JOURNAL OF WORLD SCIENCE
https://jws.rivierapublishing.id/index.php/jws
Volume 2 No. 9 September 2023
P-ISSN: 2828-8726
E-ISSN: 2828-9307

ANALYSIS OF HUMAN ERROR POTENTIAL AS A CAUSE OF WORK ACCIDENT USING SHERPA AND HEART METHOD IN THE CEMENT INDUSTRY

Annisa Maulidya[1], Katharina Oginawati[2], Suharyanto[3]
Institut Teknologi Bandung, Jawa Barat, Indoensia

annisamaulidya234@gmail.com[1], katharina.oginawati@gmail.com[2], sierra02nl@gmail.com[3]

ABSTRACT
This study was conducted to analyze the potential for human error that can cause workplace accidents in the cement industry of PT.X. The study was conducted by conducting observations, interviews, and distributing questionnaires in the mining area and production area. Questionnaires were distributed to 96 people who were mining heavy equipment operators and production operators. The research method used through Human Reliability Analysis with the Hierarchial Task Analysis (HTA) method, knowing the types of errors that occur using the SHERPA method, then calculating the probability of human errors that occur with the HEART method. Based on the results of research using the SHERPA method, the most common types of errors in mining areas and production areas are action errors (60,25%). The type of error that occurs is due to negligence in using personal protective equipment and the work process is not completed properly. Based on research using the HEART method, the greatest opportunity for human error in the mining department is cleaning with dozer with a value of 1,056 and in the production department is in the area of cleaning work with a value of 1,89. Based on the error producing conditions questionnaire (EPCs) for workers in the mining department the most common cause of error is poor equipment / instruments while for workers in the production department is a mismatch between the imagined risk and the actual risk. The recommendations given to companies are to improve work equipment, improve visual displays and provide an appropriate assessment checklist.

Keyword: human error, work accident, SHERPA, HEART.

Corresponding Author: Annisa Maulidya
E-mail: annisamaulidya234@gmail.com

INTRODUCTION

One element that plays an important role in supporting the achievement of a work system is human factors. Developments in the industrial sector require humans to increasingly master advanced technology to support the smooth operation of industrial activities (Fonna, 2019). This causes more frequent interactions between humans and machines. This condition can potentially increase errors when carrying out industrial activities both errors in the system and errors in humans.

Human error has a significant impact on the quality and production of a company (Farida, 2016). Some of the conclusions of research conducted by experts in the field of safety states that 80-90% of accidents in the chemical industry are caused by human error. Other researchers also conducted studies on costruction industry and the results indicated that the main cause of accidents and injuries are lack of awareness and experience (80%), machinery defect and errors (60%), lack of training (30%), lack of personal protective equipment PPE (25%), and no safety and health officer or supervisor and unsafe work environment (16%) (Abukhashabah et al., 2019). In the last two decades, Brazil has experienced 70 explosions and the same number of fatal victims (an average of 3.5 per year), during boiler operation or maintenance because of human error (Landi et al., 2022).

The potential for human error as a cause of work accidents has been widely studied in various fields of industry. According to several previous studies, it was found that 80% to 90% of work accidents were caused by human error (Zahroh, 2023). Human error is defined as misjudgement and inappropriate decisions of individuals in the cognitive process (Chi et al., 2013); (Choi & Lee, 2018). Human error is regarded as the significant cause of accidents in the construction industry (Liao et al., 2018); (Wong et al., 2019); (Li et al., 2020). In the construction sites, unsafe behaviours of employees occur, as a result of human errors (Choi & Lee, 2018). Such unsafe behaviours can put construction workers at potential risk, as well as lead to serious accidents on the construction site (Xia et al., 2020); (Liang et al., 2021). Humans are one important factor in the implementation of work processes so it is necessary to identify potential human errors that can lead to the risk of workplace accidents. In addition, the value of human error probability is also needed to determine the work that has the most potential for human error. The results of this study are expected to provide an overview of potential human errors and recommendations for improvement in order to reduce the risk of workplace accidents. Based on the background mentioned above, the objective of this research is to identify and analyze the potential human errors that cause workplace accidents using the SHERPA and HEART methods in the cement industry. The benefits of this research include reducing workplace accidents, this research can help identify potential human errors that may lead to workplace accidents in the cement industry. With a better understanding of contributing factors, companies can take appropriate preventive measures to reduce accident risks. Enhancing worker safety awarenesss, the research findings can be used to raise safety awareness among cement industry workers. Understanding the types of errors that may occur can make workers more cautious and compliant with safety procedures. Basis for further research, the results of this research can serve as a foundation for further studies aimed at continuously improving safety in the cement industry. Overall, this research has the potential to improve workplace safety, reduce accidents, and enhance operational efficiency in the cement industry, benefiting both companies and workers while contributing to ongoing safety improvements.

METHOD

This type of research is a qualitative study conducted in one of the cement industries located in West Sumatra, Indonesia. Research subjects are all workers who work in companies with human error research objects in the process of managing raw materials (mining departments) and production processes. Data collection techniques used in this study were observation, interviews, and questionnaires. The distribution of error producing conditions (EPCs) questionnaires was conducted to 56 mining area workers and 40 production area workers. All respondents are permanent workers at PT. X and have shift work (rolling system) so that all workers have been in the morning shift, afternoon shift, or night shift.

Secondary data needed in this study includes data on work accidents, work processes in the mining area and production area, the number of workers, and scientific references supporting research. While primary data includes observations (identification of hazards or potential hazards, recording of work processes and procedures), questionnaires (error producing conditions), and interviews to obtain information related to the analysis and evaluation process using the SHERPA and HEART methods.

Work procedure data is obtained from a work instruction sheet (LIK) which provides a detailed description of the steps involved in carrying out tasks within a company unit. In this case the LIK owned by the company includes the objectives, scope, references, definitions, responsibility, and detailed instructions at each stage of the PT.X process. This work procedure data becomes the basis for creating Hierarchial Task Analysis (HTA). HTA is a breakdown of tasks from work processes carried out by workers and an input for the SHERPA method. The SHERPA method will predict and identify human errors into five types of errors namely action error (A), checking error (C), retrieval error (R), information error (I), and selection error (S).

Questionnaire questions used refer to the list of Error Producing Conditions (EPCs) of the HEART method. The EPCs list contains the factors that cause human error where each factor has a total effect value that indicates the value of human error. This EPCs value is a fixed value that has been validated by Jeremy Williams (1986). The results of the distribution of this questionnaire were the large number of cases of Error Producing Conditions (EPCs) felt by 96 PT.X workers divided into 56 mining areas and 40 production areas.

Interviews conducted to managers, supervisors, and operators were conducted to determine the cause of errors based on work accidents that have occurred and provide judgment / assessment of the determination of the value of human unreliability on Generic Task Types (GTTs), the value of the total effect on EPCs, and the value of the proportion proportion on APOA so that it can calculate the value of Human Error Probability (HEP). The value of Human Error Probability (HEP) is calculated using Equation 1 (Dhillon, 2013).

Human Error Probability = [GTTs x APOA (total effect-1)+1] Eq. 1

Where :
HEP : human error probability
GTTs : generic task types
APOA : assessed proportion of affection

The research questionnaire was tested for eligibility with a validity test and a reliability test. Validity and reliability tests were conducted by distributing questionnaires randomly to 30 workers then analyzed using SPSS 25 software. Validity tests were performed with corrected items total correlation while reliability tests were performed with Conbach's Alpha values (Arifin, 2017). The results of the distribution of this questionnaire will be considered to conduct an assessment based on workers' complaints of the perceived error conditions.

The SHERPA method starts by conducting a Hierarchial Task Analysis (HTA) to breakdown the task by identifying the main work and determining the overall goal, then breaking down the task into sub jobs. The next stage is to do Human Error Identification (HEI) to classify jobs into error types / modes. The error mode table will be described in Table 1. The next stage is the consequence analysis to consider the consequences of each error and the probability analysis to classify human errors that occur from the high (H), medium (M), and low (L) levels.

HEART analysis aims to determine the Human Error Probability (HEP) calculated by the press. 1. The HEART method begins by defining work on a previous Hierarchial Task Analysis (HTA) into work which often results in errors that have the potential to cause work accidents at PT.X. The next stage is to determine the value for calculating HEP in accordance with the conditions set. The initial step in the HEART method is to determine Generic Task Types (GTTs) for each job and the human unreliability of each job. The next stage is to determine the total effect value based on the Error Producing Conditions (EPCs) table and the results of the questionnaire distribution. The higher the risk of errors made, the greater the total effect value. The next stage is to determine the assessed proportion according to the APOA criteria with values ranging from 0 to 1. The final step is to determine the value of HEP so that it can be known which job has the greatest chance of error. Provision of improvements made to jobs that have the largest HEP value and the main factors causing human error. The stages of working on the HEART method will be explained in more detail in Table 2.

Table 1. Error type

Error type	Error code	Note
Action error (A)	A1	Operation too long / too short
	A2	Operation mistimed
	A3	Operation in wrong direction
	A4	Too little/much operation
	A5	Misalignment
	A6	Right operation on wrong object
	A7	Wrong operation on right object
	A8	Operation omitted
	A9	Operation incomplete
	A10	Wrong operation on wrong object
Checking error (C)	C1	Check omitted
	C2	Check incomplete
	C3	Right check on wrong object
	C4	Wrong check on right object
	C5	Check mistimed
	C6	Wrong check on wrong object
Retrieval Error (R)	R1	Information not obtained
	R2	Wrong information obtained
	R3	Information retrieval incomplete
Information error (I)	I1	Information not communicated
	I2	Wrong information communicated
	I3	Information communication incomplete
Selection error (S)	S1	Selection omitted
	S2	Wrong selection made

Table 2. The steps of HEART method

Step	Description	Output
Generic Task Types	Classify tasks / activities according to the generic task type table into one of eight task types in the HEART method	Nominal human unreliability
Error producing conditions	Identify error producing conditions (EPCs) that are relevant to the task / activity / scenario being analyzed, which if an error occurs can affect performance	The total effect in accordance with the EPCs table which is the maximum predictability value of reliability

Step	Description	Output
Assessed proportion of affect	Estimating the impact of each EPC on each task based on judgment	Assessed proportion with a value between zero and one
Assessed Effect	Calculates the assessed impact for each EPC according to the equation ((*Total effect* EPC – 1) x *Assessed proportion*) + 1	Assessed impact value
Human error probability	Calculates the likelihood of human error occurring in an overall task based on the following equation: *Nominal human unreliability* x *Assessed impact* 1 x *Assessed impact* 2 x *Assessed impact* n	Overall probability of human error

RESULTS AND DISCUSSION

Respondent Characteristics

Respondents in this study amounted to 96 people who were divided into two work area groups, namely 56 people in the mining area and 40 people in the production area. The majority of respondents aged between 19-53 years. The majority of respondents' last education was high school. Meanwhile, the majority of respondents had work periods ranging from 2 years - 24 years. Recapitulation of respondent characteristic data is shown in Table 3.

Table 3. Recapitulation of data characteristics of research respondents

Respondent Characteristics	Mining Area	Production Area
Number of respondent	56	40
Gender	Male	Male
Average of age (year)	19-48	21-53
Average of working period (years)	2-30	2-34
Last education	Senior high school, bachelor	Senior high school, bachelor

Hierarchial Task Analysis (HTA)

Hierarchical task analysis is a widely used human-factors research method to structurally analyze a work or control task. HTA was developed by John Annett represent human information processing aspects that are necessary to fulfil a task (operation). It makes it possible to represent goal-directed human behavior. HTA can be applied to different human–machine systems and different workflows. The formalized description of the task can form the basis for both the design and improvement of technical support and individual operator training. These approaches include testing subtask performance, designing operator workflows for training, and specifying feedback requirements. In addition, HTA helps define evaluation criteria of support systems with respect to workload and the allocation of cognitive resources while achieving a task goal by interacting with a system (Dreger et al., 2023). Task analysis is a formal method for describing and analyzing human interactions with systems both in the form of physical activity and cognitive activity undertaken to achieve the goals of the system (Bolton et al., 2013). In the task analysis the role of operators in the system is defined in detail. HTA is the most commonly used breakdown task method because it is easy to use, detailed, and directly hits the target (Asih et al., 2019).

Here is a picture of HTA in the mining process at PT.X.

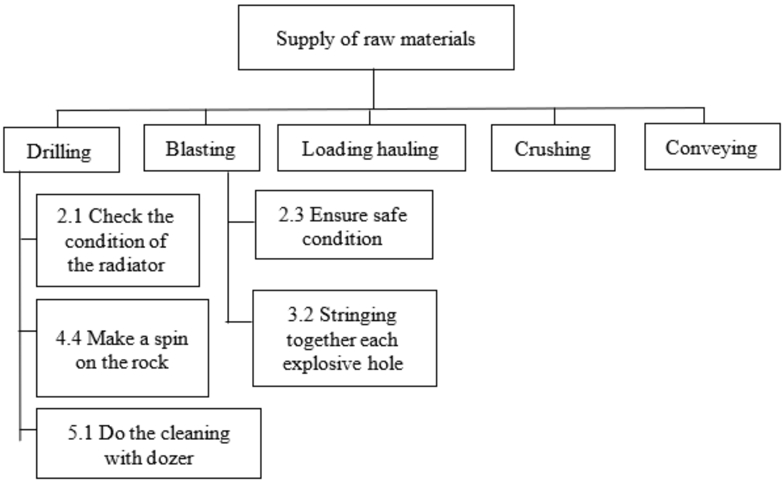


Figure 1. HTA mining area PT. X

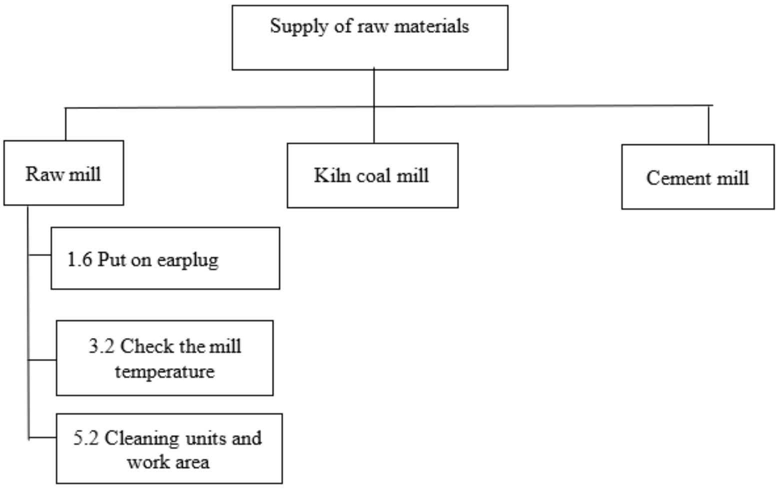


Figure 2. HTA production area PT. X

HTA for the supply of raw materials in the mining area can be seen in Figure 1. Figure 1 shows the tasks that must be performed by workers to produce raw materials that will be sent to the factory (production area). Figure 2 shows the tasks that must be performed by workers to process raw materials that have been sent from mining. From this HTA, human error can be predicted that may occur when the operator do every stage of the work process.

Human Error Analysis with SHERPA Method

Example of implementation human error analysis using the SHERPA method can be seen in Table 4 and Table 5.

Table 4. Human error identification drilling process

No	Task	Error code	Error description	Consequences	Error probability
2.1	Check the condition of the radiator water	C1	Does not check the condition of the radiator water	Overheat machine	L
4.4	Make a spin on the rock	A3	Change the position when the drill tool is plugged in	Drill rod pinched	L
		A1	Not optimal in doing the rounds	The desired depth of drill is not reached	L
5.1	Do the cleaning with dozer	C1	Don't check the condition of the area around the cleaning	The tool can crash and hit the operator around the location	M
		A5	Other operators interrupt the cleaning process		M

Table 5. Human error identification raw mill process

No	Task	Error code	Error description	Consequences	Error probability
1.6	Put on an ear plug	A8	Not implemented the use of ear plug	Exposed to raw mill noise	H
3.2	Check the mill temperature	A7	Error pressing the temperature setting button	High temperatures can hurt workers	M
5.2	Cleaning units and work areas	C1	Not checking the conditions and position of other workers in the area	There are workers who can be exposed to leaking or splashing of material	H
		A1	Rush in cleaning tools	Hand pinched tool or broken worker nails	H
		A5	Less thorough when doing cleaning		H

Human error with the SHERPA method in both the mining area and the production area is dominated by action errors which are errors that occur due to mistakes in human actions such as not using personal protective equipment, errors in pressing buttons, and so on. Table 3 and Table 4 show some prediction results from SHERPA. Overall, the SHERPA results predict 156 error descriptions from 108 tasks performed in 8 work process units, which are divided into 95 error descriptions from 67 work tasks in 5 work units in the mining area and 61 error descriptions from 41 tasks performed in 3 work process units. production area. From the description of this error it can be seen the error code shown in Table 6.

Table 6. Error code in work area

Error code	Number of errors in the study area	
	Mining	**Production**
Action (A)	58	36
Checking (C)	25	15
Retrieval (R)	5	3
Information (I)	7	7

Overall, the number of errors that occurred at PT.X were 94 action errors (60,25%), 40 checking errors (25.64%), 8 retrieval errors (5.13%), and 14 information errors (8.97 %). Based on the results of the study, the highest percentage of errors was action errors (60.25%). This is in line with the results research in a case study in the cement industry using the SHERPA method obtained the highest percentage of error ie the action category of 49.68%. It was identified that the most important and most vulnerable human errors are supervision of problem solving by supervisors, removal of warning signs by operators, and adoption of methodology when abnormal situations occur by the technical chief (Pouya & Habibi, 2015).

Human Error Analysis with HEART Method

Based on the analysis using the SHERPA method, some tasks that often cause work accidents are analyzed using the HEART method to determine the value of Human Error Probability (HEP). The following are the results of the HEP calculation described in Table 7.

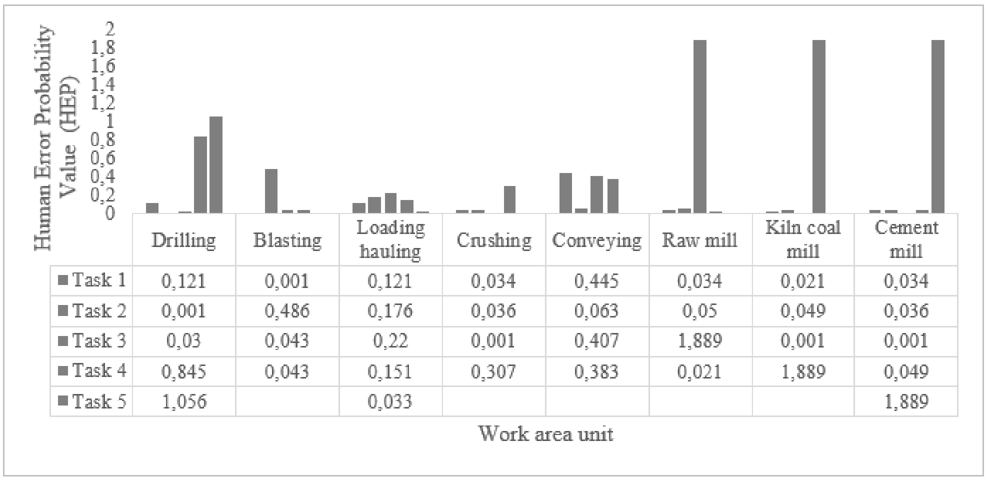
Table 7. Quantification of human error in drilling area

No	Task	Generic Task Types (GTTs)	Quantification			HEP value
2.1	Check the condition of the radiator water	D (0,09)	EPC	3	1,6	0,121
			Proportion	0,1	0,2	
			Asessed effect	1,2	1,2	
4.4	Make a spin on the rock	C (0,16)	EPC	8	4	0,845
			Proportion	0,2	0,4	
			Asessed effect	2,4	2,2	
5.1	Do the cleaning with dozer	C (0,16)	EPC	6	4	1,056
			Proportion	0,4	0,4	
			Asessed effect	3	2,2	

Table 8. Quantification of human error in raw mill area

No	Task	Generic Task Types (GTTs)	Quantification				HEP value
1.6	Put on an ear plug	E (0,02)	EPC	1,2	4		0,03
			Proportion	0,3	0,2		
			Asessed effect	1,06	1,6		
3.2	Check the mill temperature	E (0,02)	EPC	4	2		0,05
			Proportion	0,3	0,3		
			Asessed effect	1,9	1,3		
5.1	Cleaning units and work areas	D (0,09)	EPC	9	6	1,2	1,89
			Proportion	0,7	0,4	0,3	
			Asessed effect	6,6	3	1,06	

Based on Table 7 and Table 8 some human error calculations are obtained. Overall results of HEP calculations can be seen in Figure 3.



	Drilling	Blasting	Loading hauling	Crushing	Conveying	Raw mill	Kiln coal mill	Cement mill
Task 1	0,121	0,001	0,121	0,034	0,445	0,034	0,021	0,034
Task 2	0,001	0,486	0,176	0,036	0,063	0,05	0,049	0,036
Task 3	0,03	0,043	0,22	0,001	0,407	1,889	0,001	0,001
Task 4	0,845	0,043	0,151	0,307	0,383	0,021	1,889	0,049
Task 5	1,056		0,033					1,889

Figure 3. Recapitulation HEP value PT.X

Based on Figure 3 it is found that the value of Human Error Probability (HEP) in the mining area is do the cleaning with dozer with a value of 1,056 and in the production area is a work unit and work area cleaning value of 1,889. This value indicates that the error rate is high because it is greater than 0,5 and far from the value of 0. The results of the distribution of the Error Producing Conditions (EPCs) questionnaire showed that based on PT.X workers' complaints, the cause of the error was dominated by equipment that was not reliable / not in good condition with a percentage in the mining area of 91,07% and in the production area of 82,5 %, there is a mismatch between the imagined risk and the actual risk with a percentage in the mining area of 64,29% and in the production area of 90%, and excess capacity in receiving information that comes simultaneously with a percentage in the mining area of 85,71% and in the production area 72,5%.

CONCLUSION

The conclusion of this analysis is that there are various types of errors that occur with operators, including the improper use of personal protective equipment according to SOP, errors in communication and signaling, incomplete inspections, and limited operator knowledge in taking action. Human error causes can be categorized into three categories: induced human error, design-induced human error, and pure human error. Based on the research findings, system-induced human errors involve factors such as the absence of policy information labels, inadequate worker training, and production pressures leading to overtime. Design-induced human errors encompass unreliable work equipment, narrow access roads at worksites, and uncomfortable design of personal protective equipment. Meanwhile, pure human errors involve worker behavior, including carelessness, lack of alertness, poor discipline in using personal protective equipment, and lack of concentration during work. To reduce the risk of workplace accidents due to human error, improvement measures can include enhancing visual warning displays, implementing stricter supervision, issuing warnings and reprimands by supervisors for disciplinary violations, conducting work evaluations after each shift, providing appropriate assessment checklists based on field conditions to ensure workers have adequate skills and competencies through ongoing training, and repairing work equipment, such as replacing old units and regularly maintaining machinery. These measures will contribute to creating a safer and more productive work environment.

REFERENCES

Abukhashabah, E., Summan, A., & Balkhyour, M. (2019). Causes of occupational accidents and injuries in construction industry in Jeddah City. *JKAU Met. Environ. Arid Land Agric. Sci*, *28*, 105–116.

Arifin, J. (2017). *SPSS 24 untuk Penelitian dan Skripsi*. Elex Media Komputindo.

Asih, E. W., Winarni, W., & Sekarini, D. (2019). ANALISIS HUMAN RELIABILITY ASSESSMENT OPERATOR PAPER MACHINE DENGAN METODE FUZZY HEART. *Jurnal Teknologi*, *12*(2), 137–145.

Bolton, M. L., Bass, E. J., & Siminiceanu, R. I. (2013). Using formal verification to evaluate human-automation interaction: A review. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *43*(3), 488–503.

Chi, S., Han, S., & Kim, D. Y. (2013). Relationship between unsafe working conditions and workers' behavior and impact of working conditions on injury severity in US construction industry. *Journal of Construction Engineering and Management*, *139*(7), 826–838.

Choi, B., & Lee, S. (2018). An empirically based agent-based model of the sociocognitive process of construction workers' safety behavior. *Journal of Construction Engineering and Management*, *144*(2), 4017102.

Dhillon, B. S. (2013). *Human reliability: with human factors*. Elsevier.

Dreger, F. A., Englund, M., Hartsch, F., Wagner, T., Jaeger, D., Björheden, R., & Rinkenauer, G. (2023). Hierarchical Task Analysis (HTA) for Application Research on Operator Work Practices and the Design of Training and Support Systems for Forestry Harvester. *Forests*, *14*(2), 424.

Farida, N. (2016). Pengaruh Kualitas Bahan Baku Terhadap Kualitas Hasil Produksi (Studi Pada CV Mebel Bima Karya Kabupaten Blitar). *Akuntabilitas: Jurnal Ilmiah Ilmu-Ilmu Ekonomi*, *9*(2), 1.

Fonna, N. (2019). *Pengembangan Revolusi Industri 4.0 dalam Berbagai Bidang*. Guepedia.

Landi, R. G., Montedo, U. B., & Lahoz, C. H. N. (2022). Using systems theory for additional risk detection in boiler explosions in Brazil. *Safety Science*, *152*, 105761.

Li, J., Wang, H., Xie, Y., & Zeng, W. (2020). Human error identification and analysis for shield machine operation using an adapted TRACEr method. *Journal of Construction Engineering and Management*, *146*(8), 4020095.

Liang, Q., Leung, M., & Ahmed, K. (2021). How adoption of coping behaviors determines construction workers' safety: A quantitative and qualitative investigation. *Safety Science*, *133*, 105035.

Liao, P.-C., Ma, Z., & Chong, H.-Y. (2018). Identifying effective management factors across human errors–A case in elevator installation. *KSCE Journal of Civil Engineering*, *22*, 3204–3214.

Pouya, A. B., & Habibi, E. (2015). Using cream techniques for investigating human error with cognitive ergonomics approach in the control room of cement industry. *IJBPAS*, *4*(3), 1480–1484.

Wong, F. K.-W., Chiang, Y.-H., Abidoye, F. A., & Liang, S. (2019). Interrelation between human factor–related accidents and work patterns in construction industry. *Journal of Construction Engineering and Management*, *145*(5), 4019021.

Xia, N., Xie, Q., Hu, X., Wang, X., & Meng, H. (2020). A dual perspective on risk perception and its effect on safety behavior: A moderated mediation model of safety motivation, and supervisor's and coworkers' safety climate. *Accident Analysis & Prevention*, *134*, 105350.

Zahroh, D. A. S. (2023). Analisis Human Error Sebagai Upaya Pencegahan Kecelakaan Pada Bidang Maritim: Literatur Review. *Nanggroe: Jurnal Pengabdian Cendikia*, *2*(3).