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INTEGRATED RISK MANAGEMENT MODEL RELATED TO OCCUPATIONAL HEALTY AND SAFETY IN MULTI-STOREY BUILDINGS

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Abstract *The goal of this research is to apply risk management model related to the Occupational Health and Safety (OHS) by integrating Causal Effects Diagram (CED), Analytic Network Process (ANP) and Interpretive Structural Modeling (ISM). The research method consists of three (3) stages. Stage 1) Using CED method to know the correlation between the risks and their causes. Stage 2) Making an assessment by using Analytic Network Process (ANP) with Software Matlab, stage 3) Interpretive Structural Modeling (ISM) is used to get the model of connectivity in mitigation of occupational accident. From ANP method, it is clear that the dominant potential risk in structural phase is 0,6159 and the highest cause of accident by human factor is 77%, and it is due to the unsafe behavior. ISM method is used to know the mitigation in reducing the occupational accident risks, namely improvement of Occupational Health and Safety (OHS) management, Each Scaffolding establishment must be inspected by a certified expert, the working methods must obey the Indonesian National Standard (SNI), The risk control should be done in relation to potential cause of occupational accident which can minimize the risk on construction work (zero accident).*

Keywords*: Construction, Risk Management, Occupational Health and Safety*

1. Introduction

The research about risk management related to occupational safety has been done by most developed countries. It is due to the fact that the development of a country must be followed by industrial development which can lead to the occurrence of occupational accidents. The position of risk management as a management process has an important role, to indicate the source of risks and find the mitigation strategy of the risks [1]

Various researches about the risk of occupational accident in industrial area have been done. As [2] identified the risk cause of occupational accident, by explaining the causalities using Causal Effects Diagram (CED) method and gave assessment to the risk of occupational accident using Analytic Network Process (ANP) method. Furthermore, [3] made a qualitative approach using Causal Effect method to identify the risks at the construction projects in order to alter the risks into competitive advantages in marketplace. Similarly, [4] also applied Causal Effect Diagram (CED) method as a tool to identify the risks of occupational accident.

Previous study had different way to identify the risk events by using Interpretive Structural Modeling (ISM) approach and applied ANP approach for the weighting of each risk [3]. In addition, [6] used ISM model to indicate the correlation between the risks and their causes and ANP was used to measure the risk potential occurred. While for the risk mitigation, [7] used Interpretive Structural Modeling (ISM) method in describing the linkage of the risk mitigations that have been planned. Moreover, [8] also applied ISM method to indicate the interrelation at the mitigation of occupational accident risk in construction project. In conclusion, there have been many studies which applied CED, ANP and ISM methods for risks management.

However, there were no previous research had been conducted that integrates the three methods altogether to manage the risks of occupational accident; therefore this research aimed to construct the three methods using CED to obtain a model of the relationship between risks that occurs. Then the CED model results will be assessed using the Analytic Network

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Process (ANP) method to determine the magnitude of the influence of risk factors on the emergence of the risk of workplace accidents. The result will be used as a base in determining the identification of risk mitigation in construction projects. While the Interpretive Structural Modeling (ISM) being used to model the linkages of the existing variables in the risk mitigation of workplace accidents, so that appropriate mitigation scenario in reducing workplace accidents could be found.
This research will identify the OHS risks in relation to the construction project in multi-storey buildings. The respondents are the employees who are in direct contact with the implementation of building construction project, the manager of OHS, the project leader.

2. Research Methods

Construction of integrated risk management model related to occupational safety by integrating Causal Effect Diagram (CED), Analytic Network Process (ANP) and Interpretive Structural Modeling (ISM). In integrating the three methods, the first CED method is input for the ANP method, while the output of the ANP method is input for the ISM method.

The integration of ISM and ANP from this research refers to [9] The data used in this study is secondary data derived from building construction project while the primary data got by giving questionnaires and having interviews to respondents who expertise at the field of OHS. There are some stages to integrate the three methods. They will be explained as follows:

1. Causal Effects Diagram (CED) model
Data needed in making CED model derived from the result of identification and analysis of occupational risk. The steps in formulating CED model: a) Correlating the occupational risks with their risk factor related to causalities among the variables, b) finding the correlation between risk factor and risk sub factor as the root cause of occupational risks.

2. Model Validation
Model validation was conducted in order to know whether the model developed is in accordance with the real condition. Some experts who are very advance in their field has assisted the process of model validation, therefore there is compatibility between the developed model and the real condition at the field. Validation of linkages is done by brainstorming with competent expert companies in the Occupational Health and Safety (OHS)

3. ANP Model
ANP model arrangement begins with the construction of cluster model which indicate the hierarchical relationship between goal, criteria and sub criteria. Through this model, the correlation between the criteria and the sub criteria will be shown.

4. The Calculation of Criteria and Sub criteria Quality
The calculation of criteria and sub criteria quality aimed to obtain priority values for each criterion and sub criteria using Matlab software. Criteria and sub criteria values are obtained by comparing each criterion with the others, sub criteria with the others, and also comparing criteria with sub criteria. The value obtained is given by the company expert.

5. Risk Mitigation Analysis
The purpose of risk evaluation is to determine the risks which need mitigation and priority of risk management. After getting the plan of occupational risk mitigation, further there must be an identification of the correlation between risk mitigation variables using Interpretive Structural Modeling method

6. Integrated Risk Management Construction CED, ANP and ISM in reducing the Number of Occupational accidents.

3. Result and Discussion

In obtaining the construction of risk management model related to OHS in accordance with the stages of research that have been explained previously, the following will describe the result and discussion from each stage that have been reviewed.

3.1 Causal Effect Diagram Modeling

Conceptual Model of Causal Effect Diagram at this research is adopted from Causal Loop Diagram model in Dynamic System [10] believed that Causal loop diagram can reveal the causalities of problems. Moreover [4] argued that Causal Effects Diagram can identify the root cause of risks, thus the cause of problems in risk events can be detected by showing all the causes of the problems.

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Figure 1 *Causal Effect Diagram Modeling*

Causal Effect Diagram Model is illustrated in picture 1 as the root cause of risks in construction project, such as the risk of falling due to workers in preparation phase of the job. The installation of scaffolding, the workers can fall down mainly due to the slip or the collapse of scaffolding. Those may happen because the workers are careless and the scaffolding foundation is not at the flat place. The workers are sometimes careless because they are joking while doing their jobs. They do it because they have lack knowledge about occupational safety, in addition the workers do not join OHS training because they have lack commitment about OHS.

By using causal effect diagram or the root causes analysis, the causalities which focus more on the causes than the effect can be determined [3] Similarly, [10] also argued that the causal effect diagram or CED was created for the purpose of indentifying and categorizing the causes in other causal categories.

3.2 ANP Model

The assessment about the effect of occupational accident risk which is illustrated in Causal Effects Diagram model is done by implementing ANP method described in figure 2.

3.2.1 Analysis of Risk Weighted Results

In this case, criteria are a risk on each stage the process of construction project, while sub criteria are the cause of the risk. Weighting is done by having matrix appraisal pair wise between criteria and criteria, sub criteria and criteria, sub criteria on each criterion. In ANP weighting, the Software used is Matlab Software Version 16. In this case, the weight score of matrix appraisal pair wise for sub criteria and criteria is Structural phase 0.6159, Finishing phase 0.20153, Sub Structural phase 0.1368, and Preparation phase 0.0455. Occupational injury risks often happened at structural phase due to the fact that the phase is started from the beginning, since the absence of the building, wall or floor, or in short, the phase is the basic work up to finishing [11]

Based on the result, the weighting of sub criteria on the biggest occupational accident risks is from structural phase, namely 42 risks causes from 45 risk causes of occupational accident. Similarly, [12] on his research indicated Very High Risk potential at structural

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job in which the materials fell down from the height and they hit the workers. [4] stated that one cause of risk can lead to some risk events. This research is in line with the opinion, that one cause of occupational accident risk can occur at every stage of working, for example, the workers do not use Personal protective equipment at structural and Finishing stages, moreover the causes of risks are the lack of knowledge and OHS commitment on every stages of working process, this phenomenon indicates the lack implementation of safety management on construction project [13]

Table 1 is the overall global priority weighting of the causes of occupational accident risks which occur at all stages in multi-storey construction process. The cause of occupational accident risk for each stages can occur at least at two stages of process, for example the cause of risk due to the peeling wire at preparation and sub structure process, whereas the cause of risk due to wire exposing to the water (short circuit) happens at three stages of work, namely preparation stage, structure and Finishing. The next stage will be risk mitigation or risk control by considering the causes of risks.

Table 1. Global Priority Weighting

No	Causes of Risk	Global Priority Weighting
1	Limited working area	0.33
2	The collapsing of Scaffolding	0.32
3	Workers ignorance to OHS	0.30
4	Workers do not use APD	0.29
5	Electric wire exposed to water (short circuit)	0.29
6	Get a shock of electricity	0.29
7	Incorrect Construction Method	0.29
8	Unskilled workers	0.29
9	No handles	0.29
10	Manual transport error	0.29
11	In a hurry	0.28
12	Lack of rest	0.27
13	Joking while working	0.25
14	Careless	0.25
15	Lack of OHS commitment	0.25
16	Lack of OHS knowledge	0.25
17	Improper position of tools	0.25
18	Did not join OHS training	0.25
19	No warning signs	0.25
20	Error of information transformation	0.25
21	Error in working instruction	0.25
22	Wrong position of working	0.25
23	Less responsive Management	0.25
24	No barricades at cleaning area	0.25
25	Broken Flash back aristor	0.25
26	Infection	0.25
27	Narrow area	0.25
28	Undisciplined workers	0.25
29	Exhausted	0.25
30	Broken working equipments	0.25
31	Workers are not concentrate	0.25
32	Joking	0.25
33	Day dreaming	0.25
34	Working without any accordance with SOP	0.25
35	Lack of maintenance	0.25
36	Old condition of equipments	0.25
37	Peeling electric wire	0.25
38	The footrest does not use catwalk	0.25
39	Messy material	0.25
40	Hook on safety hardness is not inserted in TC hook	0.24
41	Sound of drilling process	0.23
42	Do not know how to use the tools with bar bender and bar cutter correctly	0.21
43	Scaffolding foundation is not solid in flat area	0.20
44	Slipped	0.20
45	Location in muddy soil, mud, sink in mud	0.19

Source: ANP processing results with Matlab software [11]

3.2 Risk Mitigation with ISM (Interpretive Structural Modeling)

Risk mitigation planning is based on the result of global weight (Global Priority) by considering the four biggest weights among 0.29 to 0.33. The causes of risks which have the greatest weight are limited working area, the

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collapsing of Scaffolding, workers ignorance to OHS, workers do not use Personal protective equipment, electric wire exposed to water (short circuit) , get a shock of electricity, incorrect construction method, unskilled workers, no handles, manual transport error.

Risk mitigation has been identified by OHS experts. According to [8], there are eight mitigation plans which will be applied to handle the causes of occupational accident risks. The mitigation that will be done are as follows : 1) Improvement of OHS management, 2) Workers must have SKT (Technical Skill Certificate), 3) Implementing Safety standard OHS for High-rise Building construction workers, 4) Learning about MSDS (Material Safety Data Sheet), 5) Each Scaffolding establishment must be inspected by a certified experts, 6) Provide distance during installation and demolition of scaffolding, 7) Working Methods must be in accordance with SNI (Indonesian National Standard), 8) Cable connection insulation for connecting wire must have PUIL 2000 standard (general rules of electrical installation).

Risk mitigation by using ISM method begins with the linkage between risk mitigation elements applied into Structural Self-Interaction Matrix (SSIM), by converting the numbers into letters which indicate the link category. The next step is making reachability matrix (RM) by converting SSIM into a binary matrix, converting symbol A, X and O into number 0 and 1. Based on Reachability Matrix, Driver Power and Dependence are obtained. From level partition calculation, there will be 5 levels with level 1 as a mitigation of cable connection insulation with PUIL 2000 standard (general rule of electrical installation). Level 2: Workers must have SKT (Technical Skill Certificate), level 3: Learning about MSDS (Material Safety Data Sheet), Level 4: Provide distance during installation and demolition of scaffolding, level 5: Each Scaffolding establishment must be inspected by a certified expert, improvement of OHS management, implementing safety standard K3, working Methods must be in accordance with SNI (Indonesian National Standar

Driver Power Dependence Matrix is divided into four parts, namely driver, linkage, autonomous and dependent. Driver Power Dependence Matrix from the variables is illustrated in figure 3. The high Driver Power is in quadrant IV, which has a power to affect other variables within the system. Mitigation in this quadrant is improvement of OHS management, Each Scaffolding establishment must be inspected by a certified expert, and working methods must be in accordance with SNI (Indonesian National Standard). Quadrant II has a low Driver Power so this variable has no power to affect other variables within the system.

Risk mitigation in this quadrant mostly depends on the inputs and action given to the system, especially from linkage quadrant. The risk mitigation in quadrant II are Workers must have SKT (Technical Skill Certificate), Learning about MSDS (Material Safety Data Sheet), Cable connection insulation must have PUIL 2000 standard (general rules of electrical installation).

Quadrant I weak driver-weak dependent variable (autonomous), risk mitigation in this quadrant has a relatively small or unrelated influence. Risk mitigations in quadrant I are: Provide distance during installation and demolition of scaffolding. Quadrant III : Strong driver-strongly dependent variable (linkage). Risk mitigation at this position will support the success in resolving the causes of OHS risk which may lead to risk events. In contrast, if there is no action from the risk mitigation, then the risk event can not be resolved. Risk mitigation in quadrant III is implementing safety standard OHS for High-rise Building construction workers.

3.4 Risk Management Model by integrating CED, ANP and ISM

CED Method is used to get linkage model between the risks caused and the cause of risk which happen, then the result of CED model will be assessed by Analytic Network Process (ANP) model to determine the effect of risk factor on the emergence of occupational injury risks. Then the result will be used as a basis to determine risk mitigation identification on construction projects, while Interpretive Structural Modeling (ISM) is used to model the interrelation of variables at the mitigation of occupational accident risks, so the appropriate mitigation can be obtained to reduce the occupational accidents. The construction of OHS risk management model in figure 4 is adopted from [5] who integrated ISM and ANP into Supply Chain Risk Management.

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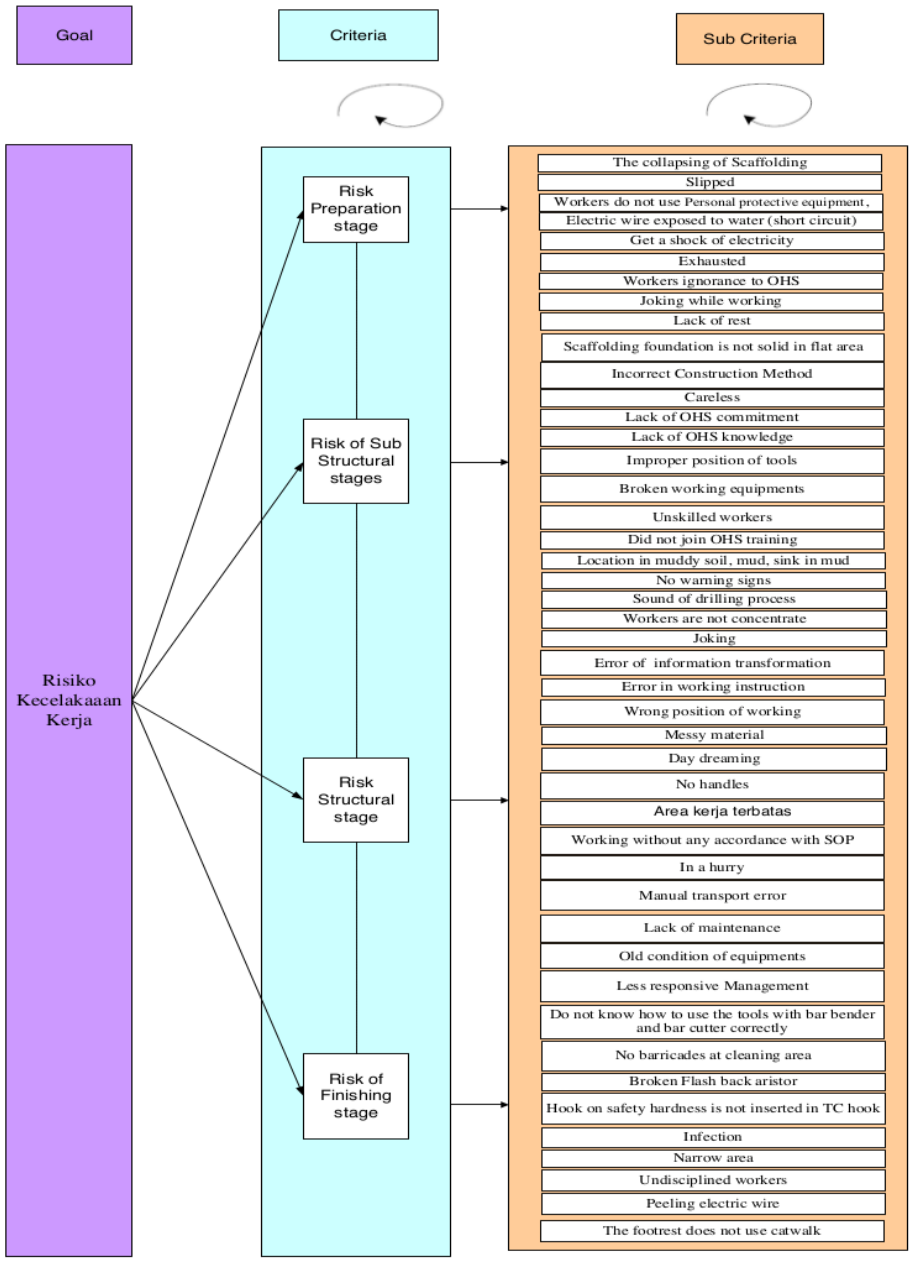

Figure 2 ANP Model

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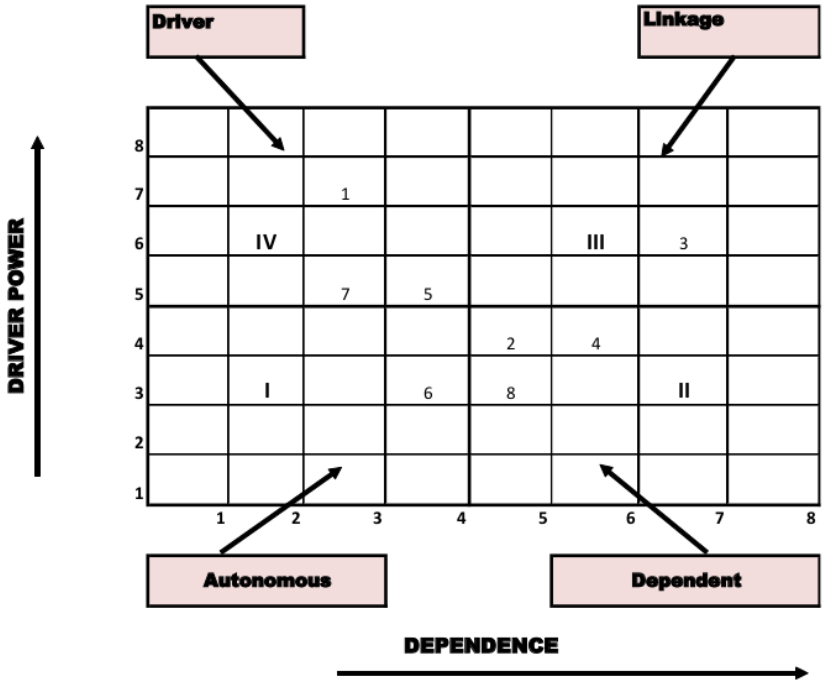

Figure 3. Driver Dependent Matrix

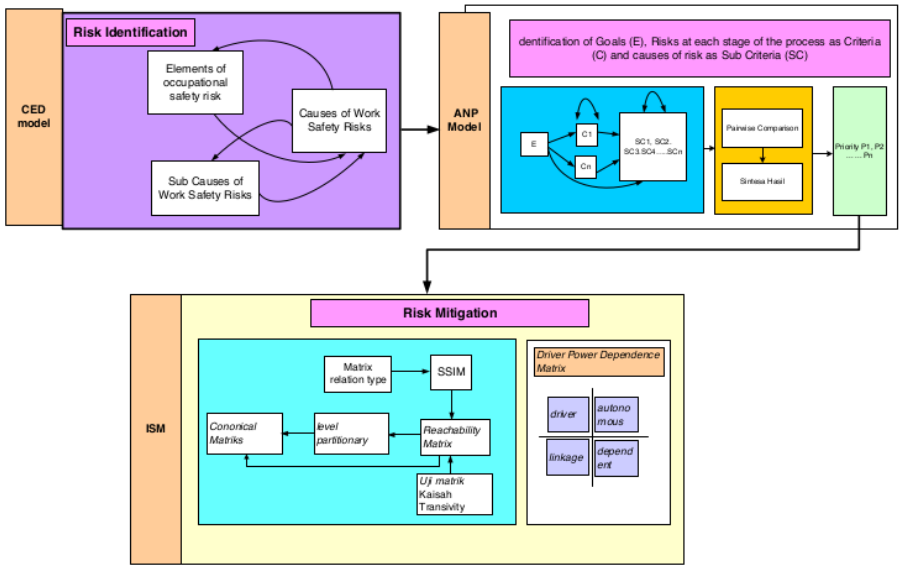

Figure 4. Risk Management Model by integrating CED, ANP, and ISM

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4. Conclusion

The use of CED method in identifying the risks can facilitate the mapping on identification result of the causes of risks in which the main cause of occupational accident is due to human factor that neglected OHS by having unsafe behavior. Based on the weighting by using ANP method, the greatest potential of occupational accident risk is firstly at structural process, then finishing phase, sub structure phase and the last is preparation phase. Risk mitigation that have to be done based on the potential causes of the risks are improvement of Occupational Health and Safety (OHS) management, Each Scaffolding establishment must be inspected by a certified Expert, the working methods must obey the Indonesian National Standard (SNI), This mitigation plan is expected to minimize the risk on construction work (zero accident).

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