Model development of risk assessment of risk-taking relationship with integrated approach

A B R Indah, S Mangngenre¹, R D Mudiastuti, N I Syamsul and Nilda

Department of Industrial Engineering, Universitas Hasanuddin, Makassar, Indonesia

Mail: a.besseriyani@gmail.com

Abstract. Each organization or company must always be dealing with risk. The decision-makers strive to be able to avoid the impact of such risks. Those generated risks may affect the achievement of the objectives, therefore risk management is needed. Risk management is a solution to avoid or to minimize the occurrence of the risk. Risk management consists of several steps, one of them is risk assessment. An appropriate risk assessment would support the achievement of the objectives. In this study, a risk assessment model is developed with PLTSa Kota Surabaya as a (research) object, which was selected because there were still constraints that affect the energy produced and waste volume used as fuel in this PLTSa. This study aims to develop risk assessment models integrated with the Delphi method, Fuzzy Cognitive Maps, and Fuzzy Synthetic Evaluation, then implementing these models in real cases and proposing risk mitigation steps by considering the relationship of the risks. The Delphi method was used to identify risks, FCM was used to identify the relationship among risks and the relationship between identified risks with the objectives of PLTSa, and FSE was used to assess the level of risks to find risks with the critical category. Delphi method identified 15 risks as a result and reached the consensus based on statistical analysis, FCM generated positive value of the relationship among all of the identified risks and negative value of the relationship between identified risks with the objectives of PLTSa. Meanwhile, FSE method obtained six types of critical risk, which were the machine brake all of a sudden (RC = 3.082), the blower did not work (RC = 3.041), congestion in fuel flow (RC = 2.954), clogged filter (RC = 2.915), lack of machine maintenance knowledge by the operator (RC = 2.872), and the energy produced had not maximum. (RC = 2.828). Those six types of risk used a scenario to run the FCM simulation and meet the dynamic behavior of the risk relationship value. The mitigation proposals are to perform maintenance activities programmatically, to improve the management system related to human resources, and to do the fuel examination according to the standard.

1. Introduction

In carrying out activities both in business and not business oriented will always face problems or obstacles. The problem is unpredictable, such problems could happen beyond human control. If the problem continues to occur then there will be something unexpected commonly referred to as risk. Risk is an uncertainty that is likely to occur in a case causing harm. In risk management, several steps must be passed. One of them is risk assessment. Several previous studies have developed models of risk assessment on several objects. Andric and Lu [1] conducted a risk assessment on the bridge construction process with the Fuzzy Analytic Hierarchy Process (FAHP). Cao and Song [2] developed a risk assessment approach to rough group and Analytic Network Process (ANP) to conduct a quantitative risk assessment. Cheng and Lu [3] developed a risk assessment on construction projects jacking pipes with...
fuzzy inference method and failure mode effect analysis (FMEA). Taylan et al. [4] conducted a study with the selection of construction projects and conducted risk assessments using fuzzy AHP and Fuzzy TOPSIS. Wu et al. [5] made a risk assessment model on the offshore pipeline project by integrating methods Interpretive Structural Modeling (ISM) and Bayesian Network.

This research will conduct development models of risk assessment which take into account the relationship between risk and risk relations with the objectives to be achieved to make risk mitigation measures. The development of valuation models is done by integrating the Delphi method, Fuzzy Cognitive Maps, and Fuzzy Evaluation Synthetic for. Delphi was used for risk identification, FCM was used to identify the relationship of risk, and FSE was used to conduct a risk assessment to find critical. Critical risk obtained will be used as the basis of the scenario FCM to run simulations of FCM to see the dynamic behavior of the risk relationship.

2. Risk assessment
Risk assessment consists of several main stages such as risk identification, risk analysis, and risk evaluation.

2.1 Risk identification
This phase will conduct a risk identification process, which first identified is the potential of risk. Identification of potential risks carried out using the Delphi method. Delphi method is a method of decision-making process involving multiple experts [6]. The aim is to avoid domination by another expert opinion and minimize bias. The stages of the Delphi method are explained in Figure 1.

![Figure 1. Stages of the Delphi Method [7]](image)

Having obtained any potential risks that may occur by using the Delphi method, the next step is obtaining the relationship between the risk potentials. To find the relationship between the potential risks we use Fuzzy Cognitive Maps. Fuzzy cognitive maps are soft computing techniques and knowledge-based method that involves human reasoning and human decision-making in its application. The purpose of this phase is to determine whether a potential risk can be occurred due to other potential risks. In this method, extracting information will be made to the expert by interviews directly related to the relationship between the potential risks categorized by risk variables. Participants will fill out the questionnaire by assigning the value of the relationship between the potential risks.

a. If participants give value > 0, then there is a positive relationship between the potential risks (proportional).

b. If participants give value = 0, then there is no relationship between the potential risks.

c. If participants give value < 0, then there is a negative relationship between the potential risks (opposite).
2.2. Risk analysis
After gaining the relationship between the risks, the next step is conducting a risk analysis process. Fuzzy Synthetic Evaluation (FSE) is a branch of the fuzzy logic developed by Zadeh [8] to represent and manipulate the vagueness of the term [9]. The risk analysis performed using Fuzzy Synthetic Evaluation, in analyzes performed consists of several stages.

2.3 Risk Evaluation
Based on the results of risk assessment, therefore, we can make proposed mitigation measures that should be conducted immediately. By looking at the critical risk category, we can determine the priority of risk mitigation. Also, we understand the terms of the relationship between risks, the relationship may be based on the results of FCM method that has been used to describe the risks that influence the critical risks by simulating FCM conducted by using a critical risk scenario.

3. Case Study
The research was conducted on a small scale PLTSa objects located in the Bratang landfill and Wonorejo landfill of Surabaya. PLTSa Surabaya was an object selected in this study because city officials until now made a target to build PLTSa in a small scale in 35 polling stations located in Surabaya, therefore the government of Surabaya can make the results of this study as a reference to face the potential risks to the development of next PLTSa. Researchers will look at the enforceability of the development of the proposed risk assessment model on that object. The data collection was conducted by using interviews and questionnaires addressed directly to the experts/stakeholders. Data collected consists of primary data and secondary data. Primary data was the data taken directly from the results of surveys, interviews, and questionnaires to the expert. The number of experts who were taken in this study is four.

3.1 Research design method
This research conducted an integrated approach (Figure. 3) by creating a model of risk assessment by integrating several methods such as the Delphi method, Fuzzy Cognitive Maps, and Fuzzy Synthetic Evaluation.

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**Figure. 2** Integrated Approach Model
3.2 Data Analysis

3.2.1 Delphi method
In this research, the Delphi method was conducted by distributing Delphi questionnaires with three turns. From the results of collection from each respondent obtained it summarized possible risk factors that occur as many as 26 risk factors. From those 26 risk factors can be classified of financial risk, operational risk, and maintenance.

Delphi's second round conducted an assessment of risk factors that have been identified in the Delphi rounds I. Assessment is based on a Likert scale to express statements of agreeing or disagree related to 26 risk factors that have been summarized in previous rounds of Delphi. The results of questionnaires showed that 11 risk factors that otherwise have an average value of 3.5 to 3.5 over indicate that respondents agree with these risk factors. Besides, there are 15 risks with the total value averaging below 3.5 indicating respondents undecided even disagree with these risk factors. Because there are still some potential risks to the value of 3 is doubtful therefore re-division of the questionnaire was conducted. It is called the Delphi questionnaire round III. In the second round of the Delphi questionnaire, there are additional risk factors, namely the explosion of the reactor. In Delphi III because the respondents remain consistent with questions of risk factors which have been summarized by the first round Delphi questionnaire, the respondents reported that they have reached an understanding uniformity through statements risk factor that has been written in the questionnaire. So the modified Delphi II questionnaire produce a questionnaire Delphi III only form of additional risk factors that originally consisted of 26 risk factors assessed by each respondent to 27 risk factors assessed at Delphi questionnaire round III. From the results obtained by the Delphi method, 15 risks were obtained to reach a consensus until the third round (Table 1)

| No. | Code | Risk                                           |
|-----|------|-----------------------------------------------|
| 1   | (R1) | Levels of methane gas produced are still inconsistent |
| 2   | (R2) | There are no tar waste processing methods      |
| 3   | (R3) | Delay operation process of PLTSa               |
| 4   | (R4) | The energy produced is not maximized           |
| 5   | (R5) | The number of engine units is still lack       |
| 6   | (R6) | The machine was broken suddenly                |
| 7   | (R7) | PLTSa process in the rainy season is not maximum |
| 8   | (R8) | There was congestion fuel flow                 |
| 9   | (R9) | The blower is suddenly not working             |
| 10  | (R10)| No determination of process schedule operation of PLTSa |
| 11  | (R11)| Filter clogged                                |
| 12  | (R12)| The workforce who lack discipline              |
| 13  | (R13)| The lack of skill of the operator to operate PLTSa |
| 14  | (R14)| Knowledge of the operator to maintain the machine is still lacking |
| 15  | (R15)| There was an explosion in the reactor          |

3.2.2 Method of fuzzy cognitive maps
In this study, besides, to identify risk factors that occurred or likely to occur also conducted the process of identifying the relationship of risk to see the correlation relationship between one risk to other risks. It also identified the relationship of risk to the objectives of PLTSa. The objectives to be achieved on a pilot project PLTSa in Surabaya consists of two main objectives, namely:

1. Anticipate an accumulation of trash by reducing the volume of waste through the operation of PLTSa (P1)
2. Produce renewable energy by using waste in Surabaya (P2)

As for the data processing with the FCM is:

1. Establish experts/stakeholders who have understood about PLTSa to determine the relationship of risk.
2. FCM questionnaire (Appendix D) for each expert to give values to the relationships between these risk factors.
3. Each expert will give values to the relationship between risk and risk relations with the objectives to be achieved by giving more values to the value range -1 to 1. Each expert determines the amount of value between these ranges generously. If there is no relationship then the assigned value of 0.
4. Each value of the relationship obtained from each expert will form an adjacency matrix. Valuing is conducted by each expert forming matrix adjacency respectively. In this study, because it uses four experts consequently there is four adjacency matrix. Below is an example adjacency matrix:

\[
A = \begin{bmatrix}
0 & 0 & 0 & w_{14} \\
0 & 0 & 0 & w_{24} \\
w_{31} & w_{32} & 0 & 0 \\
0 & 0 & 0 & 0
\end{bmatrix}
\]

Adjacency matrix obtained from four experts then processed into adjacency augmented matrix by using equation (1):

\[
W_{ij}^{Aug} = \frac{\sum_{k=1}^{m} W_{ij}^k}{m}
\]  

(1)

The pattern of risk relationships later is depicted in the form of a cognitive map based on the augmented adjacency matrix. Values obtained from the expert relationship can be seen in its dynamic behavior. If you want to see the dynamic behavior of the risk relationship therefore we should make a scenario to simulate FCM based on the equation (2) computing scenarios, namely:

\[
C_j^{t+1} = f(C_j^t) + \sum_{i=1, i \neq j}^{n} C_i^t \times W_{ij}
\]  

(2)

\(f\) is the activation function, \(C_j^{t+1}\) is the value impact (effect) node \(j\) at time \(t + 1\). \(C_j^t\) is the value impact (effect) at time \(t\). \(C_i^t\) is a cause value (causal) node \(i\) at time \(t\). And \(wij\) is to show the intensity of the relationship between causal effect node \(i\) and \(j\). The tangent function consists of two: the hyperbolic tangent function and sigmoid. The formula for the hyperbolic tangent function according to Lopez and Salmeron (2012), equation (3):

\[f(x) = \tanh(\lambda x)\]

Hyperbolic tangent is used on the value of connectedness with the value range [-1,1]. At this stage only limited identify relationships based on expert assessment.

3.2.3 method of fuzzy synthetic evaluation
The risk assessment is carried out by using FSE. After identifying the relationship of risks using the FSE method derived from the opinion of the expert, then any identified risks are analyzed quantitatively using FSE. The steps of data processing, risk assessment with the FSE method are:
1. Appoint experts to conduct a risk assessment.
2. The list of risks assessed was risks identified using the Delphi method which consists of 15 types of risk factors.
3. Furthermore, questionnaires are distributed to each expert. Parameter of risk assessment consists of two types of consequences (impact) and likelihood (likelihood of risk occurrence). Each of these parameters is assessed on a Likert scale with values 1-5.
4. Calculating process of FSE method uses the following equation:
The matrix equation for consequences (impact) type of risk R6 (broken machine suddenly) is 
\[(0.00,0.00,0.00,0.00,1.00),\text{ which answers with a value of } 1 = 0\%,\text{ value of } 2 = 0\%,\text{ value of } 3 = 0\%,\text{ value of } 4 = 0\%,\text{ and the value of } 5 = 100\%.\]

The matrix equation for Likelihood (Probability) type of risk R6 (broken machine suddenly) is as follows: (0.00,0.00,0.00,0.50,0.50). Here is the calculation:

\[
C_i = \sum_{j=1}^{5} (s_j x r_{ij}^C) \quad (4)
\]

\[
C_i = (1 \times 0.00) + (2 \times 0.00) + (3 \times 0.00) + (4 \times 0.00) + (5 \times 1)
\]

\[
C_i = 5
\]

The results of the calculations by the FSE method can be seen in Table 1. Based on the calculations conducted there are six types of risk included in the category of critical value with the value of RC is between 2.8 to 3.1:

- a. Engine broken abruptly with the value of RC is 3.082
- b. The blower is not worked suddenly with the value of RC is 3.041
- c. Fuel flow congestion occurred with the value of RC is 2.958
- d. The filter clogged with the value of RC is 2.915
- e. Knowledge of machine Maintenance operator is still lacking with the value of RC is 2.872
- f. The energy generated is not maximized with the value of RC is 2.828

3.2.4 Results of fcm simulation by critical risk
This section will conduct an FCM analysis of simulation results based on the scenario built that is critical risks that consist of six types of risk.

Simulation 1
In the first simulation, we have to understand what if scenario 1 run so if the risk factors occurred are broken engine suddenly (R6) with the value 1 on FCM simulation means active. The results obtained are affecting some of the risk factors and objectives of PLTSa. As for the risk factors associated with the R6 is:
1. R1 (levels of methane produced is still inconsistent) = 0.9434 (very powerful positive correlated)
2. R3 (delay on operation process of PLTSa) = 0.9464 (very powerful positive correlated)
3. R4 (energy produced is not maximized) = 0.9165 (very powerful positive correlated)
4. R7 (PLTSa process is not maximum in rainy season) = 0.8812 (very powerful positive correlated)
5. R8 (fuel flow congestion occurs) = 0.8946 (very powerful positive correlated)
6. R9 (blower suddenly not working) = 0.9295 (very powerful positive correlated)
7. R11 (filter clogged) = 0.9295 (very powerful positive correlated)
8. R12 (undiscipline labors) = 0.5647 (very powerful positive correlated)
9. R15 (explosion in reactor) = 0.9295 (very powerful positive correlated).

If R6 occurs it is likely that the risk of R1, R3, R4, R7, R8, R9, R11, and R15 will occur because they have a very powerful positive correlation. Meanwhile, as for relations with the aim of PLTSa R6 is negatively correlated where P1 (reduce the volume of waste) with relationship value = -0.9612 (very powerful negative correlation), and P2 (produce renewable energy) = -0.9612 (very powerful negative correlation), which means if R6 occurs then the purpose of P1 and P2 are not achieved in full potential.

Simulation 2
The second simulation conducted is running the second scenario that is R9 (blower suddenly not worked) if it happens then how is their relationship to other risk factors and objectives of PLTSa. The results of the scenario conducted are if R9 is enabled by providing value 1 on FCM simulation therefore risk factors affected are:
1. R1 (levels of methane produced is still inconsistent) = 0.9211 (very powerful positive correlated)
2. R3 (delay in operation process of PLTSa) = 0.9434 (very powerful positive correlated)
3. R4 (energy produced is not maximized) = 0.9295 (very powerful positive correlated)
4. R6 (faulty engine suddenly) = 0.9115 (very powerful positive correlated)
5. R7 (PLTSa process is not maximum in rainy season) = 0.7078 (powerful enough positive correlated)
6. R8 (fuel flow congestion occurs) = 0.8812 (very powerful positive correlated)
7. R11 (filter clogged) = 0.7861 (powerful enough positive correlated)
8. R15 (an explosion in the reactor) = 0.7516 (powerful enough positive correlated).

The relationship between risk factor R9 with the aim of PLTSa is negative with a value of P1 = (-0.9369), P2 = (-0.9403). If R9 occurs, therefore, the aims of P1 and P2 are not achieved in full potential. Meanwhile with the positive relationship occurred in R9 with other risks, if R9 happens then likely R1, R3, R4, R6, R7, R8, R11, and R15 also have a positive relationship.

Simulation 3
In the third conducted what if scenario 3 is executed if risk factors occurred is R8 (fuel flow congestion) with the value 1 on FCM simulation means active. The risk factors influenced by results of FCM simulation is:
1. R1 (levels of methane produced is still inconsistent) = 0.9369 (very powerful positive correlated)
2. R3 (delay in operation process of PLTSa) = 0.9434 (very powerful positive correlated)
3. R4 (energy produced is not maximized) = 0.9211 (very powerful positive correlated)
4. R6 (faulty engine suddenly) = 0.9165 (very powerful positive correlated)
5. R7 (PLTSa process is not maximum in rainy season) = 0.7861 (powerful enough positive correlated)
6. R9 (blower suddenly not working) = 0.9211 (very powerful positive correlated)
7. R11 (filter clogged) = 0.9006 (very powerful positive correlated)
8. R15 (explosion in reactor) = 0.9006 (very powerful positive correlated).

The relationship between risk factors R8 with aim of PLTSa is negative with a value of P1 = (-0.9295), P2 = (-0.9295). If R8 happens then likely R1, R3, R4, R6, R7, R9, R11, and R15 happen because they have a positive relationship. Meanwhile, if R8 occurred, therefore, PLTSa goals can not be achieved in the maximum because they have a negative relationship between the objective and the R8.

Simulation 4
Simulation 4 is run by third scenario if the risk factors occurred are R11 (filter clogged) to give a value of 1 on FCM simulation which means active, therefore risk factors influenced by the results of the FCM simulation are:
1. R1 (levels of methane produced is still inconsistent) = 0.9434 (very powerful positive correlated)
2. R3 (delay in operation process of PLTSa) = 0.9403 (very powerful positive correlated)
3. R4 (energy produced is not maximized) = 0.9165 (very powerful positive correlated)
4. R6 (faulty engine suddenly) = 0.9115 (very powerful positive correlated)
5. R7 (PLTSa process is not maximum in rainy season) = 0.6810 (powerful positive enough correlated)
6. R8 (fuel flow congestion) = 0.8812 (very powerful positive correlated)
7. R9 (blower suddenly not working) = 0.9165 (very powerful positive correlated)
8. R13 (lack of skill of the operator in operating PLTSa) = 0.6496 (powerful positive enough correlated)
9. R14 (lack of knowledge of operator to perform machine maintenance) = 0.6910 (powerful positive enough correlated)
10. R15 (explosion in reactor) = 0.6496 (powerful positive enough correlated).

The relationship between risk factors R11 with the aim of PLTSa is negative with a value of P1 = (–0.9568), P2 = (–0.9612). Values of relationships indicates that if R11 occurred then the risk of potentially happen is R1, R3, R4, R6, R7, R8, R9, R13, R14, and R15 because they have positive relationships, the value of the relationship between risk assessed from expert assessment directly, changing the value of the relationship after simulation of dynamic behavior based on scenarios built. While the value of the relationship between R11 with the aim of PLTSa is negative, which means that if R11 occurred it will hamper the achievement of predetermined PLTSa.

Simulation 5
To run a simulation 5 we use scenario 5 to determine the value of the relationship of risk and PLTSa purposes. In simulation 5 we run scenario 5 that is R14 (knowledge of operator to maintain machine is still lacking) if it occurred then how they relate to other risk factors and objectives of PLTSa. The results of the scenario run are if R14 activated with value 1 on the FCM simulation of risk factors affected are:
1. R1 (levels of methane produced is still inconsistent) = 0.5647 (powerful positive enough correlated)
2. R3 (delay in operation process of PLTSa) = 0.7861 (powerful positive enough correlated)
3. R4 (energy produced is not maximized) = 0.9006 (very powerful positive correlated)
4. R6 (faulty engine suddenly) = 0.9369 (very powerful positive correlated)
5. R7 (PLTSa process is not maximum in rainy season) = 0.5647 (powerful positive enough correlated)
6. R8 (fuel flow congestion) = 0.9211 (very powerful positive correlated)
7. R9 (blower suddenly not working) = 0.9434 (very powerful positive correlated)
8. R11 (filter clogged) = 0.9434 (very powerful positive correlated)
9. R15 (explosion in reactor) = 0.9434 (very powerful positive correlated)

The relationship between risk factors R11 with the aim of PLTSa is negative with a value of P1 = (–0.9493), P2 = (–0.9493), which means that if R11 occurred then PLTSa goal can not be realized in maximum. Meanwhile, the relationship between R11 to other risks associated with the positive cause most likely risk factors R1, R3, R4, R6, R7, R8, R9, R11, and R15 will occur.

Simulation 6
In simulation 6 conducted is if scenario 6 run that is if the risk factors occurred is R4 (energy produced is not maximum) with the value 1 on FCM simulation means active. The risk factors influenced by the results of the FCM simulation are:
1. R1 (levels of methane produced is still inconsistent) = 0.9454 (very powerful positive correlated)
2. R7 (PLTSa process is not maximum in rainy season) = 0.5647 (powerful positive enough correlated).

Based on the value of relationship risk factor R4 there are only two risk factors that have a positive correlation, which means that if R4 occurred then likely R1 and R7 are affected. The relationship between risk factor R8 with the aim of PLTSa is negative with a value of P1 = -0.9464, P2 = -0.9519, a negative value indicates that if risk factors R4 occurred, therefore, we will make PLTSa goal not achieved in maximum.

3.3. Proposed Risk Mitigation
Perform maintenance activities in the program and schedule on the machine/equipment of PLTSa
Programmed maintenance activities can be conducted based on the systematic scheme of maintenance activities proposed by Muhtad (2009), as well as on Figure 4.
Improving management system relating to human resources. Some efforts should be made to overcome the lack of qualified human resources according to in Widiasih [10] are:
   a. Training (education and training)
   b. Job design

Verify the fuel adjusted with fuel quality standards for the gasification process. Some standards that need to be concerned related to the energy content of the fuel, fuel moisture, shape and size of the fuel, the uniformity of fuel, heavy fuel per cubic meter, volatile substance (easily evaporated) on fuel and ash substance. Those characteristics must be considered to generate maximum energy.

4. Conclusion
In this research, we conducted the development models of risk assessment by considering relationship aspects between risks and risk relations with the objectives to be achieved to make risk mitigation measures, with a case study on power plant waste of Surabaya. The methods integrated are the Delphi method, Fuzzy Cognitive Maps, and Fuzzy Synthetic Evaluation. Delphi method is used as a method to identify risks in small-scale PLTSa in Surabaya conducted by distributing questionnaires three times round. The results of the questionnaire in reaching consensus obtained fifteen risks managed to reach a consensus. Fuzzy Cognitive Maps (FCM) is the method used to identify the relationship between risk and the relationship with the project objectives. The results of value identification of risk relationship showed that the relationship between the risks of all is positive (one-way), and risk relationship with PLTSa goal of all is negative (opposite-way). From the results of FSE methods successfully obtained six critical risks that is R6 (faulty engine suddenly), R9 (blower suddenly not working), R8 (fuel flow congestion), R11 (filter clogged), R14 (the lack of operator’s knowledge to maintain machine), and R4 (the energy produced is not maximized). The proposed mitigation measures that need to be addressed are as follows:
   a. Conduct maintenance activities programmed and scheduled on machinery/equipment of PLTSa.
   b. Improve the management system related to human resources.
   c. Examine the fuel adjusted fuel quality standards for the gasification process.

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