UDC 613.6.02
DOI: 10.21668/health.risk/2023.1.08.eng

Read online

Research article

JOB DESIGN FOR CRANE OPERATORS BASED ON FATIGUE ASPECTS AND MENTAL WORKLOAD IN INDONESIA

I. Pratiwi, S. Oktaviara

Universitas Muhammadiyah Surakarta, Jl. Jend. A Yani Tromol Pos 1 Pabelan, Surakarta, 57102, Indonesia

Terminal Teluk Lamong (TTL) in Indonesia is a company that operates in service sector managing a multipurpose terminal. It provides various services such as loading and unloading containers and dry bulk using integrated crane tools that employ the first semi-automatic facilities and infrastructure in Indonesia. Crane operators' work involves risks of work accidents because they operate at heights and their job tasks require high concentration.

This study aimed to find out fatigue levels and mental workloads typical for workplaces of crane operators and to analyze and assess working conditions. The study results gave grounds for developing recommendations on how to improve workplaces of STS and GSU crane operators who deal with loading and unloading containers and dry bulk cargoes at a seaport.

The relevant data were obtained by questioning 56 STS and GSU crane operators working in four shifts, 6 hours each. We used an employee identity questionnaire as well as SOFI and NASA TLX questionnaires. The results were analyzed to obtain scores for estimating fatigue levels and mental workloads. Statistical analysis involved correlation and regression tests on two variables on STS and GSU crane operators. Upon completion, some recommendations were suggested as regards necessary changes into work process and longer rest in order to reduce fatigue and mental workloads for operators.

The SOFI questionnaire established medium fatigue levels of STS and GSU operators but mental workloads turned out to be high. The correlation test did not reveal any correlation between fatigue and mental workloads for STS crane operators.

It was shown that fatigue could be overcome by adequate rest, well-balanced diet rich with nutrients, and relevant exercise. At the same time, arranging work shifts more rationally, socializing, and training on the importance of fatigue awareness can reduce high mental workloads. The study results can help prevent or reduce increased fatigue and mental workloads that can lead to work accidents.

Keywords: *SOFI method, NASA-TLX method, crane operator, Terminal Teluk Lamong, risks of work accidents, fatigue, mental workloads, statistical analysis, Indonesia.*

Based on the Social Security Administering Body (BPJS) for Employment data, work accident cases in Indonesia have increased from 114,000 cases in 2019 to 177,000 cases in 2020 [1]. More than 65 % of workers in Indonesia come to company polyclinics with complaints of work fatigue. This complex phenomenon occurs due to wake time, long working hours, extreme workloads, health, high responsibility at a workplace, and lifestyle both on and off work duty [2].

Tedious or repeating tasks may increase work fatigue. Fatigue can be described as critical or chronic. Fatigue can be defined as feeling very tired or sleepy due to lack of sleep, prolonged mental or physical work, and prolonged stress or anxiety [2, 3]. In general, fatigue manifests as tiredness, dysautonomia, and decreased work efficiency. This may result in some diseases such as chronic fatigue syndrome, psychosis, depression, stress-related disorders, autoimmune diseases, etc. [4].

Indah Pratiwi – Doctor of Industrial Engineering, Associate Professor at Faculty of Engineering (e-mail: indah.pratiwi@ums.ac.id; tel.: +62 813 9349-8843; ORCID: https://orcid.org/0000-0002-6412-3304).

Senja Oktaviara – Researcher at the Researches Centre for Logistics and Industrial Optimization Studies (e-mail: senjaoktaviara15@gmail.com; tel.: +62 896 9011-2775).

Work-related fatigue is highly relevant not only for workers' health assessment but also for safety issues related to preventable deaths and injuries [5]. Apart from that, fatigue consists of acute and chronic symptoms with subjective and objective features that correspond to situational and individual characteristics. Therefore, it is hard to evaluate fatigue subcomponents comprehensively [6].

Fatigue is characterized by multi-dimensional aspects of physical, mental, and functional health, all of which interact [6]. Fatigue leads to changes in a strategy for use of resources in some processes such as the initial level of mental processing or physical activity that is either maintained properly or reduced [3].

The multi-dimensional concept of mental workload (MWL) and subjective perception are the fundamentals that differ between task and operator characteristics at a crane operator's workplace. Environmental context, time pressure, and other subjective aspects influence stress perceptions or fatigue[1].

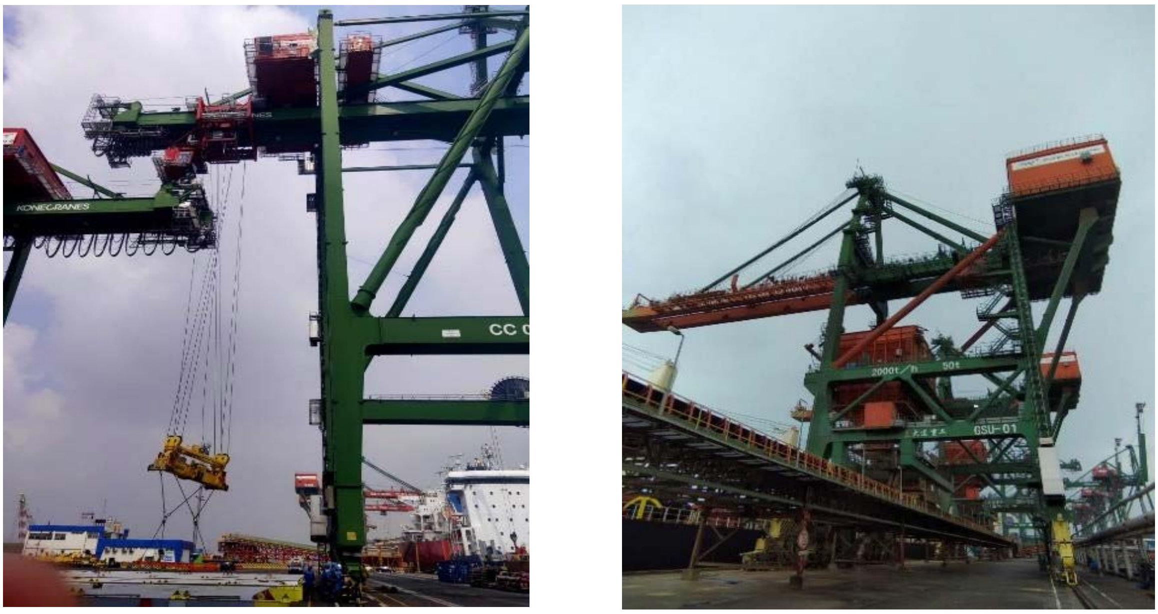
To unify these dimensions and better understand them, MWL must meet both objective and subjective criteria, mediated by task demands, external support, and experience [7]. There are three aspects of fatigue, namely: physiological fatigue (reduction in physical capacity), objective fatigue (reduction in work), and subjective fatigue (feeling tired) [8]. The underlying structure of the instrument corresponds to a new qualitative and quantitative description of the perceived physical (exertion and discomfort) and mental (lack of motivation and sleepiness) dimensions of the instrument. Within this concept, lack of energy factors relates to fatigue dimension with physical and mental characteristics [9]. Any workload must be adapted to a worker's health because it can affect a company positively or negatively [10]. E. Ahsberg developed the Swedish Fatigue Inventory (SOFI) method to evaluate fatigue levels in a practical, fast and straightforward way [9].

Intuitively, mental workload is the amount of mental work required by a person to complete a task over a certain period of time [11]. To be more precise, the construct arises from the interaction between the requirements of a given task, the circumstances in which it is performed, the context and skills, behavior, emotional state, and perception of a crane operator [12]. Mental workload is assessed by different techniques, including physiological, performance-based, and subjective measurements [13]. Mental workload is formed mentally and can be seen from the work activities performed. The most widely used mental workload measurement questionnaires are the Subjective Workload Assessment Technique (SWAT) and the National Aeronautics and Space Administration-Task Load Index (NASA-TLX) [13]. Besides that, the research [14] discusses how the work sampling method was used to determine physical workload and the NASA-TLX was utilized to analyze mental workload.

The study [15] has been carried out to analyze the performance of container cranes and supply chain efficiency modeling at the port. It was applied to four Rubber Tired Gantry (RTG) cranes from three different ports. The study results indicate that the RTG model obtains decent results with the same accuracy as the STS model. Previous research on NASA-TLX was conducted by [16] to analyze the workload level of Automated Stacking Crane (ASC) operators in TTL Indonesia. The results of this study indicate that the ASC operator's workload level is high with influencing indicators, namely performance (P) and mental demand (MD) [16]. The NASA-TLX is an excellent multi-dimensional scale for measuring mental workload. The guide by V.J. Gawron notes found that TLX is highly favorable, sensitive to changes in workload, and has high diagnostic value[2].

[1] ISO 10075-1:2017. Ergonomic principles related to mental workload – Part 1: General issues and concepts, terms and definitions, 2017, 9 p.

[2] Gawron V.J. Workload Measures, 3rd ed. Boca Raton, CRC Press, 2019, pp. 1–65. DOI: 10.1201/9780429019579



a *b*

Figure 1. (*a*) Ship to Shore (STS) Crane, (*b*) Grab Ship Unloader (GSU) Crane

Terminal Teluk Lamong (TTL) in Indonesia is a company that operates a multipurpose terminal rendering various services such as loading and unloading containers and dry bulk. The terminal uses integrated crane tools with the first semi-automatic facilities and infrastructure in Indonesia [16]. Stevedoring or loading and unloading of containers and dry bulk is an activity to unload or remove containers from the ship and load or load them into the ship. This activity uses a crane consisting of a Grab Ship Unloader (GSU) and a Ship To Shore (STS) Crane. GSU is a crane used for dry bulk unloading activities at the dock. STS is a tool used to lift containers in loading and unloading activities at the dock (Figure 1). This tool is handled by an operator from the top of a crane. Several work processes occur in the loading and unloading process using cranes, namely hoist, trolley, gantry, and boom [17].

Operators work in a shift system divided into five groups. This job is an activity with a high risk because it is performed at a height and requires high concentration. Based on the company's accident data in 2020, 39 accidents occurred during stevedoring activities at TTL Indonesia.

This study aimed to to determine the level of fatigue and mental workload experienced by crane operators. Is this partly a cause of accidents in stevedoring activities at TTL Indonesia? To achieve this, it was necessary to analyze and evaluate workloads using the SOFI method to determine the level of operator fatigue and the NASA-TLX method to determine the level of mental load experienced by the operator. The implication of the research would be to provide recommnedations on a more appropriate job design to reduce problems that occur in the stevedoring process for crane operators.

Materials and methods. This research was conducted on crane operators in TTL Indonesia, where they handled two types of cranes, namely GSU and STS. Fifty-six operators were divided into four work shifts, 6 hours each. The first shift started at midnight and finished at 6 am; the second one, 6 am – noon; the third one, noon – 6 pm; and the last one, 6 pm – midnight. The workers were divided into five groups: E, F, G, H, and I. The five groups included 46 STS crane operators and 10 GSU crane operators. The tools handled by operators were cranes for dry bulk unloading activities, lifting containers for loading and unloading of containers at the dock.

This study type is qualitative research that emphasizes objective phenomena and their quantitative estimation. The objectivity of this research design is maximized by using statistical processing numbers, structures, and controlled experiments. Relevant data were collected by questioning performed among crane operators at TTL Indonesia between January and March 2021.

The research procedure involved several stages. The first stage was a literature study on theories related to fatigue, mental workload, SOFI method, and NASA-TLX method. Then we conducted a field study to determine the location of the research object. The next step was to identify the problems that occur at crane operators' workplaces. Then we collected relevant data using SOFI and NASA TLX questionnaires. Fifty-six crane operators were asked to fill out the questionnaire honestly, especially regarding the conditions they felt when working. The data on fatigue levels were estimated as per the SOFI scales; mental workloads, as per the NASA TLX scales. The hypothesis was that there was a relationship between the level of fatigue and mental workload using statistical tests.

Finally, analysis was carried out and improvements were suggested to overcome fatigue and mental workload experienced by crane operators.

Research methods. The SOFI method is a tool used to identify factors that cause fatigue during work activities subjectively. The SOFI method was developed by E. Ahsberg in 1999; it involves observing several indicators, each of them having five multi-dimensional questions [9]. SOFI's five dimensions are sleepiness, physical discomfort, lack of motivation, lack of energy, and physical exertion. Each dimension is described in 25 questions. Each participant was asked to provide a subjective self-assessment on a scale from 0 to 6. A scale of 0 means it is not felt, while a scale of 6 means it is very felt [18]. To find out which statement has the highest level, a rating with a sub-maximum level is made [19].

Thus, the first dimension describes lack of energy with such words as 'overworked', 'worn out', 'exhausted', 'spent', 'drained'. The second dimension is physical exertion described with 'sweaty', 'breathing heavily', 'palpitations', 'hot', 'out of breath'. The third dimension is physical discomfort, consisting of 'tense muscles', 'stiff joints', 'numbness', 'hurting', 'aching'. The fourth dimension is the lack of motivation, which consists of 'uninterested', 'passive', 'listless', 'indifferent', 'lack of concern'. The last fifth dimension is sleepiness described with 'sleepy', 'falling asleep', 'drowsy', 'yawning', 'lazy' [18].

The steps used to apply the SOFI method are: (1) calculating the average of each dimension, (2) calculating the total average, (3) interpreting the score. After calculating using the SOFI method, the level of fatigue experienced by a crane operator can be analyzed. This method makes it easy to classify the types of fatigue that can be seen based on the fatigue rating classification. The rating categories are < 1.13 for the low fatigue category, a rating value of 1.13–4.87 for the moderate fatigue category, and a rating value of > 4.87 for the high fatigue category [21].

The NASA-TLX method developed by Hart and Staveland is a tool to analyze the characteristics of workloads precieved by a crane operator [12]. The method was used to subjectively collect workload scores based on the average of the six-factor ranking considerations [22]. Workers were asked to assess (between 0–100) six factors of the job [15]. These factors include mental demand (MD), physical demand (PD), temporal demand (TD), performance (P), effort (E), and frustration level (FL). MD component is measured with a low-high scale and means the mental activity and perception needed to do a task. PD component also measured with a low-high scale is physical activity needed to do a task. TD component is the time needed to do a task. These three components of the workload are related to specific demands a worker has to meet to perform the relevant job tasks [22]. The FL dimension measured with a low-high scale is the mental and physical activity needed to do a task at a certain level. The P dimension is measured with a good-poor scale and determines overall stress and / or satisfaction related to the complexity of the task. The E dimension measured with a low-high scale is the level of success or satisfaction and the level of completion of the given assignment. These three dimensions are associated with interactions between a worker and a job task [22]. When respondents fill in a questionnaire, they have to give their scores at five high – low scale and pone good – poor scale. NASA-TLX consists of two phases in its application, namely the weighting phase and the assessment phase. The weighting phase aims to determine the source of the load, while the assessment phase aims to provide an assessment of the six dimensions [23]. The data collected in the NASA-TLX questionnaire are average weighting data on mental workload and mental workload assessment. The mental workload weighting data select the most dominant mental workload dimension felt by respondents while the assessment data give a rating on questions related to the mental workload dimension.

NASA-TLX data processing included several steps: (1) weighting, (2) rating, (3) calculating the value of the moment product (see eq. 1), (4) calculating the weighted workload (WWL), (5) calculating the mean WWL (see eq. 2), (6) interpretation of the score [24]:

$$\text{Product} = \text{raiting} \cdot \text{weight} \qquad (1)$$

$$\text{WWL} = \sum \text{Product} \qquad (2)$$

The work is categorized as heavy if the score is 80; moderate if the score is 50–80; and relatively easy if the score is < 50 [14]. The categories of high and low mental workload experienced by crane operators are given to facilitate the type grouping, namely: low, medium, relatively high, high, and very high. The assessment categories for the NASA-TLX method are rating value 0–9 for very low workload category, rating value for 10–29 for low workload category, rating value for 30–49 for medium workload category, rating value for 50–79 for high workload category, and a rating of 80–100 in the very high workload category [23, 25].

Data analysis. The calculation results in SOFI and NASA TLX scores were then analyzed using the Statistical Package for the Social Sciences Version 21.0 (SPSS Version 21.0) software. We perfromed correlation and regression tests on two variables to test a hypothesis about a possible relationship between the level of fatigue and the level of workload of the STS and GSU crane operators.

H0: there is no relationship between the level of fatigue and the level of mental workload of a crane operator;

H1: there is a relationship between the level of fatigue and the level of mental workload of a crane operator.

Regression analysis was aimed at determining whether there is a positive effect between two variables, mental workload and the fatigue level for STS and GSU crane operators.

H0: There is no positive effect between two variables;

H1: There is a positive influence between two variables.

The results of the correlation test with SPSS Version 21.0 were put into the Pearson Correlation tavle. The regression test produced an ANOVA table to determine the relationship between the dependent and independent variables.

The analysis was continued by providing alternative solutions in the form of proposed improvements, namely the right job design to reduce fatigue levels and workloads that are too high.

Results and discussion. General data on respondents included the following: age (years), body mass index obtained from weight (kg) and height (cm), history of illness, work records (years), sleep duration (hours per day), and commuting time (minutes). The questionnaire was filled out by 56 respondents, consisting of 46 STS crane operators and 10 GSU crane operators, as shown in Table 1.

Table 1

General profiles of STS and GSU crane operators

Characteristics		STS crane		GSU crane	
		Abs.	(%)	Abs.	(%)
Age (years)	17–25	1	2.17	0	0.00
	26–35	28	60.87	7	70.00
	36–45	17	36.96	3	30.00
	46–55	0	0.00	0	0.00
Body mass index	Skinny	1	2.17	0	0.00
	Normal	21	45.65	5	50.00
	Overweight	9	19.57	1	10.00
	Obese	15	32.61	4	40.00
Work records (years)	< 5	32	69.57	3	30.00
	≥ 5	14	30.43	7	70.00
Diseases in a case history	Yes	5	10.87	1	10.00
	No	41	89.13	9	90.00
Sleep duration (hours/day)	< 7	25	54.35	6	60.00
	≥ 7	21	45.65	4	40.00
Commuting time (minutes)	< 43	21	45.65	3	30.00
	≥ 43	25	54.35	7	70.00

Table 1 shows that work records affect work performance. The longer a person's work records, the better he can understand his body condition so that it can prevent fatigue symptoms that arise [26]. Respondents of STS cranes with a history of disease were 10.87 %, namely 5 people, and respondents without a history of disease were 89.13 %, namely 41 people. Respondents of GSU cranes with a history of disease accounted for 10 %, namely 1 person, and respondents without a history of disease, 90 %, namely 9 people. If a person has a history of certain diseases such as flu, glandular fever, anemia, sleep disorders, Chronic Fatigue Syndrome or Myalgic Encephalopathy (CFS/ME), hypothyroidism, hepatitis, tuberculosis or chronic pain, celiac disease, Addison's disease, Parkinson's disease and heart disease, HIV/AIDS, or cancer, they can be a cause of fatigue. Taking certain medicaiton cal also lead to it [27].

STS crane respondents with sleep duration below the normal limit of < 7 hours accounted for 54.35 %, and respondents with a normal sleep duration of 7 hours accounted for 45.65 %. Sixty percent of GSU crane respondents slept for less than 7 hours, and 40 % of respondents had normal sleep duration of 7 hours and longer. Normal sleep time for adults, according to the National Sleep Foundation, is 7–9 hours per day. Reduction of sleep time by about 2–3 hours from the normal limit can cause a lack of sleep. A lack of sleep that occurs continuously for 5–10 days can reduce a person's awareness, worsen cognitive performance, slow response time, reduce mood, motivation, morale, and initiative [28].

Respondents with STS cranes with commuting time < 43 minutes accounted for 45.65 %, and respondents with commuting time ≥ 43 minutes accounted for 54.35 %. Meanwhile, 30 % of GSU respondents reported commuting time < 43 minutes and 70 % of respondents reported commuting time ≥ 43 minutes. Workers who spend 43–90 minutes on a single walk can waste 14 minutes of sleep each night and report experiencing mental fatigue on weekdays from arriving late [29]. Time spent by workers on commuting to and from work coupled with overtime work can reduce sleep or rest time as well as time for family [30].

Data analysis. Data were analyzed after collecting those related to the level of fatigue and mental load of workers. Data analysis was perfomed first using SOFI and NASA-TLX methods and then by statisitcal methods.

1) Calculation results using the SOFI method

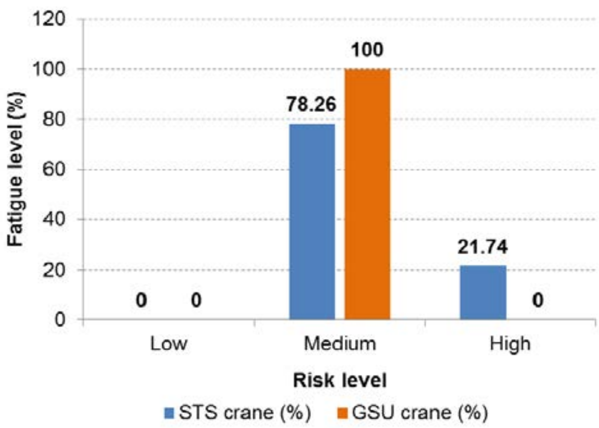
Based on the SOFI method questionnaire filled by 46 STS crane operators, the level of fatigue in the low category was 0 %, the medium category was 78.26 % with a total of 36 operators, and the high category was 21.74 % with a total of 10 operators (see Figure 2(*a*)). Based on Figure 2, it can also be seen that the fatigue level of the GSU crane operator is in the medium category at 100 %, with a total of 10 operators. So it can be concluded that based on the SOFI questionnaire, the fatigue level of the STS and GSU crane operators is in the medium category.

The results obtained for the dimensions of the level of fatigue using the SOFI method indicate that the highest total value for GSU crane operators was identified for the 'physical discomfort'scale equaling 199.6; the next was sleepiness with a total value of 190.6, and lack of motivation with a total value of 158.8 (Figure 2(*b*)). Figure 2 also shows the results of the fatigue level dimension for STS crane operators using the SOFI method; they given with the blue curve. The highest total value was identified for physical discomfort equaling 46, then sleepiness folowed with a total value of 42, and lack of energy with a total value of 27.8. So it can be concluded that physical discomfort and lack of motivation are two dimensions that greatly affect the fatigue level of STS and GSU crane operators. Other studies describe related but a bit difefrent states, such as physical exhaustion, lack of strength, and lethargy that shift workers may be quite sensitive to. Thus, long shifts or a series of long working days can have a greater effect on physical fatigue.

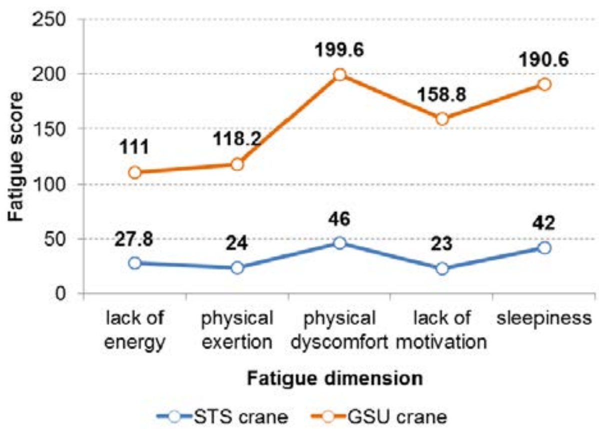
The state of high sleepiness occurs in night shift workers [19]. In addition, shift cycles with short rest periods between shifts can lead to sleep deprivation, resulting in drowsiness during a work day [9].

2) Calculation results obtained by using the NASA-TLX method

Based on the NASA TLX questionnaire filed by 46 STS crane operators, it was established that the mental workload level in the very low category was 0 %, the low category was 0 %, the medium category was 0 %, the high category was 57 % identified for 26 operators, and the very high category was 43 % identified for 20 operators. For GSU crane operators, the medium category was identified for 10 % (1 operator); the high category, 60 % (6 operators); and the very high category was identified for 30 % (3 operators). So it can be concluded that based on the NASA-TLX questionnaire, the mental workload level is in the high category for the STS and GSU crane operators (see Figure 3(*a*)).

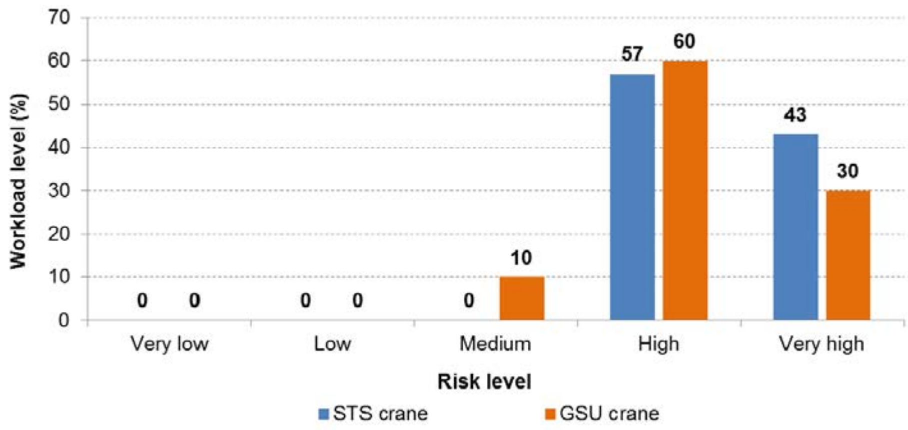


a

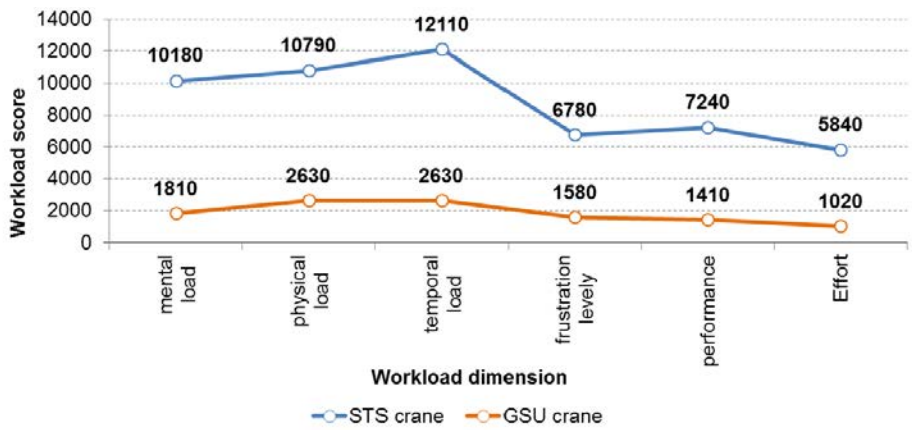


b

Figure 2. SOFI method to measure (*a*) fatigue level, (*b*) fatigue dimension in STS and GSU crane operators



a



b

Figure 3. NASA-TLX method to measure (*a*) risk level, (*b*) workload level for STS and GSU crane operators

Figure 3(*b*) shows mental workload scores using the NASA-TLX method. The dimensions of workload with the three highest scores are temporal demand, physical demand, and mental demand and they are are experienced by both STS and GSU crane operators. Each has a score: temporal demand is 12,110 for STS crane operators and 2630 for GSU crane operators, physical demand is 10,790 for STS crane operators and 2630 for GSU crane operators, and mental demand has a score of 10,180 for STS crane operators and 1810 for GSU crane operators.

Table 2 shows the results of the Kolmogorov – Smirnov normality test using the SOFI method and the NASA-TLX for STS crane operators, and the P-value is 0.2. The data is said to be normally distributed if the P-value $> \alpha$ ($\alpha = 0.05$). From the resulting normality test, the data is normally distributed, or the data is not biased because the P-value $> \alpha$. The correlation test was aimed to identify a possible relation between the level of fatigue and mental workload on STS crane operators; as a result, P-value of $0.761 > 0.05$ was obtained so that H0 is accepted. There is no relationship between fatigue and mental workload for STS crane operators.

The correlation analysis stabliched the value of the correlaiton coefficient equal to 0.046 indicating that the relationship between the two variables is insignificant. Based on the results of the calculations in the ANOVA table for STS crane operators, it is known that the F-Count value is $0.094 <$ F-Table value which is 4.06. So, H0 is accepted meaning there is no positive effect between the independent variable and the dependent one. The obtained regression model is $Y' = 3.154 + (0.006)X$.

Table 2

Normality test results

Results		STS crane		GSU crane	
		SOFI	NASA-TLX	SOFI	NASA-TLX
Normality test	N	46	46	10	10
	significance	0.200	0.200	0,200	0,200
Correlation analysis	P	0.761		0.751	
	Correlation coefficient	0.046		-0.115	
Variation analysis	F-count	0.094		0.108	
	F-table	4.06		5.32	

Based on the results of the Kolmogorov-Smirnov normality test on the GSU crane operator, a P-value of 0.2 was obtained. The data are considered to be normally distributed if the P-value > α (α = 0.05). From the normality test, the data are normally distributed and not biased because P-value > α. The correlation test between the level of fatigue and mental workload for GSU crane operators establsihed a P-value of 0.751 > 0.05 so that H0 is accepted indicating there is no relationship between the level of fatigue and mental workload for GSU crane operators. The correlation coefficient was established to be equal to -0.115 indicating there is no relationship between the two variables. Based on the results of the calculations in the ANOVA table, it was established that the H-Count value is 0.108 < F-Table of 5.32. So, H0 is accepted meaning there is no positive effect between the independent variable and the dependent one. The obtained regression model is $Y'= 3.791 + (-0.007)X$.

Suggestions on improvement. The results of the study using the SOFI method showed that the largest percentage of moderate fatigue levels was 78 % for STS crane operators and 100 % for GSU crane operators. Meanwhile, using the NASA TLX method, the largest percentage was established for the high mental load level, namely 57 % for STS crane operators and 100 % for GSU crane operators. Measurement of fatigue levels and workloads is subjectively considered a flexible and comfortable method to estimate a workplace; it is not time-consuming and the cheapest to evaluate workload[3]. High levels of fatigue can contribute to work errors and accidents, especially if jobs require high level of alertness [31].

The improvements that can be made to reduce high fatigue on crane operators based on the highest indicators experienced are provided in Table 3.

Based on the results of mental workload research using the NASA-TLX method, it can be seen that crane operators have a fairly high level of mental workload. The improvements that can be made to overcome the high mental workload at crane operators' wokrplaces considering the highest indicators experienced are provided in Table 4.

The high mental load can also lead to chronic fatigue, demotivation, poor health, and absenteeism [31]. Ergonomic workplace design can reduce the impact of fatigue and can help reduce mental workload and avoid work accidents [31]. In addition to the job demands, operator performance is related to fatigue, alertness, and duration of work[4]. It is necessary to search for balance between workers' fatigue, stress, and independent control [35].

Work fatigue can be overcome with adequate rest, eating nutritious food, exercising, ergonomic exercises, and adequate sleep duration. High mental workloads can be overcome by adjusting them with operators' own ability, providing rewards and employee motivation. The company can conduct socialization or training about the importance of mental workload and fatigue awarness, maximaze safety talk, and roster shift adjustment.

[3] Gawron V.J. Workload Measures, 3rd ed. Boca Raton, CRC Press, 2019, pp. 1–65. DOI: 10.1201/9780429019579
[4] Handbook of Cognitive Task Design. In: E. Hollnagel ed. Boca Raton, CRC Press Publ., 2003, 840 p.

Table 3

Suggested measures to reduce fatigue levels

Indicator	Suggested improvements
Physical discomfort	Operators experience physical discomfort, namely: pain, cramps, joint stiffness, and muscle tension due to a bent working posture. In addition, operators also experience complaints and pain in the neck and back of the body, leading to musculoskeletal disorders (MSDs). MSDs occur in nine body parts, namely: neck, shoulders, forearms, elbows, lower back, waist, wrists, thighs, and knees [22]. Work methods should be revised to reduce muscle fatigue caused by repetitive motion [32]. The solution is for operators to exercise regularly, participate in fitness challenge programs, perform ergonomic exercises and relaxation/neck stretching movements such as head drops, shoulder blade squeeze, prone extension in between of work activities. Operators can carry out regular medical check-ups at the company's clinic and participate in a fit to work program [30].
Lack of energy	There is an increase in the amount of energy released during the night shift and this is correlated with the dimension of sleepiness [19] due to larger workload on the body during a night shift. Operators are overworked, feeling tired, and drained of energy. The improvement is that an operator gets enough rest time which he uses efefctively. They should consume nutritious food, avoid spicy and high-fat foods because they can interfere with digestion and sleep patterns.
Sleepiness	Operators can do a power nap, which is a short nap for 30–45 minutes before work. This is considered to increase a person's awareness. Maintain a normal sleep pattern of 7–9 hours per day. The duration of the break between working hours needs to be controlled, the average rest time for 8 hours of work is 30 minutes to 2 hours [22] which is divided into coffee breaks, toilet breaks, and food breaks[5]
Lack of motivation	The company can appreciate the operator's achievements/performance by providing bonuses and allowances, evaluate operators' work, maximize safety talk activities, and provide punishment if an operator does not work according to procedures. It is also necessary to conduct training on ergonomic principles [33].

Table 4

Suggestions for reducing mental workload for crane operators

Indicator	Suggested improvements
Temporal demand	Operators have high time requirements, and this is related to repetitive work. Operators can take advantage of waiting time and prayer breaks as a way to reduce this load.
Physical demand	Crane operators have high physical needs because they work with continuous physical activity. An operator who works at height requires a healthy physique to be able to focus on work. Awkward posture, lifting heavy weights, and long shifts cause pain in body parts [34]. The suggestion is to adjust the roster shift schedule so that the operator's circadian rhythm pattern is not disturbed.
Mental demand	Crane operators require high concentration, focus, and vision in their work. Single workers have 3.43 times more distractions than married ones. It is necessary to understand that emotional support from a family can be considered a factor able to adjust workload and behave more safely [34]. In addition, operators should be able to control boredom while working. Companies can provide rewards for operator performance to increase work motivation.

Conclusion. Measurements of fatigue levels and mental load were carried out at workplaces of 46 STS crane operators and 10 GSU crane operators in TTL Indonesia. The results showed that the crane operator's fatigue level was in the medium category, while the crane operator's mental workload was in the high category. The dimensions of fatigue level for STS crane operators in a descending order are physical discomfort, sleepy, lack of motivation, physical exertion, and lack of energy; for GSU crane operators, physical discomfort, sleepy, lack of energy, physical exertion, and lack of motivation. STS and GSU crane operators have the

[5] Haworth N., Hughes S. The International Labour Organization. London, Routledge, 2012.

same descendimg order for the mental workload dimension, namely: temporal demand, physical demand, mental demand, performance, effort, and frustration level. Work fatigue can be overcome with adequate rest, nutritious food, and exercise. At the same time, high mental workload can be reduced by arranging work shifts, socializing, and training on the importance of fatigue awareness. All this aims to reduce high fatigue levels and mental workload, which can lead to industrial accidents.

Funding. The research was not granted any sponsor support.

Competing interests. The authors declare no competing interests.

References

1. Kliping Berita Ketenagakerjaan 13 Januari 2020. *Kementerian Ketenagakerjaan RI*. Available at: http://perpustakaan.kemnaker.go.id/admin/assets/product_img/pdf/13_Januari_2020.pdf (August 08, 2021) (in Indonesian).

2. Caldwell J.A., Caldwell J.L., Thompson L.A., Lieberman H.R. Fatigue and its management in the workplace. *Neurosci. Biobehav. Rev.*, 2019, vol. 96, pp. 272–289. DOI: 10.1016/j.neubiorev.2018.10.024

3. Santos J., Carvalhais C., Ramos C., Coelho T., Monteiro P.R.R., Vaz M.A.P. Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) among assembly workers: Cultural adaptation, reliability and validity. *Int. J. Occup. Med. Environ. Health*, 2017, vol. 30, no. 3, pp. 407–417. DOI: 10.13075/ijomeh.1896.00760

4. Techera U., Bhandari S., Hallowell M., Littlejohn R. Impact of worker fatigue on hazard recognition skills. *Constr. Res. Congr. 2020*, 2020, pp. 306–314. DOI: 10.1061/9780784482872.034

5. Lee S., Seong S., Park S., Lim J., Hong S., Cho Y., Kim H. Korean version of the swedish occupational fatigue inventory among construction workers: Cultural adaptation and psychometric evaluation. *Int. J. Environ. Res. Public Health*, 2021, vol. 18, no. 8, pp. 4302. DOI: 10.3390/ijerph18084302

6. Saito K. Measurement of fatigue in industries. *Ind. Health*, 1999, vol. 37, no. 2, pp. 134–142. DOI: 10.2486/indhealth.37.134

7. Soria-Oliver M., López J.S., Torrano F. Relations between mental workload and decision-making in an organizational setting. *Psicol. Reflex. Crit.*, 2017, vol. 30, no. 1, pp. 7. DOI: 10.1186/s41155-017-0061-0

8. González J.L., Moreno-Jiménez B., Garrosa E., López López A. Spanish version of the Swedish Occupational Fatigue Inventory (SOFI): Factorial replication, reliability and validity. *Int. J. Ind. Ergon.*, 2005, vol. 35, no. 8, pp. 737–746. DOI: 10.1016/j.ergon.2005.02.007

9. Åhsberg E., Gamberale F., Gustafsson K. Perceived fatigue after mental work: An experimental evaluation of a fatigue inventory. *Ergonomics*, 2000, vol. 43, no. 2, pp. 252–268. DOI: 10.1080/001401300184594

10. Junaedi D., Rizkiyah N.D., Pratya D.B. Determination of the Optimal Number of Workers Using the NASA-TLX Method in Chemical Company, Indonesia. *Int. J. Eng. Res. Adv. Technol.*, 2020, vol. 6, no. 7, pp. 51–56. DOI: 10.31695/ijerat.2020.3627

11. Longo L., Rusconi F., Noce L., Barrett S. The importance of Human Mental Workload in Web design. *WEBIST 2012, 8th Int. Conf. Web Inf. Syst. Technol.*, 2012, pp. 403–409. DOI: 10.5220/0003960204030409

12. Hart S.G., Staveland L.E. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. *Hum. Ment. Workload. Adv. Psychol.*, 1988, no. 52, pp. 139–183.

13. Chi S., Neubert M.S., Buranruk O., Limroongreungrat W., Eungpinichpong W., Puntumetakul R. Comparison of workload perception for original and modified cognitive tasks. *Ind. Eng. Manag. Syst.*, 2019, vol. 18, no. 4, pp. 701–709. DOI: 10.7232/iems.2019.18.4.701

14. Widiasih W., Nuha H. Workload Analysis Using Work Sampling and NASA-TLX for Employee of Private University in Surabaya. *J. Ilm. Tek. Ind.*, 2019, vol. 18, no. 2, pp. 134–141. DOI: 10.23917/jiti.v18i2.8247

15. Aulanko S., Tervo K. Modeling and analysis of harbor crane work efficiency using work cycle recognition. *IEEE/ASME Int. Conf. Adv. Intell. Mechatronics, AIM*, 2010, pp. 61–66. DOI: 10.1109/AIM.2010.5695907

16. Suryadi A., Zadi F.I., Sukma D. Analisis Tingkat Beban Kerja Operator Automated Stacking Crane (Asc) Dengan Metode Nasa-TLX (National Aeronautics and Space Administration Task Load Index) Di Pt. Terminal Teluk Lamong Surabaya. *Tekmapro J. Ind. Eng. Manag.*, 2018, vol. 13, no. 2, pp. 31–40. DOI: 10.33005/tekmapro.v13i2.40

17. Jo J.-H., Kim S. Key performance indicator development for ship-to-shore crane performance assessment in container terminal operations. *J. Mar. Sci. Eng.*, 2020, vol. 8, no. 1, pp. 6. DOI: 10.3390/JMSE8010006

18. Mixter S., Mathiassen S.E., Hallman D. Alternations between physical and cognitive tasks in repetitive work–effect of cognitive task difficulty on fatigue development in women. *Ergonomics*, 2019, vol. 62, no. 8, pp. 1008–1022. DOI: 10.1080/00140139.2019.1614229

19. Åhsberg E., Kecklund G., Åkerstedt T., Gamberale F. Shiftwork and different dimensions of fatigue. *Int. J. Ind. Ergon.*, 2000, vol. 26, no. 4, pp. 457–465. DOI: 10.1016/S0169-8141(00)00007-X

20. Åhsberg E., Fürst C.J. Dimensions of fatigue during radiotherapy: An application of the Swedish Occupational Fatigue Inventory (SOFI) on cancer patients. *Acta Oncol.*, 2001, vol. 40, no. 1, pp. 37–43. DOI: 10.1080/028418601750071037

21. Johansson S., Ytterberg C., Back B., Holmqvist L.W., von Koch L. The Swedish Occupational Fatigue Inventory in people with multiple sclerosis. *J. Rehabil. Med.*, 2008, vol. 40, no. 9, pp. 737–743. DOI: 10.2340/16501977-0236

22. Akyeampong J., Udoka S., Caruso G., Bordegoni M. Evaluation of hydraulic excavator Human-Machine Interface concepts using NASA TLX. *Int. J. Ind. Ergon.*, 2014, vol. 44, no. 3, pp. 374–382. DOI: 10.1016/j.ergon.2013.12.002

23. Campoya Morales A.F., Hernandez Arellano J.L., González Muñoz E.L., Maldonado Macías A.A. Development of the NASA-TLX Multi Equation Tool to Assess Workload. *Int. J. Comb. Optim. Probl. Informatics*, 2020, vol. 11, no. 1, pp. 50–58.

24. Nikulin C., Lopez G., Piñonez E., Gonzalez L., Zapata P. NASA-TLX for predictability and measurability of instructional design models: case study in design methods. *Educ. Technol. Res. Dev.*, 2019, vol. 67, no. 2, pp. 467–493. DOI: 10.1007/s11423-019-09657-4

25. Nur I., Iskandar H., Ade R.F. The measurement of nurses' mental workload using NASA-TLX method (a case study). *Malaysian J. Public Heal. Med.*, 2020, vol. 20, no. 1 (Special), pp. 60–63. DOI: 10.37268/MJPHM/VOL.20/NO.SPECIAL1/ART.705

26. Nordbakke S. Driver fatigue and falling asleep – experience, knowledge and conduct among private drivers and professional drivers. Oslo, 2004, pp. 6.

27. Theron W.J., Van Heerden G.M.J. Fatigue knowledge – a new lever in safety management. *J. South. African Inst. Min. Metall.*, 2011, vol. 111, no. 1, pp. 1–10.

28. Ramey S., MacQuarrie A., Cochrane A., McCann I., Johnston C.W., Batt A.M. Drowsy and dangerous? Fatigue in paramedics: an overview. *Irish J. Paramed.*, 2019, vol. 4, no. 1. DOI: 10.32378/ijp.v4i1.175

29. Mason S. Office Ergonomic: Practical Applications. *Ergonomics*, 2008, vol. 51, no. 11, pp. 1791–1793.

30. Costa G. Shift work and health: Current problems and preventive actions. *Saf. Health Work*, 2010, vol. 1, no. 2, pp. 112–123. DOI: 10.5491/SHAW.2010.1.2.112

31. Berlin C., Adams C. Production Ergonomics: Designing Work Systems to Support Optimal Human Performance. London, Ubiquity Press Publ., 2017. DOI: https://doi.org/10.5334/bbe

32. Pratiwi I., Brillyanto V., Fitriadi R., Anis M., Rahman M.N.A. Postural evaluation and hand activity level at batik cap process using LUBA and ACGIH HAL methods. *Int. J. Recent Technol. Eng.*, 2019, vol. 8, no. 3, pp. 2552–2560. DOI: 10.35940/ijrte.C4765.098319

33. Njaka S., Mohd Yusoff D., Anua S.M., Kueh Y.C., Edeogu C.O. Musculoskeletal disorders (MSDs) and their associated factors among quarry workers in Nigeria: A cross-sectional study. *Heliyon*, 2021, vol. 7, no. 2, pp. e06130. DOI: 10.1016/j.heliyon.2021.e06130

34. Khandan M., Mirshekari F., Koorsani E., Mosaferchi S., Koohpaei A. Subjective Workload and Musculoskeletal Disorders among Workers of a Manufacturing Company in Iran. *Biotech. Health Sci.*, 2018, vol. 5, no. 1, pp. e13599.

35. Javaremi M.N., Wu D., Argall B. The Impact of Control Interface on Features of Heart Rate Variability. *Annu. Int. Conf. IEEE Eng. Med. Biol. Soc.*, 2021, vol. 2021, pp. 7544–7550. DOI: 10.1109/EMBC46164.2021.9631053

Pratiwi I., Oktaviara S. Job design for crane operators based on fatigue aspects and mental workload in Indonesia. Health Risk Analysis, 2023, no. 1, pp. 63–74. DOI: 10.21668/health.risk/2023.1.08.eng

Received: 04.09.2022
Approved: 20.02.2023
Accepted for publication: 27.03.2023