effect
Mid rest time 2	X24-->Y24	0.047	-1,420	0.163	Positive effect, but not significar
End of shift	X25-->Y25	0.009	-0.615	0.542	Positive effect, but not significar

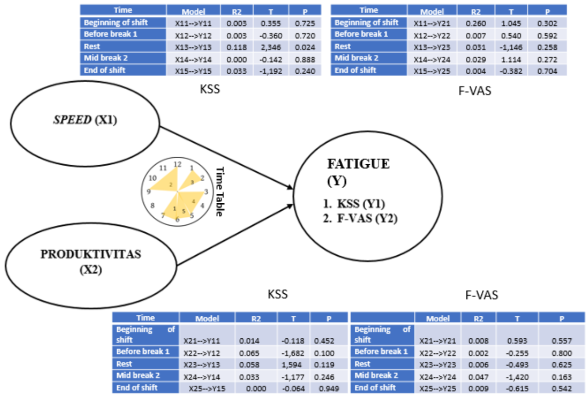

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Figure 2 Figures of Research Model Results

3.2 Discussion

3.2.1 Employee Fatigue Level Discussion

Theoretically there are three factors that cause fatigue (Williamson, 2011 [15]) namely Time on Task, Time of Day, and Task Related Factors. This study examines fatigue in relation to work, or fatigue at work. Fatigue at work means that it belongs to the category of Task Related Factors, which includes fatigue due to time on task factors and workload related factors.

Between the two factors that cause work fatigue (time on task factors; and workload related factors), the focus of this study is more related to fatigue in the context of time on task factors. This is because this research was conducted on types of employees with the same job-desk (heavy equipment operators) but tested with different working hours in the context of one working day. The different times in this study include five working time in one working day, namely: (1) The start time of work (07.00), (2) The time before the first rest time (09.00-12.00). (3) After the afternoon rest time (13.00), because the afternoon rest time or the first rest time takes place between 12.00-13.00. Then (4) the middle of the 2nd rest time or Ashr rest time (15.00-16.00).

The main indicator of work fatigue measured in this study is fatigue measurement uses subjective measurements, which in this case uses the Karolinska Sleepiness Scale (KSS) and Fatigue-Visual Analogue Scale (F-VAS). KSS is a scale to measure the level of sleepiness subjectively. Measurement of KSS with a Likert Scale of 1-9 (Kaida, 2006 [20]). The F-VAS is a response psychometric scale that can be used in questionnaires and is an instrument for measuring subjective characteristics, using a Scale of 1-10(Funke, 2008 [4]).

The results showed that in general the fatigue level of heavy equipment operators working in the Bengalon-East Kutai-East Kalimantan area was relatively low. The results of measuring the level of fatigue with the Karolinska Sleepiness Scale (KSS) and Fatigue-Visual Analogue Scale (F-VAS) proxies produce numbers on a Likert Scale that are not much different (KSS = 3,0186, F-VAS = 2,349). It means KSS & F-VAS scale indicate a healthy and fit state and remains sensitive to the responses that occur during work activities and the fatigue scale of heavy equipment operator is still relatively low due to it is still on a scale of 2-3. When compared to the level of fatigue of the heavy equipment operators at five daily working times (beginning of the shift, before rest time 1, during lunch rest time, mid rest time 2, and the end of the shift), it appears that there is a similar or different trend between the KSS and F-VAS measurements. The peak of sleepiness in the results of the KSS measurement occurs at rest (12.00-13.00), while the peak of sleepiness in the results of the F-VAS measurement occurs more quickly, before rest time (9:00-12.00 hours). It means there is a difference between the results of the KSS and F-VAS measurements regarding the timing of the peak occurrence. However, between the KSS and F-VAS measurements, there are similarities in the second lowest timing of sleepiness (which means approaching the most highly awake point, or approaching the very fresh point), which is at mid-rest 2. After a period of rest, both with the KSS and F-VAS measurements, the level of fatigue was equally increased again. The measurement results are in the same direction between KSS and F-VAS when viewed from the timing of working hours, then at the beginning of the shift for both measurements both conclude as the lowest sleep point.

3.2.2 Employee Fatigue Model

If the fatigue model of employees who perform the function as heavy equipment operators is associated with speed and productivity variables, several findings will be obtained. First, the partial influence of Speed on KSS and F-VAS is relatively small and insignificant. It applies to all five measurement times (beginning of the shift, before rest time 1, during lunch rest time, mid rest time 2, and end of shift). The effect of Speed on KSS has different directions of influence among the five measurement times. Speed has a positive effect on KSS at the beginning of the shift, and during the afternoon rest time. However, Speed has a negative effect on KSS at the time before the rest time (11.00-12.00), in the middle of rest time 2, and at the end of the shift. Likewise, the effect of Speed on the F-VAS varies in the direction of its influence between the five measurement. Speed has a positive effect on F-VAS at the beginning of the shift, and at the second rest time. However, Speed has a negative effect on F-VAS during lunch rest times, and at the end of the shift. It means that in general the influence of Speed partially on KSS and F-VAS is more balanced between positive and negative directions, with the direction of negative influence being slightly more than the direction of positive influence.

Productivity partially to KSS and F-VAS is relatively small and not significant. It applies to all five measurement times. The effect of Productivity on KSS has different directions of influence between the five measurement times. Productivity has a positive effect on KSS only during the afternoon rest time. Meanwhile, at the other four times, productivity has a negative effect on KSS. Likewise, the effect of Productivity on F-VAS varies in the direction of its effect among the five measurement times. Productivity has a positive effect on the F-VAS at the beginning of the shift. Meanwhile, at the other four times, productivity has a negative effect on the F-VAS.

Thus, in general it can be concluded that the influence of Speed and Productivity partially on KSS and F-VAS has two directions of influence, namely positive and negative. Only when compared between the tendency of negative and positive influence, the tendency of negative influence is stronger than positive influence. Based on the proof of the partial effect of Speed and Productivity on the KSS and F-VAS, it can be proposed that the relationship model of Speed and Productivity with KSS and F-VAS can be negative or positive for different times of the day.

3.2.3 Fatigue Risk Management

Based on the fatigue pattern found in the study, mining companies can make adjustments regarding the level of fatigue risk. The results showed that the fatigue level of the operators in their daily work tended to fluctuate between the five times measured, both measured by the KSS and F-VAS methods. These peaks of heavy equipment operator fatigue can be a concern for the company so that all possible risks can be mitigated.

The risks that may occur due to work fatigue, as stated by William (2009) include: (1) Impaired performance capabilities; and (2) work accidents. These risks need to be mitigated.

Referring to Coppola (2007 [18]) regarding risk mitigation, in mitigating risks that may be caused by work fatigue, several kinds of mitigation can be carried out. The optional of risk mitigation shown at Table 5.

Table 5 Table of examples of risk mitigation options

Risk Mitigation	No	Optional
risk likelihood reduction	1	Make a declaration of work readiness at the beginning of the shift
	2	Replace operators that not fit to work
	3	Make a wake up call via radio communication
	4	Stretching the operator during peak hours of fatigue (before taking a rest
risk-sharing	1	Operator change during critical hours
	2	Setting the alternating operator operation pattern
	3	Assist with other instructors or operators in the unit
risk transfer	1	Distributing risk to insurance
	2	Appoint subcontractors for certain operations

4. Conclusions

In general, the fatigue level of heavy equipment operators working in the Bengalon-East Kutai-East Kalimantan area is relatively low. The peak of sleepiness occurs during rest time (12.00-13.00), while the peak of fatigue occoure before the rest time (9:00-12.00 hours). It means that there is a difference between the results of the KSS and F-VAS measurements regarding the timing of the peak occurrence.

The partial influence of Speed and Productivity to KSS and F-VAS is relatively small and insignificant. During rest time, productivtiy has positive correlation with KSS, however in other 4 times measurement, the correlation is negative. It can be concluded that the relationship does not have absolute value but also depends on time of day.

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