Developing Occupational Accident Causation Model in Manufacturing Industry

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Abstract

Occupational accidents in manufacturing industry are an ongoing problem, mainly caused by human error or failure to adhere to established procedures and regulations. This research focuses on the devel-opment of a comprehensive model to identify the causes of occupational accidents in manufacturing environments, with the aim of reducing the frequency of such events. It draws on existing theories of accident causes, including Domino Heinrich's Theory and Swiss Reason's Cheese Model, and inte-grates factors of unsafe behavior, workplace conditions and safety culture. Through a study on 50 cases of industrial accidents in Medan industrial Zone, this research identifies the key variables leading to accidents, such as work supervision, workplace conditions and employee behavior. These factors, to-gether with safety culture and safety motivation, form the basis for the development of conceptual mod-els for accident prevention. This research highlights the importance of strengthening safety culture and improving supervision and working conditions to reduce the risk of accidents in the manufacturing in-dustry. The research findings suggest that a proactive safety approach is needed to prevent accidents at all levels.

Keywords: Occupational Accidents, Safety Culture, Safety Motivation, Human Factors, Manufacturing Industry.

Occupational accidents generally occur because employees make mistakes or perform work that devi-ates from provisions (regulations) and procedures (methods). This encourages business leaders in every sector to implement preventative efforts [6]. Acci-dents at work can happen every day, in any way, with consequences for everyone. The chance of this hap-pening is almost always present and inevitable. It is impossible to prevent all occupational accidents, but it is possible to reduce its rate of occurence [2].

Occupational accidents are caused by employees or working conditions in a company that are not or-ganized or orderly. Employees also often perform dangerous actions without realizing them. They also keep performing dangerous actions despite knowing the danger. Research by [9] shows that approximately 75% of the causes of occupational accidents are due to human factors. The theory of occupational accidents caused by human error is formulated by H.W. Heinrich is often mentioned in Domino theory. Most workplace accidents occur as a result of human error, primarily due to a lack of awareness and commitment to safety at both the individual and organizational levels.

Occupational accidents still take place regularly in various sectors in Indonesia. Over the past five years, the average trend of claims for workers' compensa-tion insurance (JKK) and death insurance (JKM) has continued to increase. From 2019 to November 2023, the number of workers applying for the social securi-ty program for employment at JKK and JKM contin-ues to increase (BPJS Employment 2024).

The still high rate of occupational accidents is a concern in developed and developing countries. This is considered the third leading cause of death in the world. It is also one of the most important socio-economic and health risk factors in developed and developing countries [5].

Based on data from the Labor and Social Security Agency (BPJS), there is a trend towards an increase in the number of occupational accident cases, with most claims taking place in companies and plantations (BPJS Employment 2024). This is supported by the increase in the number of workers in Indonesia from 2021 to 2023, which increased by 7.56 million people or approximately 5.39% (One Data from the Indone-sian Ministry of Labor, 2024).

The top five sectors with the most accident vic-tims are the trade and services sector (22%), miscel-laneous industry (21%), consumer goods production industry (17%), agriculture - plantations - forestry - fishing (16%), and basic and chemicals industry (12%) and the rest by other sectors such as transport, mining, real estate and others (11%). The miscellane-ous industry sector is the second highest sector (21%), with all subsectors in the miscellaneous indus-try being producers of products with basic consump-tion needs, such as various food processing (marga-rine, cooking oil, wheat flour, etc.), various garments. processing (textiles, woven materials, etc.), various chemicals and fibers (vehicle tires, soap, toothpaste, etc.) and various building materials (wood, ceramics, glass, etc. others).

Miscellaneous industry is part of the manufactur-ing company sector in Indonesia. The manufacturing industry is an industry that processes raw materials into semi-finished products and end products. There are risks and dangers in every production process and every work activity. Research shows that occupational accidents that occur in the manufacturing industry are caused by inadequate safety practices in that sector.

Situations are still found in the manufacturing in-dustry, indicating a high rate of occupational acci-dents. The increase in occupational accidents is a phenomenon or symptom, showing that implementa-tion of the safety management system in the manu-facturing industry is still not going well. This situation or condition is still not in line with the expectations of corporate and government programs, namely zero occupational accidents.

In this research, a total data of 50 cases on occu-pational accidents in the manufacturing industry in Medan Industrial Zone are identified. Based on the collected data, an analysis is carried out based on the results of occupational accident investigations con-ducted by the company. The human factors analysis framework and classification system are used to em-pirically search for new variables that can be included in the conceptual model of this study.

Research Method

a. Research Design

The research uses quantitative approach with Human Analysis and Classification Systems (HFACS) framework. Once the data collection has been carried out, the next stage is to process the data using the standard HFACS framework to classify the causes of occupational accidents that occur. There are several steps required to use the standard HFACS method, namely:

Step 1: Reading all data on occupational accidents in the manufacturing industry

To provide a general overview of the accidents that occur, it is necessary to first read the occupa-tional accident data that will be analyzed. This overall picture can be obtained through factual in-formation, analysis, and the variables reported in each data.

Step 2: Identifying variables leading to accidents based on all accident data received

After reviewing the accident data used in this re-search, variables contributing to the accidents can be identified. This variable is easy to find because its properties are clearly stated. However, there are times when the variable is not written directly. According to [7], researchers should not add con-tributing variables in the identification phase be-cause adding variables only refers to researcher's assumptions.

Step 3: Classifying accident-causing variables in the HFACS framework

Step 2 generates a list of causal variables contrib-uting to an accident. Then, in this step, these vari-ables are classified into categories in the HFACS taxonomy. First, classification is done by identify-ing layers that correspond to variable, then identi-fying sublayers to classify the variable.

Step 4: Summarizing the classification results

The final step in using the HFACS method is to summarize the accident causing variables, includ-ing the number of accident causes in one layer and sublayer. This summary may be useful for further analysis processes.

After obtaining a summary of the classification re-sults using standard HFACS, the undefined varia-bles leading to occupational accidents are summa-rized to obtain alternative proposed variables cor-responding to the research model for each varia-ble. The research model is validated by grouping each cause of occupational accidents according to the variables in the research model.

b. Analyzing and reporting

Based on the identification results of every oc-cupational accident that occurs in the manufactur-ing industry, a database that was previously creat-ed will be obtained. It is one of the identification results of 50 occupational accidents. This identifi-cation is based on a review of the company's in-dustrial accident investigation reports as well as field observations and interviews with involved parties to obtain or dig up detailed information about the industrial accident.

The results of investigations into occupational accident reports that the company maintains are compared with real data or field observations to determine the causal factors. Then, for each vari-able, an identification is carried out using the HFACS standard framework to find out which variables are the factors causing the occupational accident. From these results, it is known that there are several variables that are not listed or de-fined in the HFACS standard framework. This is a gap for development in this research.

c. Structural Model

Based on the results of the development of the above HFACS framework, a reference regarding the factors causing occupational accidents in the manufacturing industry is obtained. For this reason, a relationship analysis is performed on each variable in the existing HFACS framework to determine the influence between these variables. The analysis of the relationship among these variables is carried out using a questionnaire research instrument developed to determine the influence of each variable in the occupational accident.

According to [4], he conducted occupational accident analysis by combining HFACS with the Structural Equation Model (SEM). In the first phase, a model for the causes of occupational accidents was designed, based on analysis and classification of human errors. The human factors hypothesis model is then applied in the structural model.

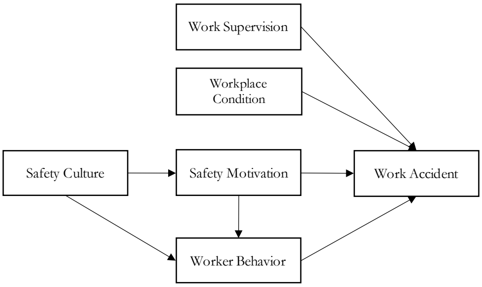


Fig. 1 Development of Model Causes of Work Accident

The development phase of this research model starts with collecting data (data collection) on occupa-tional accidents in the manufacturing industry. An analysis was then conducted on 50 existing occupa-tional accident data using the Human Factors Analy-sis and Classification (HFACS) framework developed by [7]. This is done to investigate information related to the variables that cause occupational accidents and to obtain alternative new causal variables that cause occupational accidents. The data analysis was carried out using the main framework [7], which was adapted based on the results of the identification of existing data on occupational accidents [1]. Based on these results, new variables were obtained that accounted for occupational accidents, namely work supervision, workplace conditions and employee behavior, in addi-tion to the safety culture variable [9]; [1]; [10], safety motivation [3]. Based on these results, a conceptual model was obtained for the variables that cause oc-cupational accidents in the manufacturing industry.

The development of the above conceptual model was carried out by adding new variables. The results of this model development are followed by a hypoth-esis. From this hypothesis, the existing conceptual model was tested using structural equation modeling (SEM). Hypothesis testing or relationship analysis of the relationship among variables was performed to determine the relationship of each existing variable [1]. The final step taken was to finalize the results of the relationship analysis of each variable. This was done to provide understanding and attention in pre-venting occupational accidents and to draw conclu-sions in this research.

Result

The results of the frequency analysis of 50 cases of occupational accidents, carried out in the table above, showed that the most dominant variables in the occurrence of occupational accidents were super-vision at work, especially inadequate supervision by 15%, errors, both in the form of wrong skills-based behavior (13%) and wrong decisions (13%) and or-ganizational influence factors, especially organization-al culture, amounted to 10%. The above results are a consideration in preventing workplace accidents, with the dominant variables above being one of the keys to preventing occupational accidents. It is a considera-tion not only in developing the HFACS framework, but also by considering other variables that can be taken into account in developing the model.

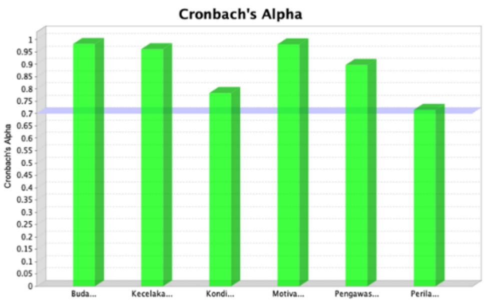
The results of the above alternative new variables resulted in a conceptual model will form the basis for this research. The results of this model development are then continued with the hypothesis to be tested. Then, a relationship analysis iss performed on each existing variable to determine the influence of these variables. The analysis of the relationship between these variables was carried out using a questionnaire research instrument (questionnaire) developed to determine the influence on each variable in the occu-pational accident development model produced above. According to [4], in his research he conducted an analysis of industrial accidents by combining HFACS with the Structural Equation Model (SEM). In the first stage, a model of the causes of industrial accidents is built, based on the analysis and classifica-tion of human errors. A hypothetical human factors model is then applied to the structural model.

The first thing to do is testing whether the indica-tors used are good or not when measuring a variable. Indicators commonly used in validity and reliability testing in SEM PLS are Composite Reability, Cronbach Alpha, and Average Variance. A good indi-cator value is above 0.6. From the results of the relia-bility test using SEM PLS, the Cronbach's alpha val-ues were obtained as follows.

The results in Table 1 show that the Cronbach's Alpha and CR values for all variables have values greater than 0.6. It can be concluded that all variables and items used in this research meet the validity and reliability in measuring variables.

Tab. 1 Validity and Reliability

	Cronbach's Alpha	*rho_A*	*Composite Reliability*	*Average Variance Extracted (AVE)*
Safety Culture	0.983	0.986	0.987	0.952
Work Accident	0.962	0.968	0.972	0.898
Workplace Condition	0.784	0.784	0.848	0.482
Safety Motivation	0.981	0.982	0.984	0.900
Work Supervision	0.898	1.050	0.903	0.651
Worker Behavior	0.716	0.718	0.825	0.541



Graph 1 Cronbach's Alpha Graph

This path analysis is used based on the SEM model supported by the use of SEM PLS 3.0 soft-ware. This is done to determine the relationship among all variables in the HFACS framework. When forming this model, there are two relationships, namely a direct relationship (direct effect) and an indirect relationship (indirect effect).

The relationship between variables is significant if the p-value of the T-statistic is less than the 5% sig-nificance level ($p < 0.05$). This relationship is illustrat-ed in Table 2. The processing of the resulting data shows the relationship between variables in the fol-lowing table:

Tab. 2 P-Value between Research Variables

	Path Coefficient	*Sample Mean (M)*	*Standard Deviation (STDEV)*	*T Statistics (|O/STDEV|)*	*P Values*
Work Supervision -> Work Accident	-0.043	-0.040	0.023	1.859	0.032
Workplace Condition -> Work Accident	0.043	0.045	0.027	1.585	0.057
Worker Behavior -> Work Accident	0.066	0.061	0.034	1.917	0.028
Safety Motivation -> Worker Behavior	0.569	0.558	0.074	7.727	0.000
Safety Culture -> Safety Motivation -> Work Accident	0.178	0.170	0.068	2.615	0.005
Safety Culture -> Worker Behavior -> Work Accident	0.016	0.015	0.010	1.672	0.048

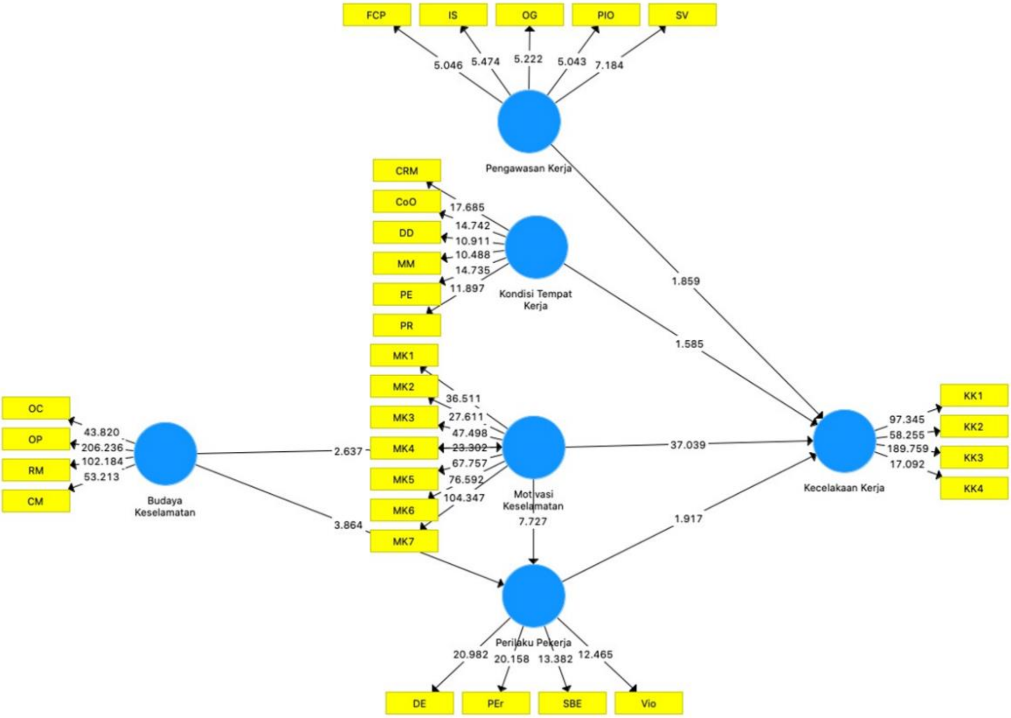


Fig. 2 Path Coefficient and P-Value

Table 2 illustrates that an evaluation of the struc-tural model or inner model was conducted to predict the relationship between latent variables (Ghozali and Latan, 2015). The inner model in-cludes latent variable correlation values (valid if r > 0.05), path coefficients (if r is valid, the path coefficients are significant), and R-squared. To measure the inner model, this can be done by using R2 for the construct of interest, as well as path coefficients or t-values for each path to test the significance of the relationship between each variable or construct.

As shown in Table 2 above, these results state that all direct relationships between all variables have a p-value less than the 0.05 significance level, so the in-fluence between these variables is significant. With the exception of variable workplace conditions related to occupational accidents.

Discussion

The research results obtained from the data pro-cessing carried out include several statements regard-ing the results of the data analysis:

1. After identifying occupational accident data from 50 accident cases, it was found that the variables that causes occupational accidents include safety culture, work supervision, workplace conditions, employee behavior, and safety motivation.

2. The results of the validity and reliability tests con-cluded that Cronbach's alpha and composite reliabil-ity (CR) values were greater than 0.6 for all varia-bles. It can be concluded

that all variables and items used in this research meet validity and reliability in measuring variables.

3. As a result of the path analysis performed on the existing structural model, the p-values of all direct relationships (direct effects) for all variables are less than the significance level of 0.05, so all relation-ships between variables are significant. It turns out that it has an impact, excluding variable working conditions regarding occupational accidents, the p-value is 0.057.

4. Indirect relationship analysis shows that safety culture has positive and significant influence on oc-cupational accidents with a significance of 0.005 ($p < 0.05$) when mediated by safety motivation. Simi-larly, the relationship between safety culture has a positive and significant influence on occupational accidents when mediated by employee behavior, with significance of 0.048 ($p < 0.05$). Therefore, the variables of employee safety motivation and behav-ior successfully mediate the relationship between safety culture and occupational accidents.

5. As a result of testing the coefficient of determina-tion, it was found that the R-square value of each variable, namely workplace conditions, work super-vision, employee behavior, safety culture, and safety motivation variables, contributed to the explanation of work. Accident variable is 93.8%, remaining 6.2 % is explained by other variables outside of the model.

The implications of this study are as follows:

a. Developing a more effective safety management system

This research provides companies with the tools to identify key variables that cause workplace ac-cidents, such as inadequate supervision, unsafe work environments, and unsafe employee behav-iors. In this way, companies can develop or im-prove more comprehensive and data-driven safety management systems to prevent accidents from happening again.

b. Improving workplace safety culture

This research shows the importance of strength-ening safety culture in the workplace. Companies need to ensure that safety awareness and com-mitment permeates all levels of the organization. Improving a good safety culture can help signifi-cantly reduce the number of occupational acci-dents by focusing on changing employee attitudes and behaviors towards safety aspects.

c. Improving work environment and supervision

The results of this investigation also emphasize the importance of increasing the quality of super-vision and improving the physical conditions of the workplace. With stricter supervision and better work environments, companies can minimize the risk of accidents and improve worker safety.

d. Emphasizing safety motivation as a key to prevention

This research highlights that motivation for safety, both internal (workers' awareness) and external (company incentives and training), plays an important role in preventing occupa-tional accidents. Companies can implement more effective safety training programs and provide incentives for safe behavior on the job.

e. Contributions to occupational safety research

The model developed in this research makes an important contribution to work safety re-search, especially in the manufacturing indus-try. This can form the basis for future re-search and become a reference for compa-nies in designing better security policies. With these implications, companies can take strategic steps to improve their workplace safety systems, reduce the risk of accidents and, ultimately, increase productivity and workers' well-being.

Conclusion

Based on the results of the research analysis and discussion that have been described in the previous chapter, the conclusions in this study are as follows:

1. Work supervision has a positive and significant effect on work accidents with a value of 0.032 (p <0.05). Then the condition of the workplace has a positive but insignificant effect on work accidents with a value of 0.057 (p <0.05). Furthermore, safe-ty motivation has a positive and significant effect on worker behavior with a value of 0.000 (p <0.05). And worker behavior has a positive and significant effect on work accidents with a value of 0.028 (p <0.05).

2. The model of causes of work accidents developed by adding variables of work supervision, work conditions, and worker behavior can be consid-ered in addition to safety culture and safety moti-vation. Each variable has an effect on work acci-dents. This is a consideration in preventing work accidents in the manufacturing industry.

The novelty of this report can be identified through several aspects that distinguish it from previ-ous research. Here are some points of novelty found in the research on the development of a model of causes of work accidents in the manufacturing indus-try:

1. Integration of safety motivation variables into the model, one of the main aspects of novelty in this report is the inclusion of safety motivation as an important variable in the model of causes of work accidents. Previously, research related to work ac-cidents focused more on physical factors such as workplace conditions and worker behavior, while the aspect of safety motivation has not been ex-plored in depth.

2. Development of a model that combines safety culture and work supervision. This study intro-duces a new approach by combining safety cul-ture, work supervision, and workplace conditions in one conceptual model. This combination offers a holistic view of the causes of accidents, allowing companies to not only focus on one causal factor but also see the relationship between various causal factors in an integrated manner.

3. Empirical approach based on real cases in the Me-dan Industrial Area: Another novelty of this study is the use of empirical data collected from 50 real accident cases in the manufacturing industry in the Medan Industrial Area. This provides added value compared to research that uses secondary or theoretical data, because the research results are based on actual cases that occur in the field.

4. Application of the Human Factor Analysis and Classification System (HFACS) in the Manufactur-ing Industry: HFACS was previously more often used in accident analysis in the aviation or trans-portation sectors. This study expands the applica-tion of HFACS in the context of the manufactur-ing industry, which has not been widely done, thus offering a new approach to investigating work accidents in this sector. These novelties indicate that this study not only continues previous re-search, but also offers new theoretical and practi-cal contributions in understanding and preventing work accidents in the manufacturing industry.

In conducting investigations into the causes of occupational accidents, practitioners in the manu-facturing industry can already use more detailed and comprehensive methods or models. So far, practitioners are still using the cause and effect theory developed using a fishbone diagram to ob-tain the root cause or route cause of the accident. In the future, the HFACS framework can be used in the manufacturing industry so that a more de-tailed and in-depth analysis can be carried out so that the root cause of the main cause of work ac-cidents can be obtained correctly and the follow-up actions taken are also on target.

For further research, the safety awareness variable can be considered in developing a work accident model and modifying HFACS. Safety awareness is an important point for workers to be able to avoid work accidents [8].

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