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Application of 360 Camera Technology and Excavator Operator Workload at a Nickel Ore Mine and Its Implication for Work Accident Rates Using the Nasa-TLX Method

Fadly*, Jenni Ria Rajagukguk, Kartiko Eko Putranto, Suwanda

Magister of Management Technology, Faculty of Engineering, Krisnadwipayana University, Jakarta, Indonesia

**Corresponding author Email: fadhlyaliminhasyim@gmail.com*

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Abstract

Indonesia, as one of the largest nickel producers in the world, has around 90% of nickel reserves spread across various regions, such as Central Sulawesi, South Sulawesi, Southeast Sulawesi, and North Maluku. Even though demand for nickel continues to increase, a severe problem that needs attention is the rate of work accidents in mining fields. Most heavy equipment accidents that occur are caused by operator negligence while operating. This negligence can occur when operators are in a hurry, make mistakes while using heavy equipment, or do not have proper work time management. This research aims to analyze the impact of 360-degree camera technology on excavator operators in nickel ore mines on work accident rates and operator workload. The case study was carried out at PT Rifky and Raisha Anursyah using the NASA-TLX method to measure workload. In contrast, the number of accidents that occurred to each operator within one month was used to measure work accidents. The 360 camera technology provides a comprehensive view of the work environment, allowing operators to monitor the surrounding area better and reduce blind spots. The research results show that applying this technology can reduce the risk of work accidents and increase the work efficiency of excavator operators. With better monitoring, operators can identify potential hazards earlier and reduce the risk of accidents. Workload evaluation using NASA-TLX shows a decrease in operator workload after implementing 360 camera technology. This research provides strategic recommendations for workload management and implementing safety technology in the mining industry.

***Keywords**: NASA TLX Methods, 360 Camera Technology, Excavator Operator, Accident.*

1. Introduction

Nickel has become one of the most important mineral resources in the global market. The demand for nickel continues to rise alongside the growth of renewable energy trends. The demand for nickel for clean energy technology is expected to increase significantly by up to 20 times between 2020 and 2040. Indonesia is one of the largest nickel producers in the world. Around 90% of nickel reserves have spread across Central Sulawesi, South Sulawesi, Southeast Sulawesi, and North Maluku. The base metal industry in Indonesia is expected to grow around 10 - 15% this year due to the nickel downstream project driven by the government. Although, the demand for nickel continues to increase. However, a severe problem that needs attention is the level of work accidents in the mining field. Most of the heavy equipment accidents that occur are caused by operator negligence while operating. This negligence can happen when the operator is in a hurry, makes mistakes when using heavy equipment, or does not have proper work time management. The many accidents show that there is still much to improve regarding occupational safety in the mining industry. One worker even complained about unsafe working conditions, such as broken machines and a lack of Personal Protective Equipment (PPE) that meets standards. This shows that companies must pay more attention to team member occupational safety, as well as several accident cases that have occurred to excavator operators at mining sites, as follows: A mine worker died in a series of work accidents that happened in the mining area, PT Adi Daya Tangguh into long Village, Lede District, Pulau Taliabu Regency [1], Sunday (03/10/2021) at around 09.00 WIT. Suddenly, the excavator car went straight toward the main gate and could not be controlled by the victim, so the crane car overturned and crushed the victim, who was still in the car at that time. Because of the incident, the victim died immediately (Accident Occurs in the PT ADT Mining Area, 1 Person Dies - Berita lima.com).

Another accident occurred at the Clay Mining in Gunung Sarik, Kuranji District, Padang City, West Sumatra. Claimed two lives at 13.30 WIB, namely an excavator operator and a miner, who were buried by a landslide during the caving process [2]. Various causes can cause work accidents, one of which is workload. The level of worker performance is closely related to the worker's workload [3]. When the demands of the workload obtained by workers are excessive from what they should be, it can cause physical and mental fatigue [4]. External and internal factors can generally affect workload [5]. Physical work environment factors influence a person's mental workload [6]. Physical work environment elements include air temperature, lighting, noise, cleanliness, and safety. The physical work environment affects the workload of workers, and this is shown that with light intensity that following the provisions according to the type of work can minimize errors, noise levels that are outside normal limits affect the level of worker concentration, and optimal temperatures can provide comfort and work satisfaction [7].

In addition to measuring the workload, technology continues to develop for various operational challenges in the mining industry, such as the latest 360-degree camera technology. The use of 360 cameras provides a comprehensive view of the work environment, allowing operators to monitor the area around them better. This is especially useful in mining environments with difficult and dangerous terrain. The application of 360 camera technology in excavators can improve operator visibility, reduce blind spots, and assist in faster and more accurate decision-making. With a more comprehensive view, operators can identify potential hazards earlier and reduce the risk of accidents. In addition, this technology allows management to monitor remotely, providing an additional layer of work safety supervision. The level of occupational accidents in the mining industry is a vital indicator of the effectiveness of occupational safety programs, implementing technologies such as 360 cameras and evaluating operator workloads with the NASA-TLX method. This method can have a significant impact on reducing occupational accidents. The risk of accidents can be minimized by increasing visibility and situational awareness through 360 camera technology and managing operator workloads. Given this background, the author wants to test the hypothesis that implementing 360-camera technology can reduce workloads and occupational accident rates.

Thus, this study is entitled "Application of 360 Camera Technology and Excavator Operator Workload at A Nickel Ore Mine and Its Implication for Work Accident Rates Using The Nasa -TLX Method**".** Formulation of the problem: Does the application of 360 camera technology significantly reduce the operator's workload, and does the application of 360 camera technology substantially reduce the level of work accidents? The study aims to evaluate the workload of excavator operators after applying 360 camera technology using a qualitative research method through the NASA-TLX method. Identify and analyze the impact of the application of 360 camera technology on the safety and work efficiency of excavator operators in nickel mines. The benefits of the study are that it will provide empirical data that will help understand the impact of 360 camera technology on workload, operations, and safety in the workplace. This can be the basis for future research and technological innovation. It will also benefit the public. For the general public, this study can increase awareness of the importance of technology in maintaining work safety. This information can also be a basis for entrepreneurs in making decisions to implement new technology in their work environment.

2. Literature Review

ISO 45001 is an international standard that sets occupational health and safety requirements and OHS management systems. Using augmented reality technology, Zerosicks is an innovation in occupational safety, health, and the mining environment. Zerosicks is a work safety management that applies personal protective equipment (PPE) standards and conducts accident analysis based on Job Safety Analysis (JSA).

With Zerosicks, mining companies can improve efficiency and work safety proactively. Dan NASA-TLX (National Aeronautics and Space Administration Task Load Index) is a workload measurement method developed by Sandra G. Hart of NASA-Ames Research Center and Lowell E. Staveland of San Jose State University in 1981. This method uses a questionnaire to measure subjective workload more easily but sensitively. NASA-TLX uses six dimensions to assess workload, namely physical requirements, mental requirements, time, Performance, Effort, and frustration levels. Occupational safety methods in mining areas using the implementation of ISO 45001, the implementation of ISO 45001, Zerosicks, and NASA-TLX, mining companies can improve health, safety, and work efficiency. International standards such as ISO 45001 provide clear guidance for achieving occupational safety and health goals, while technological innovations such as Zerosicks help implement these standards more effectively. Using workload measurement methods such as NASA-TLX can also help identify areas that need improvement in occupational safety and health management. Thus, mining companies can achieve optimal occupational safety and health levels and increase productivity and operational efficiency. The physical work environment affects the workload of workers. For example, the intensity of light that follows the provisions according to the type of work can minimize errors, noise levels outside normal limits affect the level of worker concentration, and optimal temperatures can provide comfort and work satisfaction.

The physical work environment has a significant effect and the influence of the physical work environment on work stress or mental workload and the opportunity to resign. So, it can be seen that an organization or company needs an optimal work environment to improve the Performance of its workers. On the other hand, if the physical working environment does not support worker performance, it can lead to a decline in company performance.

Workload is a worker's subjective view of the number of tasks that must be completed in a certain period, as well as the Effort required to overcome various problems that may arise during work. This workload includes all tasks and responsibilities a team member must complete within a specified time limit [8].

In the work environment, workload is a crucial thing to pay attention to because it can affect a worker's productivity and mental well-being. If the workload is too heavy, it is likely to cause stress and fatigue, ultimately hurting a person's Performance and mental health. To manage the workload properly, a manager must pay attention to several things. First, managers must adequately assess the number of tasks given to each team member so that it does not burden them too much. Second, managers need to provide support and assistance to employees who have difficulty completing their tasks so that they can work more effectively and efficiently. Third, managers need to provide opportunities for employees to rest and reset their minds to stay fresh and productive at work. By managing the workload properly, workers can work more efficiently and effectively while maintaining their mental and physical health. Therefore, individuals and organizations must prioritize and manage their workload wisely to create a healthy and productive work environment [9].

Workload is a condition in which a worker must complete some tasks set within a specified time limit. This work involves mental and physical activity, giving each different burdens. In the world of work, workload is an essential thing to pay attention to so that worker productivity and well-being are maintained. When the workload is too heavy, workers can experience stress fatigue, negatively impacting

their physical and mental health [10]. To manage workload well, companies need to take various steps such as organizing tasks well, providing sufficient support and resources to workers, and ensuring that the deadlines given are realistic and following individual abilities. In addition, it is also essential to pay attention to the balance between mental and physical work so that workers can work optimally without feeling too burdened.

In managing workload, effective communication between superiors and subordinates is also essential. Superiors need to understand the needs and abilities of individuals in completing the tasks given. In contrast, subordinates must be open when conveying if they feel overburdened or need additional assistance. In addition, it is also essential to pay attention to other factors that can affect workload, such as a supportive work environment, a fair reward system, and opportunities for career development. By paying attention to these factors, companies can create a healthy and productive work environment for all employees. Each must manage stress and pressure well in increasingly complex and diverse workloads.

This can be done by managing time well, exercising regularly, and taking sufficient rest time. In addition, it is also essential to have a hobby or activity that can help relieve stress and improve mental well-being. By managing the workload well, individual productivity, well-being, and happiness will increase. Therefore, each individual and company needs to understand the importance of workload management and take the necessary steps to create a healthy and productive work environment. Workload is a collection of tasks or jobs that must be completed with predetermined time rules, where the tasks or jobs must be completed precisely at the specified time [11]. Practical workload assignments can provide clarity for employees to carry out their duties following the workload that is their responsibility and prevent the possibility of errors and difficulties [12].

The workload is work that employees must complete within a certain period. The workload can be balanced if the work received by employees follows the employees' abilities [13]. Workload is a collection or number of activities that must be completed by an organizational unit or job holder within a certain period [14]. Workload arises from the interaction between task demands, the work environment where employees are placed, skills possessed, behavior, and perceptions of employees [8] (Budiasa, 2021). Meanwhile, workload compares the total standard time to complete tasks and work to the total standard time [8] (Budiasa). Workload is divided into three levels [15], as follows: (1) Excessive Workload refers to a situation where the time required to complete tasks exceeds existing working hours or the volume of work exceeds work capacity.

Employees may experience stress and exhaustion due to this illness, which may lower output and worse-quality work output. As a result, to maintain optimal team member welfare and Performance, management must closely monitor and handle excessive workload. Achieving a Normal Workload occurs when the amount of work assigned to an individual is commensurate with their skill level or when the time needed to accomplish tasks aligns with the current work schedule. This is the perfect environment for balancing worker productivity and well-being. To get the best results, management must ensure that staff workloads are kept within realistic bounds. (3) Below average: A workload is created when the amount of work exceeds work capacity or the time needed to finish the task is less than the amount of time available. While this might sound good, it's essential to be aware of this condition since it may be a sign of underutilization or a lack of challenge in the workplace. Management must ensure that workers continue working on projects that help them reach their full potential.

There are several essential aspects that management must pay attention to when managing a workload. First, there needs to be a regular evaluation of team member workload to ensure no excess or underload. Second, management must provide adequate support and resources so employees can effectively complete tasks. Third, management must encourage open communication between leaders and staff to identify and resolve workload-related issues. Factors that influence workload can vary and significantly impact a person's health and Performance in the work environment. In this context, some factors that need to be considered are time pressure, work schedules, role ambiguity, noise, information overload, extreme temperatures, repetitive actions, and responsibilities [16]. as follows (1)Time PressureTime pressure, such as deadlines, can be a motivator to increase productivity. However, time pressure can become an excessive workload if not appropriately managed.

This can lead to increased errors and a decline in a person's health due to excessive stress. (2) work Schedule: A busy and continuous work schedule without breaks or holidays can hurt a person's physical health and mental well-being. The experience of intense work demands can cause stress in the work environment and disrupt the work-life balance. (3) Role ambiguity and Role Conflict: Role ambiguity or role conflict can affect a person's perception of their duties and responsibilities in the workplace. Unclear roles can create confusion and tension, which in turn can increase a person's workload. (4) Noise in the work environment can interfere with workers' concentration and work efficiency. Boisterous working conditions can affect health and workability, as well as increase the workload that employees must bear, (5) information Overload,

The amount of data and information that comes in simultaneously can create an ever-increasing workload for workers. Using technology and integrated workspaces requires unique adaptation from employees to manage information effectively without sacrificing their health and well-being. (6) Extreme temperatures, such as high air temperatures in the workspace, can also affect workers' health. Hazardous working conditions, such as heat overload, comfort, and even long-term health problems if not handled correctly; (7) repetitive Actions, Tasks that require repetitive physical movements, such as typing on a computer or working with machines that perform the same operations every time, can cause boredom and monotony.

This can interfere with concentration, reduce work efficiency, and increase the risk of injury due to negligence and (8) responsibility. Significant responsibility for work and others can be a burden for some people. A high level of commitment can create additional work-related stress and increase the overall workload. In managing workload, companies need to pay attention to these factors and create a healthy and productive work environment for employees. Through good management and proper support, workload can be reduced, and team member well-being can be improved. Workload Dimensions According to [17], namely (1) Time Load is the time pressure experienced when carrying out tasks. The time load dimension depends on time availability and overlap in activities. The higher the time load, the less free time and the overlap between functions. (2) Mental Effort Load is the attention and concentration required to complete tasks without regard to the number of tasks or time constraints.

This involves recalling information from long-term memory, decision-making, calculations, storing and recalling information from short-term memory, and problem-solving, and (3) psychological Stress Load is related to conditions that can cause confusion, frustration, and fear at work. The higher the psychological burden, the greater the confusion, frustration, and fear, so greater concentration is needed to control the situation. According to (Putra et al.), there are four indicators of workload, namely (a) Goals to be Achieved In achieving the work targets that have been set, it is essential for employees to have a clear view of the work results that must be completed within a certain period. This will help them prioritize tasks that need to be completed on time.

Thus, employees can work more efficiently and effectively to achieve the targets. (b) working Conditions In addition, working conditions are something that employees must pay attention to. They need to have a good view of their work conditions and be ready to face unexpected events such as demands to do extra work outside the time set. Employees can complete their work better by having a flexible attitude and being ready to overcome challenges. (c) Use of Time: Time is also essential in assessing an employee's Performance. Employees need to manage their time well to complete their tasks efficiently. By using time wisely, employees can improve their productivity, quality of work, and work Standards. Finally, work standards are also something that employees need to pay attention to.
They need to have a positive impression of their work, although sometimes the workload must be completed within a certain period, which can be challenging. Employees can overcome various obstacles and succeed in their careers by having a professional attitude and focusing on achieving targets. Meanwhile, there are 3 (three) aspects of workload, according to (Fadilla et al.), namely Physical Workload. Physical work is a type of work that requires physical energy from a person's muscles as a source of power. Physical work is also known as "manual activity," where work implementation depends entirely on individual efforts as a source of power and strength regulator. In addition, two objective methods can be used to assess physical activity: direct and indirect. (1) Mental/Psychic Workload. Every mental activity involves the perception and interpretation of information from the senses to make decisions in the mental process or remember information received to remember the past. Assessment of mental Workload is essential in research and development of the relationship between humans and machines, where comfort, satisfaction, efficiency, and safety in the workplace are the main focus in applying ergonomics. (2) Time Utilization. Calculation of Workload that focuses on the aspect of time utilization is divided into two things: repetitive work. Work with a short and repeated work duration at one time. Working in short and repeated cycles can cause fatigue in workers and reduce their alertness and non-repetitive work. Work with irregular schedules, usually related to administrative and desk work. Excessive workload can cause physical and mental fatigue and emotional reactions such as headaches, indigestion, and irritability. On the other hand, a workload that is too light due to lack of movement can cause boredom and monotony. Workloads that are not in accordance with the workforce's capabilities can negatively impact employees [18], including decreased Quality of Work.
Excessive workloads without being balanced by the capabilities of the workforce can cause decreased quality of work due to physical fatigue and reduced concentration, self-supervision, and work accuracy; customer Complaints often arise due to work results that do not meet expectations, such as slow or unsatisfactory service, increased Absenteeism. Excessive workloads can cause fatigue and even illness in employees, ultimately resulting in high Absenteeism. This can harm the smooth running of the organization and overall Performance. Thus, management must pay attention to employees' physical and mental workload to create a healthy and productive work environment. Proper ergonomics and workload assessment must be implemented to prevent the negative impacts of an unbalanced workload. Work Fatigue
or Fatigue is a process that results in decreased well-being, capacity or Performance as a result of work activities, fatigue is a state when a person feels physically and/or mentally tired [19], which can be caused by long working hours without rest/recovery period intervention, solid and continuous physical activity, intense and continuous mental effort, working during some or all of the natural time to sleep (as a result of shifts or working for long periods) and insufficient sleep and rest, work fatigue is a variety of conditions accompanied by decreased efficiency and endurance in work, caused by fatigue whose primary source is the eyes (visual fatigue), general physical fatigue, nervous fatigue, fatigue by a monotonous environment and fatigue by an chronic climate that continues as a permanent factor, the type of fatigue is divided into 2 (two), namely physical fatigue (reduced ability to work manually) and mental fatigue (decreased levels of concentration and alertness) and Some individual factors that can affect fatigue are Internal factors, namely factors related to the individual, such as age, gender, psyche, health, marital status, nutritional status and work attitude and external factors, such as length of service, workload, work shifts and work environment. [20].
Work accidents or, etymologically, occupational safety and health, protect workers and other people in the workplace so that they are always safe and healthy production sources can be used or operated safely and efficiently. Essentially, occupational safety and health are efforts of thought and implementation aimed at ensuring the integrity and perfection of the physical and spiritual workforce, particularly humans in general. Based on the general understanding, occupational safety, and health have been widely known as requirements for carrying out tasks and a human rights factor. (Occupational safety law in the Binwasnaker document of the Ministry of Manpower and Transmigration of the Republic of Indonesia Number 1 of 1970).
A work accident is related to work, including diseases arising from work relationships and accidents that appear on the way to and from work. In general, accidents are caused by physical and human factors. Physical factors include unsafe work environment conditions, slippery floors, poor lighting, glare, etc. At the same time, human factors include worker behavior that does not meet safety due to fatigue, drowsiness, fatigue, and so on [21]. Basically, work accidents are caused by three: environmental factors in the workplace, human factors, and physical factors [22].
To prevent work accidents, paying attention to "Occupational Safety" is very important. Occupational safety is essentially a human effort to protect life and those related to it by taking preventive and protective measures against work accidents while we are working [23] (Martono et al.). Prevention of work accidents can be prevented by the following laws and regulations, namely mandatory provisions regarding general working conditions, planning, construction, maintenance, and maintenance, supervision, testing and working methods of industrial equipment, duties of employers and workers, training, medical supervision, first aid, and health checks [22]. Are observations of hazard risks in the workplace. Observation of hazard risks in the workplace is an information base related to the number and level of types of accidents that occur in the workplace. And 20 implementation of SOP (Standard Operating Procedure) correctly in the workplace Standard Operating Procedure is a work guideline that must be adhered to and carried out correctly and sequentially according to the instructions stated in the SOP; incorrect treatment can cause visitors are not aware of the danger factors in the workplace.
NASA-TLX (National Aeronautics and Space Administration) Method, task Load Index was developed by Sandra G. Hart of NASA-Ames Research Center and Lowell E. Staveland of San Jose State University in 1981. This method is a questionnaire developed based on the emergence of the need for subjective measurements that are easier but more sensitive to measuring workload. NASA-TLX uses six dimensions to assess workload, namely several physical requirements (Physical Demand), mental requirements (Mental Demand), how much mental or cognitive load, time (Temporal Demand), Performance (Performance), Effort (Effort), and frustration (Frustration Level) [24]. Scores from 0 to 100 are obtained on each scale. A weighting procedure combines the six individual scale ratings into a final score, requiring a pairwise comparison between two dimensions before assessing the workload. Pairwise comparison requires the operator (respondent) to choose the dimension more relevant to the workload in all pairs of the six dimensions. The number of dimensions selected as the weight is more appropriate as the dimension scale for the task given to the excavator operator. The workload score from 0

to 100 is obtained for each dimension score by multiplying the weight by the dimension scale score (rating), summing all dimensions, and dividing by 15 (the total number of pairwise comparisons) [24] (Rubio et al.). The following are the mental load indicators measured in NASA-TLX, as in Table 1.

Table 1. Mental load indicators

Scale	Rating	Description
Mental Demand	Low- high	how much activity and perceptual is needed to see, remember, and search
Physical Demand	Low- high	the amount of physical activity required (examples: pushing, pulling, and controlling turns)
Temporal Demand	Low- high	the amount of time-related stress felt during the element.
Performance	Not right- Perfect	how successful a person is in their job and how satisfied they are with the results of their work.
Frustration Level	Low- high	how insecure, hopeless, irritated, and disturbed one feels compared to feelings of security, satisfaction, comfort, and self-satisfaction.
Effort	Low- high	how much mental and physical work is required to complete the job.

The rating stage to obtain the workload (mean weighted workload) [25] is as follows: calculating the Product, and the Product is obtained by multiplying the rating by the factor weight for each descriptor. Thus, six product values are produced for six indicators (MD, PD, TD, OP, FR, and EF)

Product = Rating x factor weight…….. (1)

Calculating Weighted Workload (WWL), WWL is obtained by adding the six product values.

WWL = Σ product ……(2)

Calculating Average WWL Average WWL is obtained by dividing WWL by the total weight Score = Σ (weight x rating) ……...…..…(3)

Interpretation of Score Results Based on the explanation above in the NASA-TLX method, the workload score obtained is divided into three parts, namely, a value > 80 indicates a rather heavy workload, a value of 50-80 indicates a moderate workload, and a value < 50 indicates a relatively light workload. The utilization of a 360 camera is the most popular tool in photography. This name is taken from camera obscura, Latin for "dark room." Camera Obscura is a camera box that is not equipped with film (celluloid) to capture images or shadows [26] (Pitriade et al.). "A 360-degree camera is a type of camera that can detect objects from various directions, unlike other cameras that can only detect from one direction depending on the placement of the camera". Therefore, using 360 cameras on heavy equipment units is very useful because object detection from the camera is beneficial in terms of safety. 360 cameras use multiple lenses placed at different angles to capture images from all directions. These images are combined using special software to produce a seamless panorama that can be viewed in interactive mode.

This technology allows users to look around by panning the image or using a virtual reality or VR device [26]. The role of using 360 cameras in the industry is as follows: (1) increased visibility and situational awareness, (2) visibility and situational awareness in the industry, especially in the mining sector, are critical factors in operational safety and efficiency. Three hundred sixty cameras allow heavy equipment operators such as excavators to see their surroundings more fully and detailedly. This helps reduce blind spots and will enable operators to detect potential hazards earlier, (3) Reduction of Work Accidents. One of the main benefits of 360 camera technology is increased work safety. These cameras provide a comprehensive view of the work environment and help in real-time risk identification and mitigation. This is in line with risk management theories that emphasize the importance of early identification and risk mitigation to reduce accident incidents, and (4) increased Operational Efficiency with better visibility, operators can work more efficiently, reducing the time spent adjusting positions or correcting errors.

This increase in efficiency is in line with operational management theories that emphasize the importance of technology in increasing industrial productivity. And then Nickel ore mining. In connection with the enactment of the mandate of Law No. 4 of 2009 concerning the processing and refining of nickel ore, it was updated with Law No. 3 of 2020 concerning mining business permits and the issuance of government regulation no. 96 of 2021 concerning implementing mineral and coal mining business activities in Indonesia. The above regulations regulate nickel ore mining from upstream to downstream and from semi-finished products or finished goods. The determination of the mining method by a nickel mining company, whether using the open cast or underground method (tunnel mines), depends on the type of nickel deposit being mined. Generally, laterite nickel deposits are mined using the open-cast method because nickel deposits are found at relatively shallow depths.

While nickel sulfide deposits are not disturbed by tectonic activity deposits (faults, folds, structures) generally located far below the earth's surface, they are more suitable for underground or tunnel mining methods [27]. Using the open-cast mining method, the nickel ore mining process is a series of activities to extract nickel from nickel ore deposits found in the soil or rocks. This exploration process activity includes several stages. During the initial stage, exploration is carried out to find nickel deposits with the potential for mining.

Miners conduct geological and geophysical surveys to determine the right location for drilling. After finding a potential nickel deposit, the next stage is to mine nickel ore. The next stage is the preparation of land clearing, which generally involves forest or shrubs using a chainsaw or dozer. Topsoil stripping, namely the top layer of soil that has been opened and cleaned of plants, then dug and peeled according to a particular area according to the previously planned pit design.

This topsoil layer should not be disposed of carelessly because it will be reused for land reclamation activities after mining the nickel ore. The topsoil layer is vital because it contains essential nutrients plants need. At the mining location, the tools commonly used for this process are excavators and bulldozers, and overburden removal is carried out after the topsoil has been removed. The removal of this overburden layer (clay) is adjusted to the thickness and hardness of the material. This soil material contains much less organic matter than the topsoil layer. Its color is slightly yellowish or reddish brown or tends to be gray. The tools commonly used for this process are

excavators and bulldozers. Like topsoil, this OB is also usually stored in a landfill, often called disposal. This OB is for reclamation or filling in mining holes completed in the mine.
The activity of filling these holes is called backfilling. Next, mining activities can be carried out, namely nickel ore excavation (Open pit). This nickel ore excavation activity uses an excavator, which is operated by someone experienced in this field. In this mining activity, usually in every 10 or 20 tons of nickel ore excavation, samples are always taken to be tested in the laboratory. It is essential to do so that the mine manager knows the mined nickel ore content. The best nickel ore content is at least 1.8 and above; if it is below 1.8 in the mining process, it will usually be placed in a different stockpile with a content of 1.8. It can be mixed with better content for later to get the maximum price.
Every nickel ore obtained is immediately moved to the stockpile using a dump truck. From the stockpile, nickel ore will be taken directly into the barge and immediately sent to the nickel smelter for processing. Excavator activities other than in the pit are also widely carried out in the barge when filling nickel ore. When the barge fills nickel ore via dump truck, the mine manager also re-checks the nickel ore content. Every 10 to 20 tons of nickel ore that enters the barge, samples are always taken to find out whether the nickel ore results are the same as the pit or if there are changes when going up into the barge before being sent to the nickel smelter for further processing (Indonesian Nickel Towards Energy Transition (Irwandi Arif)).

3. Research Method

Place of Research Object (Excavator Operator at PIT in POMALA Southeast Sulawesi). Data Collection. Two types of data are used in this study: 1. Primary Data is data obtained directly from the research object by distributing questionnaires to respondents, namely excavator operators. This questionnaire was distributed after the excavator operator had finished the morning and night shifts. The morning shift starts from 06.00 to 18.00, and the night shift from 18.00 to 06.00. This questionnaire was distributed to all excavator operators, totaling five people, and had a working duration of 12 hours. The type of questionnaire was distributed to respondents according to the method used in this study, namely the NASA-TLX method. The NASA-TLX questionnaire has two stages: weighting (Weights) and rating (Ratings). At the weighting stage, a comparison will be made on each dimension. The excavator operator will choose the most influential or dominant pair of dimensions that source mental workload from the work. At the rating stage, the excavator operator will rate the 6 NASA-TLX dimensions according to what is felt during the work. Each dimension has a scale of 0 - 100 or low to high. Secondary data is data obtained from literature studies that lead to the completeness of the explanation of the research topic so that the conclusions obtained have scientific weight. Secondary data in this study is a database related to accidents in Nickel mines. Operational Variables: The dimensions of the NASA-TLX measurement are as follows: (1) Mental Needs, How much mental and perceptual activity is needed in your job (for example: thinking, deciding, calculating, remembering, seeing, searching). the job is easy or difficult, simple or complex, loose or tight. (2) Physical Demand. How much physical activity is required in your job (e.g., pushing, pulling, twisting, controlling, running, etc.)? The job is easy or difficult, slow or fast, calm or rushed. (3) Time Demand: How much time pressure do you feel during the job or elements of the job? Is the job slow and relaxed, or fast and tiring? (4). Performance: how successful are you in achieving your job goals? How satisfied are you with your Performance in achieving those goals? (5) Effort Level: how much mental and physical Effort is required to achieve your level of Performance. (6) Frustration Level, how much insecurity, hopelessness, irritation, stress, and irritation compared to feelings of security, satisfaction, fit, comfort, and self-satisfaction felt while doing the job. The scale for filling the mental load indicator with NASA-TLX is as follows. Mental Demand: A value of 0-25 if the job does not require remembering and searching, is simple and full of tolerance.A value of 26-50 if the job requires remembering or searching is easy and simple, and the job is certain. A value of 51-75 if the job requires remembering or searching, is easy, complex, and the job is certain.A value of 76-100 if the job requires remembering and searching is difficult and complex, and the job is certain. (2)Physical Demand: 0-25 if the job does not require physical activity (e.g., pushing, pulling, controlling rotation, etc.). If the job is light, slow, and rested enough.A value of 26-50 if the job requires physical activity (e.g., pushing, pulling, controlling rotation). If the job is light, fast, and rested enough. A value of 51-75 if the job requires physical activity (e.g., pushing, pulling, control rotation, etc.). If the job is light, fast, and not enough rest. Score 76-100 if the job requires physical activity (e.g., pushing, pulling, controlling rotation). If the job is heavy, fast, and not enough rest. (3) Temporal Demand: Score 0-25 if the job is relaxed. Score 26-50 if the job is slow., Score 51-75 if the job is fast. And Score 76-100 if the job is tiring. (4) Performance: Score 0-25 if very dissatisfied in meeting work targets. Score 26-50 if dissatisfied in meeting work targets.Score 51-75 if satisfied in meeting work targets. And Score 76-100 if very satisfied with meeting work targets. (5) 5. Frustration: Score 0-25 if the respondent feels safe, satisfied, comfortable, and self-satisfied while completing the job. Score 26-50 if the respondent feels safe, comfortable, and not disturbed but unsatisfied with completing the job.Score 51-75 if the respondent feels safe, comfortable, disturbed, and dissatisfied in completing the work. Score 76-100 if the respondent feels unsafe, hopeless, offended, and disturbed. (6) Effort: Score 0-25 if the job does not require high mental and physical work. Score 26-50 if the job requires light mental and physical work. Score 51-75 if the job requires moderate mental and physical work. And Score 76-100 if the job requires high mental and physical work. The data collection technique used in this study consisted of 2 activities: direct observation (survey) and questionnaire. The questionnaire was filled out two times, namely before the application of the 360 camera and after using the 360 camera. Likewise, data on work accidents were collected for one month before using the 360 camera and one month after using the 360 camera. The following is an explanation of the data collection technique in this study. Direct Observation (Survey) Field research or direct research is conducted by conducting a survey of folding division operators as primary data and library research as secondary data. Questionnaire Distribution This study uses a questionnaire to find out respondents' opinions regarding the activities of folding division operators related to mental burden. Respondents in large numbers are suitable for using this technique because they can read well and reveal confidential matters. Literature Study Data collection is carried out through a literature study of literature related to the existing production process and mental workload analysis using the NASA TLX method. Research Design : (1) Implementation of 360 Camera Technology (M) As a moderating variable that is expected to increase excavator operators' visibility and situational awareness at the PT RR nickel mine. Operator Workload (NASA-TLX) (X): As an independent variable measured using the NASA-TLX method. Implementing a 360 camera is expected to reduce the operator's workload. Occupational Accident Rate (Y): A dependent variable that shows the number and level of occupational accidents in nickel mines. Implementing 360-camera technology and better workload management is expected to reduce it. The research began with a preliminary study of the processes at the nickel mining site. Problems can be identified and formulated based on the field observation results. The next stage is to determine the objectives of the research, namely to determine the level of mental workload of workers at the nickel mining site, to determine the most dominant factors that

influence the level of mental workload, and to provide suggestions for improvements to reduce the level of mental workload of employees. After determining the objectives, data collection was carried out. Data were obtained from interviews, direct observations, and questionnaires distributed to employees of the logistics department. Data processing was done by measuring the mental workload using the NASA TLX method before and after using a 360 camera. At the analysis stage, factors that influence the mental workload of the logistics department employees were determined based on the questionnaire that had been distributed to them. Then, suggestions for improvement were given. From the data processing and analysis results, conclusions were drawn regarding the processes that occur in the logistics department, the level of mental workload of employees, and how much the 360 camera reduces the workload of employees. In addition, suggestions for future improvements are provided.

4. Result and Discussion

Implementing 360 camera technology significantly reduces workload and work accidents: Accidents in nickel mining fields are often caused by various factors related to excessive workload on excavator operators. Here are some accidents and how excessive workload can affect them. Based on the effects of Physical Fatigue, a High physical Workload can cause fatigue in excavator operators. This fatigue can reduce reflexes and the ability to respond quickly to emergencies.

A tired operator may fail to control the excavator properly, causing collisions with other vehicles, structures, or piles of material. Based on Accidents due to Decreased Concentration, a High mental Workload can drain the operator's concentration. Decreased concentration can cause errors when operating heavy equipment. Errors in controlling the excavator arm or bucket can cause material to fall uncontrollably, risking hitting other workers or damaging equipment.

Then, in Accidents due to Failure to Supervise the Work Environment, Operators who experience excessive workloads often have difficulty paying attention to the surrounding environment. This can lead to a lack of supervision in risky work areas. For example, accidents may occur when operators do not see other workers who are too close to the excavator, causing the risk of being hit or injured by the movement of the machine. Accidents due to Operational Errors High workloads can lead to operational errors, including errors in excavator controls or operational decisions. Accident Example: Errors in positioning the excavator can cause machine instability and the risk of overturning, especially on uneven terrain. Accidents due to Neglect of Safety Procedures: When operators experience excessive workloads, they may ignore safety procedures to speed up the work. Accident Example: Ignoring safety measures such as not wearing a seat belt, not checking the condition of the tool before operation, or not following safe shutdown procedures. Accidents due to Stress and Frustration High workloads can increase stress and frustration levels in operators. This stress and frustration can affect mental health and decision-making abilities.

Accident Example: Stressed operators may become less patient and rush in operations, increasing the risk of errors and accidents. Application of 360 cameras: 360 cameras: On the excavator unit, the camera is installed at a strategic point that can cover blind spots, such as above the excavator cabin. The sensors already on the camera can detect objects around the excavator. On the bulldozer unit, the camera is mounted on the top of the cabin to monitor the entire unit's safety. On the container car, the camera is mounted on the top of the rear and front containers to cover the whole box. Data processing: Data from the camera will be processed by the application or system provided by the camera developer.

This system will analyze and process the data captured by the camera. Display and Interface: Information obtained from the camera will be displayed on the cellphone screen that has been connected to the camera. This screen will display a visual of what the camera captures in real time, including the condition of the surrounding environment and the objects detected. This interface is straightforward to use and also provides a remote control system. Internet Connection: This system requires an internet connection for remote monitoring and control. With the implementation of a 360 camera on this heavy equipment unit, the heavy equipment unit can reduce the risk of accidents caused by blind spots and provide better monitoring of heavy equipment operations.

This has a very positive impact on safety, efficiency, and productivity during unit operation. NASA-TLX Questionnaire Results Before and After Using 360 Camera: With this table, we can see the complete NASA-TLX questionnaire results for each operator before and after using the 360 camera, including scores for each question in each dimension. From the data above, the NASA-TLX value is calculated by adding up the scores for each dimension weighted by each operator, then divided by the number of dimensions. After Using 360 Camera Operator 1: (50 + 45 + 40 + 55 + 60 + 35) / 6 = 47.5; Operator 2: (45 + 40 + 35 + 50 + 55 + 30) / 6 = 42.5, Operator 3: (55 + 50 + 45 + 60 + 65 + 40) / 6 = 52.5, Operator 4: (50 + 45 + 40. Based on the analysis of the Work Accident Rate, based on data on the number of work accidents that occurred before and after using a 360 camera, the data on the number of work accidents was taken in one month, then the average work accident before using a 360 camera: 5.2 Average work accident after using a 360 camera: The Effect of Workload on the Work Accident Rate. The data shows that the average work accident before using a 360 camera was 5.2, while after using a 360 camera, it dropped to 2.2.

This decrease shows that with the reduction in workload measured through NASA-TLX, the work accident rate also decreased significantly. The reduction in the average NASA-TLX value of 26.7% (from 67.03 to 49.1), accompanied by a decrease in the average work accident of 57.7% (from 5.2 to 2.2), shows a strong correlation between workload and work accident rate. With technology that reduces the workload, operators can work more safely and efficiently, reducing the likelihood of accidents. Discussion: From the results of the research that has been conducted, it is known that the impact of implementing 360 camera technology on the safety and work efficiency of excavator operators in nickel mines is quite significant.

This can be seen from the decrease in the number of accidents for each operator. The average number of work accidents decreased from 5.2 to 2.2 points. This is because the viewing distance using a 360 camera is greater. From research conducted by (Pitriadi et al., 2024), it is known that excavators have significant blind spots in the rear area of the unit. In the normal position, the rearview mirror on the excavator can generally provide a better view of the operator's area, such as the front and side areas. However, some areas are still difficult to see or cannot be reached using the rearview mirror alone, such as the area behind and just below the excavator.

The percentage of blind spots on a medium excavator using a rearview mirror in a normal position can reach around 30-45% of the total area around the excavator. A portable 360 camera on the excavator unit can significantly reduce blind spots. The operator will be able to see objects or humans that are within a certain distance from the excavator track. However, it should be noted that blind spots still exist. Therefore, operators must still be careful when maneuvering a 360 camera with an optimal position and good viewing angle on a medium-type 313D excavator in ground area conditions, which can reduce the risk of blind spots in operations by 85.62%. With a reduction in blind spots by 85.62%, it can reduce the workload of excavator operators before and after the implementation of 360 camera

technology, especially in the mental demand, Performance, and frustration sections; this is because with a broader viewing distance, the stress pressure of accidents will be reduced and work becomes easier to do.
Changes in workload with new technology have reduced work accidents in nickel mines. This increases work time efficiency and reduces the cost of handling work accidents. For workload management and safety technology in the mining industry, new technology is needed, such as the use of 360 cameras in several heavy equipment, especially on excavators in mining areas, because it is proven that using a 360 camera can reduce the workload felt by workers and reduce the rate of work accidents in the field.

5. Conclusion

This study shows that using technology such as 360 cameras on excavators in nickel mining fields significantly reduces operators' mental and physical workload, as measured by NASA-TLX. The average decrease in NASA-TLX value by 26.7% (from 67.03 to 49.1) and a reduction in blind spots by 85.62% by using a 360 camera can reduce the workload of excavator operators before and after the implementation of 360 camera technology, especially in the mental demand, Performance, and frustration sections, this is because, with a broader view, the stress pressure will reduce accidents and work becomes easier to do. Overall, the average work accident decreased from 5.2 points to 2.2 points. This is because the view using a 360 camera is more excellent. Implementing 360 camera technology can reduce operators' workload and is a practical step to improve safety and work efficiency in the mining industry. This recommendation can be expanded by adopting similar technology on other equipment and operations to improve overall safety and productivity. Periodic evaluation of operator workload to ensure optimal working environment and implementation of 360 camera usage on all excavators in mining. Thus, this study provides a significant contribution to understanding the benefits of technology in improving productivity and occupational safety in the mining industry.

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