

## ORIGINAL ARTICLE

## FATIGUE ANALYSIS OF HIGH DUMP TRUCK OPERATORS IN INDONESIA'S COAL MINING INDUSTRY: A CASE STUDY

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## ABSTRACT

A coal mining industry typically applies a 24-hours working time, which enforces some workers to stay conscious during night shift, opposing human body's biological clock. This study aims to analyse the level of fatigue experienced by high dump truck operators (HD operators) in a coal mining site in East Kalimantan, Indonesia. This study utilizes primary data which obtained from distributing Industrial Fatigue Research Committee (IFRC) survey to all HD operators and secondary data (for Fatigue Likelihood Scoring - FLS) which consists of HD operators' working schedule that currently applied in the company. Results obtained is analyzed using Fatigue Risk Management System (FRMS) framework which combines FLS classification and Dawson-McCulloch's model of fatigue risk trajectory. This study reveals that based on IFRC survey, HD operators experienced low/mild fatigue due to insignificant influence of fatigue-related factors contained in the survey. However, consideration for improvement is in need since the result of fatigue for night shift operators is close to moderate level. In addition, based on FLS, the level of fatigue indicates that HD operators experienced excessive working hours, in which in FRMS graph classified as fatigue-related errors. Thus, this study proposes several strategies as the hazard control mechanism: (1) providing optimum resting time, (2) equipping operators with audio music that lead to positive energy and increasing work focus, and (3) adding afternoon shift to balance the working hours.

**Keywords:** Coal mining, fatigue, Fatigue Likelihood Scoring (FLS), Fatigue Risk Management System (FRMS), high dump truck operator, Industrial Fatigue Research Committee (IFRC)

## INTRODUCTION

Indonesia owns a significant amount of extractive natural resources, which enables the country's mining industries as one of dominant factors in accelerating the development of social economic aspect. The mining industries stir economic activities through applying a 24-hours working time. To increase the productivity of a mining site and minimize cost, a mining company allocate investment more on tools than basic production<sup>1</sup>.

High Dump-truck (HD) is one of the essential heavy equipment that plays important factor in the mining industry on a large scale. HD operators are people who have special skills or expertise in operating certain HD, hence the mastery of this equipment is highly necessary and treated as professional staff in their field with a permit in operating it. However, the 24-hours working time enforces HD operators to stay conscious during night shift, which opposite human body's biological clock. This working system could create fatigue and leads to work injury.

Fatigue is a condition in which someone feel extremely tired and lack of energy, lead to unconscious situation, and followed by low quality of decision making and decreased skills level of workers<sup>2</sup>. Fatigue can be measured using a questionnaire developed by the Industrial Fatigue Research Committee (IFRC) Japan. The

survey aims to measure the level of subjective fatigue based on 30 items of general fatigue symptoms experienced by workers. In addition, the level of fatigue can be determined through Fatigue Likelihood Scoring (FLS) on the existing work schedule system and provides the mitigations based on Fatigue Risk Management System (FRMS).

This case study to identify and analyze a fatigue condition has been conducted at a coal mining site in East Kalimantan, Indonesia. Preliminary observation reveals that the working system of High Dump Truck operators (HD operators) lead to fatigue, i.e. doing monotonous and repetitive works particularly at night shift, experiencing strong whole-body vibration due to bumpy road, experiencing noise and massive dust, requiring high concentration due to the density of temporary infrastructures in the mining site, and slippery road during rainy season. Those factors influence HD operators in delivering their tasks. Hence, this study will further discuss about fatigue analysis of the work shift effect on these workers in a coal mining site in Indonesia.

**Fatigue in Coal Mining Industry**

Fatigue is a result of energy used for physical and mental activities in a long duration of time, which affect performance, reduce mental awareness,

and lead to hazardous conditions<sup>3</sup>. Fatigue defines as a combination of symptoms which reduce working performance such as loss of attention, long reaction time, and reduced the ability to make decisions<sup>4</sup>. Fatigue could be analyzed through working systems applied in a company, which consist of working shift and working time. Working shift is a pattern of employees' working time set by a company<sup>5</sup>.

In relation to the case study which conducted at a coal mining company, the Minister of Energy and Mineral Resources of the Republic of Indonesia through the Ministerial Decree No. 004/2007, sets a working-hours standard for mining workers as follows<sup>6</sup>:

- a. Seven working hours in a day or 40 working hours in a week for six working days in a week.
- b. Eight working hours in a day or 40 working hours in a week for five working days in a week.

The total 40 working hours in a week is a maximum working hours allowed. Excessive working hours could lead to fatigue, affect workers' health condition, and reduce workers' productivity. Fatigue could be measured through several methods, quantitatively and qualitatively. The information of employees' fatigue condition could assist a company in managing its resources.

**METHODOLOGY**

This study employs 28 HD operators, in which 14 operators work at day shift and the other 14 work at night shift. There are two methods conducted for data collection. The first method is distributing Industrial Fatigue Research Committee (IFRC) survey to all HD operators. IFRC survey was developed by Industrial Research Fatigue Committee in Japan. The survey aims to

measure the level of fatigue in a subjective method thus this survey also known as fatigues subjective self-rating. IFRC survey consists of 30 questions (Table 1) and employs Likert scale in range 1 to 4 to response to each question. Likert scale chosen by respondent will determine the frequency of fatigue that occurred.

*Table 1. Questions in IFRC survey<sup>7</sup>*

No.	Description
1	Feel heavy in the head
2	Feel tired in the whole body
3	Feel tired in the legs
4	Give a yawn
5	Feel the brain hot or muddled
6	Become drowsy
7	Strained in the eyes
8	Become rigid or clumsy in motion
9	Feel unsteady while standing
10	Want to lie down
11	Find difficulty in thinking
12	Become weary while talking
13	Become nervous
14	Unable to concentrate attention
15	Unable to have interest in thinking
16	Become apt to forget things
17	Lack of self-confidence
18	Anxious about things
19	Unable to straighten up in posture
20	Lack of patience
21	Have a headache
22	Stiff in the shoulders
23	Pain in the waist
24	Constrained in breathing
25	Feeling thirsty
26	Have a husky voice
27	Have a dizziness
28	Have a spasm of the eyelids
29	Have a tremor in the limbs
30	Feel ill

Result obtained from the IFRC survey then classified based on the classification of fatigue shown in Table 2 below.

**Table 2. The classification of fatigue based on IFRC survey<sup>3</sup>**

Category	Level	Action needed
30	-	No fatigue occurred
31-52	Low/Mild	No action for improvements needed
53-75	Moderate	Consideration for improvements
76-98	High/heavy	Improvements are needed
99-120	Very high	Action for improvements are needed immediately

The second method is Fatigue Likelihood Scoring (FLS), which aims to measure the level of fatigue based on employees' working schedule that applied in the company [8]. FLS will assess whether the company has allocate appropriate working schedule (including resting time) for their employees using FLS matrix shown in Table 3 and FLS level of categorization shown in Figure 1. This study utilizes secondary data which attained from

company's record and collected in assistance and acknowledgement of Safety Health Environment (SHE) Department and Human Resource Development General Affair (HRDGA) Department in the coal mining company. The secondary data consists of HD operators' total working time in a day and in a week, total working time before resting time, maximum working time at night shift, and total holiday in a year.

Table 3. FLS Matrix<sup>8</sup>

Indicator	Scoring category				
	0	1	2	4	8
Total working time in a week (hours)	≤ 36	36,1 - 43,9	44 - 47,9	48 - 54,9	≥ 55
Maximum shift duration (hours)	≤ 8	8,1 - 9,9	10 - 11,9	12 - 13,9	≥ 14
Minimum hours difference before starting the next shift	≥ 16	15,9 - 13	12,9 - 10	9,9 - 8	≤ 8
Total night shift working time in a week (hours)	0	0,1 - 8	8,1 - 16	16,1 - 24	≥ 24,1
Frequency of holidays given by the company	≥ 1 day/ week	≤ 1 day/ week	1 day/2 week	1 day/3 week	1 day/4 week

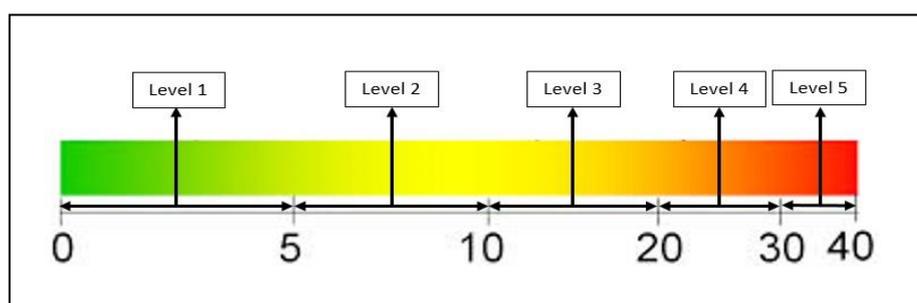


Figure 1. FLS level of categorization<sup>8</sup>

In addition, FLS' result could be developed to provide recommendations thus reduce fatigue that occurred. In this regards, the study employs Fatigue Risk Management System (FRMS) which was developed by Transport Canada. FRMS contains fatigue risk trajectory or the hazard control model (Figure 2) which provides guidelines to maintain safety procedures as a

result of fatigue based on the principles and scientific knowledge and also operational experience<sup>9</sup>. The model aims to ensure that employees work in high level of awareness towards fatigue. As a follow up to FLS, the level of fatigue obtained is analyzed according to the risk trajectory graph shown in Figure 2.

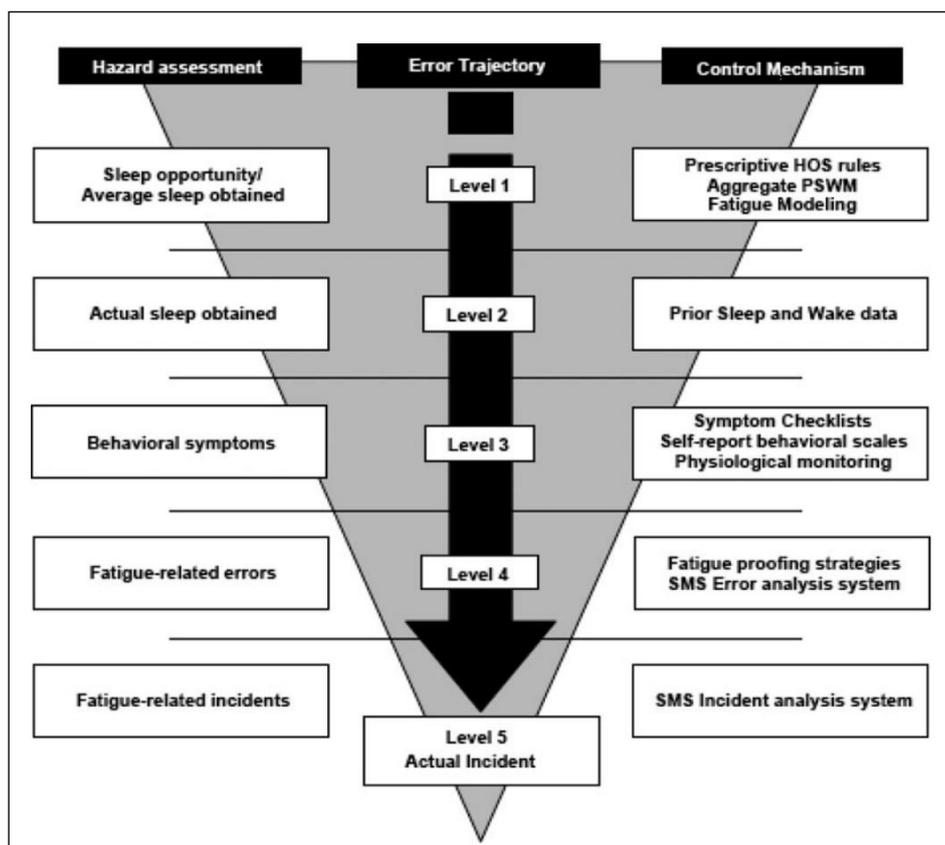


Figure 2. Dawson and McCulloch’s Model of Fatigue Risk Trajectory in FRMS<sup>9</sup>

**RESULTS**

Fatigue measurement using IFRC survey reveals that HD operators who work at night shift experience higher level of fatigue compare to those who work at day shift (Figure 3). The values of both day and night shift operators show that fatigue classified into low/mild fatigue level (range 31-52; refer to Table 2). In detail, the exact value of fatigue for night shift operators (51.85) is close to moderate fatigue level (range 53-75) thus requires for improvement.

Fatigue measurement using FLS (Table 4) shows the scoring result of fatigue as of 22. The value is categorized into level 4 (Figure 1) and indicates a high level of fatigue. In addition, the FLS scoring category shows that HD operators experience excessive working hours (more than 55 hours per week and against government regulation, which is 40 hours per week). Particularly for night shift operator, the excessive working hours might influence the operator resting time and lead to sleepiness.

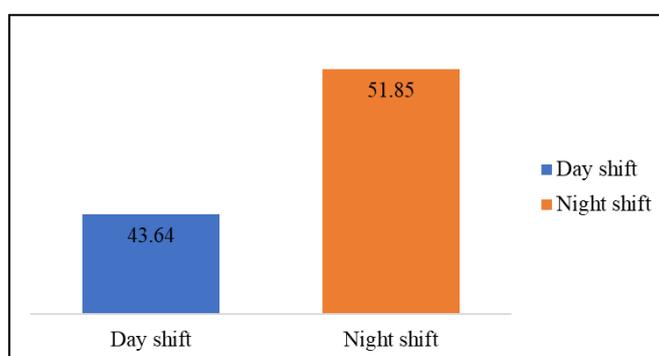


Figure 3. The average value of fatigue based on IFRC survey

**Table 4.** FLS results based on HD operators’ working schedule

Indicator	Scoring category					Scoring result
	0	1	2	4	8	
Total working time in a week (hours)	≤ 36	36.1 - 43.9	44 - 47.9	48 - 54.9	≥ 55	8
Maximum shift duration (hours)	≤ 8	8.1 - 9.9	10 - 11,9	12 - 13.9	≥ 14	2
Minimum hours difference before starting the next shift	≥ 16	15.9 - 13	12.9 - 10	9.9 - 8	≤ 8	2
Total night shift working time in a week (hours)	0	0.1 - 8	8.1 - 16	16.1 - 24	≥ 24.1	8
Frequency of holidays given by the company	≥ 1 day/ week	≤ 1 day/ week	1 day/2 week	1 day/3 week	1 day/4 week	2
	<b>Total score</b>					<b>22</b>

**DISCUSSION**

Result obtained from the IFRC survey implies that working shift influence fatigue that occurred, that lead operators to feel drowsy easily, less focus on work, and against the body rhythm. Particularly for night shift operators, they have to adjust their body rhythm to the opposite condition (sleep at day time and work at night time) after work; as a consequence, they cannot rest easily and directly after finishing their work shift. According to<sup>10</sup>, when the amount of light increases, the secretion of melatonin hormone which functions to stimulate the body to sleep decreases, hence body will remain conscious. As a consequence, consideration for improvement is still required.

Furthermore, FLS total scoring indicates that fatigue experienced by the HD operators is categorized into level 4 (refer to Figure 1). According to<sup>9</sup>, fatigue has a correlation to sleep duration and time (also known as circadian rhythm) and affected by various working shift and or schedule.

The level of fatigue obtained from both IFRC survey and FLS indicated that fatigue experienced by the HD operators was significantly affected by the prevailing working schedule compared to fatigue-related factors represented by 30 questions contained in the IFRC survey. Thus, the consideration for improvement required is more on managing the existing operators’ working schedule to be able to minimize fatigue events during work.

Since the results from both IFRC survey and FLS concern on excessive working schedule hence, this study focus on proposing strategies to manage the HD operators’ working schedule that applied in the company. Table 5 shows a systematic control mechanism as recommendations for

further action to reduce the level of fatigue that occurred.

Moreover, as a follow up to FLS, the study analyzes the level of fatigue obtained using Fatigue Risk Management System (FRMS) graph (Figure 2). FLS resulted that the level of fatigue based on HD operators’ working time is categorized into level 4 thus in FRMS graph, further analysis refers to error trajectory level 4. In this level, hazard assessment lead to fatigue-related errors, which indicates that fatigue experienced by the HD operators during their working shift lead to human errors and might cause work injury. To response to the hazard assessment, FRMS provides a control mechanism which consists of having fatigue proofing strategies and safety management system (SMS) of errors analysis system.

**CONCLUSION**

This study employs Industrial Fatigue Research Committee (IFRC) survey, Fatigue Likelihood Scoring (FLS), and Fatigue Risk Management System (FRMS) graph to determine and analyze fatigue experienced by HD operators in a coal mining company in Indonesia. Based on data collection and analysis, this study reveals that:

1. The level of fatigue obtained from IFRC survey shows that HD operators experienced low/mild fatigue. To compare the value between day and night shift, the level of fatigue experienced by night shift HD operators is higher than day shift operators. The condition is influenced by operators’ working shift that lead operators to feel drowsy easily, less focus on work, and against the body rhythm (stay awake at night and sleep at day time). Even though the level of fatigue is low/mild, the exact value closes to moderate level hence consideration for improvements is in need.

**Table 5. Control mechanism based on the level of fatigue obtained from Fatigue Risk Management System (FRMS) graph**

Actual condition	Effect	Proposed strategies	Objectives
Excessive working hours	Less resting time	Provide optimum resting time (8-16 hours)	Avoid and minimize work injury as a result of fatigue
Monotonous working systems	Feeling easily drowsy, boring dan less focus	Equipped the operators with audio music which encourage positive energy and increase focus in doing routine tasks	Improve operators' performance through the benefits of music
Two working shift available; day shift and night shift	Excessive working hours (>40hours/week)	Applied three working shift: day shift, afternoon shift, and night shift.	Reduce the excessive working hours and the level of fatigue

2. The level of fatigue obtained from FLS shows that HD operators experienced excessive working hours, particularly night shift operators. HD operators work more than 55 hours per week which against government regulation about working-hours standard for mining workers.

3. The level of fatigue obtained from FLS relates to fatigue-related errors in FRMS graph (both FLS and FRMS are in level 4) and requires a control mechanism to reduce fatigue that occurred.

Based on the above results, this study proposes recommendations as a control mechanism to response and reduce the existing fatigue as follow:

1. Provide optimum resting time thus minimize fatigue which can lead to work injury.
2. Equip HD operators with audio music which enable their positive energy and reduce boredom as a result of monotonous and routine tasks thus increase performances.
3. Apply three working shift in 24 hours working schedule, which are day shift, afternoon shift, and night shift.

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