Power Generation Fire Risk Evaluation Using House of Risk (HoR) Method With an Asset Management Approach

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Abstract. The risk of fire in power generation is the latest issue of concern to the electricity business. Several preventive programs such as coal dust control and the improvement of coal handling facilities to the provision of fire fighting infrastructure have been carried out continuously, but the main problem in the implementation of further work programs is finding the right policy in the main risk and determining the priority of mitigation. Integrating the House of Risk method with ISO 55001 can become an alternative to the previous methods that already exist and will be able to support the establishment of fire safety risk mitigation policies. A holistic review of business processes taking into consideration emerging risk agents in addition to risk events, risk impacts, and the occurrence of risk agents, then the method used will be able to generate a selected list of prioritized preventive actions. The results showed 41 risk events with 28 identified risk agents, furthermore, 17 risk agents were chosen as a preventive measure, and finally 8 proposed preventive actions to reduce the probability of the occurrence of risk agents that can lead to business interruption.

1. Introduction
The average growth of electricity sales every year has increased in line with the growth of the Indonesian economy. According to the long term planning of the 35,000 MW electricity development program, most power plant types projected to build are fueled by low-rank coal which tends to create self-combustion events that lead to fire [1]. Company X engaged in power generation contributed to the construction and management of the 35,000 MW electricity supply project, considering the risks of fire in its generating unit requires action to mitigate the risks. Several incidents of fire due to self-combustion of coal dust occur within 2015 - 2020 ranging from small-scale fires to fire incident that has a significant impact. Several preventive programs such as coal dust control and improvements of coal handling facilities have been carried out continuously, but the obstacles found in the implementation of the program is finding the right policy in evaluating the most significant risk of the cause and setting a priority of its preventive action.
Company X in carrying out its business processes has obtained several international certificates such as ISO 55001: 2014 (asset management). ISO recognition of this business process means that the company's corporate governance assets have been executed according to world-class standards and best practices. Each level of the business process has been defined in detailed activities to achieve increased company value. Based on the challenges on company X as its role in the 35,000 MW program, a risk mitigation design was developed to minimize fire safety risks in low-level coal-fired power plants that could disrupt business. The mitigation plan chosen is based on the risk of each business process activity to be able to respond holistically to power plant fire risks.

The concept of the House of Risk (HoR) is an emphasis on preventive activities, which in this case is to prioritize efforts to reduce the chance of a risk event by reducing the chance of a risk agent occurring. In its formulation, the House of Risk (HoR) also determines quantitatively how closely the relationship between risk events and risk agents is, and sometimes it is found that several risk events arise from a single risk agent [3]. The ultimate goal of the HoR method is to get the risk agent with the highest priority value and then determine what preventive actions are correlated with it.

In general, The HoR method modifies the House of Quality (HoQ) model through two calculation stages:

HoR1 is used to determine which risk agents are the top priority of preventive actions.

HoR2 is prioritizing actions that are considered effective but with a reasonable commitment to budget and resources.

Some qualitative studies have presented fire risk rating methods such as Edinburg [4], Gretener [5] method based on NFPA 101 - Life Safety Code developed under the terms Fire Safety Evaluation System [6] and Dow’s Fire and Explosion Index [7] to fire resistance risk analysis methods at nuclear power plants [8]. The development of information technology with supporting software utilization that implements existing methods is considered to have advantages in terms of obtaining easy analysis and fast traceability to the database results of the assessment. Some risk ranking software that has been developed such as COFRA [9], FREM [10], and EFSES [11]. Focusing only on the information of the assets under study (according to the method adopted) is a weakness of the software, so it is necessary to improve by considering the overall aspects of asset management.

A review of previous research found that the method used has not considered the asset management aspect holistically and does not involve a risk agent as one of the potential risk rating calculation variables. Considering the limited budget and resources, the risk agent in the HoR analysis will present how to prioritize fire prevention programs, while asset management considerations are needed to map the overall risk inherent to the organization’s business processes in this case as an asset operator or service provider in the electricity business.

2. Method

This study evaluates fire risk based on asset management of company X’s power generation plant business processes outside Java island where company X acted as the asset operator or service provider. These are several steps of this study that refer to fire risk and asset management framework and House of Risk that has been explained in the previous chapter. First, all the power generation plant business processes are mapped by asset management framework, which divided into strategy and planning, asset management decision-making, asset information, organization and people, lifecycle delivery, risk, and review. Business processes activities starting from setting the asset management policy to the measuring stakeholder engagement. Second, identifying quality risks. There might be some risks along with business processes activities. Risks are identified by doing direct observation and brainstorming involving employees from many different fields within the selected company based on their long working experience and knowledge related to the fire risk and business management. The next step is assessing its potential risks to determine the severity, likelihood, and relationship scoring between risk agents and risk events, since one risk agent could lead to more than one risk events, it is necessary to quantify the potential aggregate risk of a risk agent.
If $S_i$ is the severity of impact if risk event $i$ occurred, $O_j$ is the probability of risk agent $j$ to occur, and $R_{ij}$ is the correlation between risk event $i$ and risk agent $j$. The number of $R_{ij}$ interpreted as how likely risk agent $j$ would create risk event $i$. Then the aggregate risk potential of risk agent $j$ ($ARP_j$) can be calculated as follows:

$$ARP_j = O_j \sum_i S_i R_{ij}$$

(1)

This step output is the HOR-1 matrix which shows risk agent rank, the most critical risk agents, and the Pareto diagram. The next step is developing risk mitigation. This study uses the output of the risk evaluation process, Pareto diagram, to decide the risk agent. Then determine the correlation score between the mitigation strategy and risk agent formulated as follows:

$$TE_k = \sum_j ARP_j E_{jk} \forall k$$

(2)

Where is:
- $TE_k$ = total effectiveness of each action
- $E_{jk}$ = relationship between each preventive action and each risk agent {0,1,3,9} represents no, low, moderate, and high relationships between action $k$ and agent $j$

Its scoring result was validated by company stakeholders through a questionnaire. All the related questions were designed based on the previous results and plotted to an HoR-2. At the end of this study, some of the mitigation programs produced will be under the company's capacity as an asset operator or service provider.

3. Result and discussion

3.1. Asset Management Model for Company X

Asset Management is a process that links between asset owners, asset managers, and asset operators [12]. In this concept, the asset owner sets the business values, corporate strategy, and corporate objectives in terms of cost, reliability, and risk. The asset manager identifies the best way to achieve these objectives and develops this in a multi-year asset plan. The service provider executes the plan effectively and efficiently and provides asset and reliability data into the asset management process. Based on the conceptual model of ISO 55001:2014, the business process divided into 6 elements and breakdowns to 41 key activities [13].

3.2. Risk Identification

This stage is the most important phase in risk management where any potential risks that affect the business process should be identified. Based on its definition, the risk is anything that causes losses and leads to more than one risk events. This study identifies risks through direct observation, both analyzing historical data and interviewing company stakeholders. The next steps are validating all potential risks that have been identified. Expert employees specialized in fire protection engineering involved in this validation process. There are ten potential risks in strategy and planning, thirteen risks in life cycle delivery, five risks in asset information, five risks in organization and people, and four risks in risk and review as shown in table 1. Through focus group discussion as many as 28 risk agents set as the trigger factor of the occurrence of a risk event as shown in table 2.

The occurrence and severity values follow the assessment guidelines set by Company X, while the correlation value between risk event and risk agent follows the terms of value 0.1,3,9 where 0 represents no correlation and 1, 3, and 9 represent, respectively, low, moderate, and high correlations [3].

3.3. Risk Evaluation

In this stage, risks are analyzed. Analyzing activities including determining risk agents by using ARP scoring from HOR 1 stage, questionnaire resume, and ARP scoring plotted in the Pareto diagram. Relevant questions are deployed to assess risk agents. It has been validated by the list of respondence.
ARP calculation in HOR 1 aims to gain risk agent ranking in the process of risk mitigation. ARP score is obtained by multiplying the value of risk likelihood, the severity of the events, and the value of the correlation between risk agent and risk event as shown in table 3. The highest ARP score is there is no standard guideline of Fire Protection System, which it has 67.62 of ARP score. This risk agent occurred as Company X doesn't have any guideline book or policy document related to the fire protection system. There are 17 most critical risk agents identified.

Once the rank of risk agents was determined, the next step is analyzing the Pareto chart as shown in Figure 1 to obtain critical risk agents by using a concept of 20:80 [14]. The identification of the 39 elements of business process activity found a number of 41 risk events that represent what could be wrong in the implementation of business processes in the context of fire safety management. As an asset operator, it brings consequences of risk inconsistent risk management policy between asset operator, asset manager, and asset owner.

**Table 1. Occurrence of Risk Identified From Business Process.**

| Code | Risk Event |
|------|------------|
| E₁   | The asset management policy cannot describe the needs of the company |
| E₂   | The asset management policy is not aligned with the vision of the mission of the holding company |
| E₃   | The purpose of asset management is unclear |
| E₄   | Organizational focus is not clear between Cost, Risk or Performance |
| E₅   | Strategic planning is less adaptive |
| E₆   | Asset management planning is not available |
| E₇   | Asset investment planning is not on target |
| E₈   | Strategic planning does not focus on achieving the mission |
| E₉   | Unstructured work program planning |
| E₁₀  | Annual Planning Program does not overcome the unit risk profile |
| E₁₁  | The Investment Program did not solve the problem |
| E₁₂  | The proposed investment work program is not acted upon |
| E₁₃  | Incomplete maintenance management policy |
| E₁₄  | Repeated damage to the Fire Protection System |
| E₁₅  | Fire Protection System does not comply with the standard |
| E₁₆  | The performance of Fire Protection System has not been proven |
| E₁₇  | Fire Protection System infrastructure is not standby |
| E₁₈  | Fire Protection System infrastructure is not available |
| E₁₉  | Fire Alarm not monitored |
| E₂₀  | Fire alarm system abnormal |
| E₂₁  | Output maintenance activity is not right on target |
| E₂₂  | The reliability of Fire Protection System equipment is low |
| E₂₃  | Fire is not handled quickly |
| E₂₄  | The available water capacity cannot cover the duration of 2 hours of fire extinction |
| E₂₅  | There is no control on coal dust |
| E₂₆  | Fire incidents are not handled as long as fire protection equipment is not ready |
| E₂₇  | Late incident handling |
| E₂₈  | The absence of a Fire Protection System mapping |
| E₂₉  | The choice of Fire Protection System type is not correct |
| E₃₀  | The choice of Fire Detection System type is not correct |
| E₃₁  | Fire Protection System is not maintained |
| E₃₂  | Fire Protection System maintenance history does not exist |
| E₃₃  | The equipment specifications do not match |
| E₃₄  | The absence of PIC field assets Fire Protection System |
| E₃₅  | Absence of Authority Having Jurisdiction |
36. Fire because of cigarettes
37. Work accident due to hot work
38. Can not identify the major hazard in the power plant
39. Fire Alarm Equipment Obsolete
40. Asset wellness does not reflect actual conditions
41. Violation of electricity regulation

Table 2. Risk Agents.

| Code | Risk Agents |
|------|-------------|
| A1   | Asset owner has no asset management policy |
| A2   | SWOT analysis is not accurate |
| A3   | Asset owner does not have long term planning |
| A4   | Asset owner does not have a projection on electricity growth |
| A5   | Limitations of asset historical data |
| A6   | Focusing on short-term problems |
| A7   | Asset owner does not have an asset management plan |
| A8   | The procedure for preparing an asset management plan is not appropriate |
| A9   | The choice of an alternative work program is not appropriate |
| A10  | Risk Management Document not made |
| A11  | Limited information available regarding the material requirement |
| A12  | There is no Fire Protection System maintenance planning |
| A13  | There is no standard guideline of Fire Protection System |
| A14  | Fire Protection System assets not yet handed over to asset owner |
| A15  | The fire alarm system is not integrated with power plant DCS (Distributed Control System) |
| A16  | The fire pump is in manual operating mode |
| A17  | Fire protection system manual activated mode |
| A18  | The water capacity for Fire Protection System is limited |
| A19  | Dust control equipment not available |
| A20  | There is no impairment strategy |
| A21  | No Emergency Respond Plan |
| A22  | Fire Protection System asset is not registered in the Computerized Maintenance Management System (CMMS) |
| A23  | No power plant management policy |
| A24  | Lack of understanding of power generating business processes |
| A25  | There is no smoking prohibition in the power plant |
| A26  | No hot work permit |
| A27  | Fire Risk Assessment not implemented a Fire Risk Assessment |
| A28  | Fire Protection System assets separate from the protected equipment |

The company's business values, strategy, and objectives in terms of cost, reliability, and risk associated with fire safety management determined by asset owners are potentially not correctly
translated by asset operators and vice versa, feedback from asset operations can not support the achievement of vision and mission has been proclaimed by the asset owner. Program prioritization errors, delays in procurement of parts, and recurrent damage from fire protection systems are some of the impacts of these risk events. The risk events identified at this stage are then evaluated for their severity as presented in table 1. The trigger factor of the risk event is set forth and obtained by 28 risk agents causing the occurrence of the risk event and its probability of occurrence. It revealed that some risk events on the elements of business process activity come from one cause of risk. This similarity of emerging risk agents causes a close correlation between multiple risk events and one risk agent presented in table 3. The ARP House of Risk 1 calculation results will present which risk agents are the top priority of preventive measures.

House of Risk 1 data processing in table 3 is followed by a ranking of risk agent priority using the Pareto analysis method, getting as many as 17 selected risk agents for next in House of Risk 2 will be set its preventive action as shown in table 4. Table 5 presents 17 selected risk agents in the first order is the absence of standard fire protection system guidance. The lack of these standard guidelines complies with the company’s current conditions that there is no specific policy-setting guideline regarding fire protection system assets.

Table 3. House of Risk 1.

| Business Process | Activities | Risk Event | Risk Agent | Si |
|------------------|------------|------------|------------|----|
| Strategy and planning | AM Policy | E₁ | 9 | 9 | 3 | ... | 0.4 |
| | AM Strategy and Objectives | E₂ | 9 | 3 | 9 | 3 | 1 | ... | 0.4 |
| | Demand Analysis | E₃ | 9 | 9 | 3 | 3 | ... | 0.4 |
| | Strategic Planning | E₄ | 9 | 3 | 3 | ... | 0.4 |
| | Asset Management Planning | E₅ | 3 | 3 | 9 | 3 | 3 | 3 | 3 | 0.8 |
| | Capital Investment | E₆ | 3 | 3 | 9 | 3 | 3 | ... | 3 | 0.8 |
| | Decision-Making | E₇ | 3 | 3 | 9 | 3 | 3 | ... | 3 | 0.8 |
| | Asset Management | E₈ | 3 | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Management | E₉ | 3 | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Decision Making | E₁₀ | 3 | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Lifecycle Value | E₁₁ | 3 | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Technical Standart and Legislation | E₁₂ | 3 | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | System Engineering | E₁₃ | 3 | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Configuration | E₁₄ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Management | E₁₅ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Maintenance Delivery | E₁₆ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Reliability Engineering | E₁₇ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Asset Operations | E₁₈ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Resources Management | E₁₉ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Shutdown and Outage | E₂₀ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |
| | Fault and Incident | E₂₁ | 3 | 3 | 3 | 3 | ... | 3 | 0.8 |

Table 3. House of Risk 1.
Table 4. House of Risk 1. (cont.)

| Business Process          | Activities     | Risk Event | Risk Agent | Si  |
|---------------------------|----------------|------------|------------|-----|
| Asset Information         | E28            | 1 3        | 3          | 0.4 |
| Asset Information         | E29            | 3 3 1      | 3          | 0.4 |
| standard                  | E30            | 3 3 1      | 3          | 0.4 |
| Asset Information         | E31            | 3 3 1      | 3          | 0.4 |

| ARP Code                  |                |            |            | 28  |
|---------------------------|----------------|------------|------------|-----|
| Aggregate risk potential  | 51.9           | 39.9       | 13.1       | 13.1|
| Priority rank of agent    | 3 9 6          | 24 11      | 25         |     |
Table 5. Preventive Action Selected Risk Agent.

| Code | Risk Agent                                      | Preventive Action                                      |
|------|------------------------------------------------|--------------------------------------------------------|
| A13  | There is no standard guideline of Fire Protection System | Preparation of standard Fire Protection System          |
| A12  | There is no Fire Protection System maintenance planning | Preparation of standard Fire Protection System          |
| A1   | Asset owner tidak memiliki kebijakan aset manajemen | Capacity building of power plant business processes     |
| A27  | Not implemented Fire Risk Assessment              | Implementation of Fire Risk Assessment                  |
| A23  | No unit management policy                         | Capacity building of power plant business processes     |
| A3   | Asset owner does not have long term planning      | Capacity building of power plant business processes     |
| A16  | The fire pump is in manual operating mode         | Setting the Fire Protection System in Automatic mode    |
| A7   | Asset owner does not have an asset management plan| Capacity building of power plant business processes     |
| A2   | SWOT analysis is not accurate                     | Capacity building of power plant business processes     |
| A17  | Fire protection system mode manual activated      | Setting the Fire Protection system in Automatic mode    |
| A5   | Limitations of asset historical data              | Utilization of the Computerized Maintenance Management System |
| A6   | Focusing on short-term problems                   | Capacity building of power plant business processes     |
| A10  | Risk Management Document not made                 | Employee training in preparing the Risk Management document |
| A14  | Not yet handed over Fire Protection System assets | Formally propose to asset owner to hand over the asset |
| A15  | The fire alarm system is not integrated with plant DCS | Upgrading Fire Protection System of generating unit |
| A24  | Understanding of generating business processes is lacking | Capacity building of power plant business processes |
| A18  | Water source capacity is limited                  | Upgrading Fire Protection System of generating unit     |

3.4. Risk Response

Risk mitigation then determined from the scoring result before. This study deployed some risk mitigations for 17 most critical risk agents as stated at the previous subchapter. The next step is choosing the most appropriate mitigation based on the validation process, through HOR 2 analysis as well as stakeholder confirmation. Table 5 below presents a list of valid mitigation planning of each critical risk agents, and its correlation score.

The next stage of ARP calculations sorted by Pareto analysis is to identify relevant preventive actions (PA). Respondents are guided to identify preventive actions based on an understanding of management expertise and experience in the generating unit. Obtained 8 relevant preventive actions from 17 selected risk agents as shown in table 5. Multiplying the ARP value with the correlation value between the risk agent and preventive action results in the effectiveness of the action and by comparing it with the degree of difficulty for its implementation, the highest calculated value becomes the recommended first priority.
| Code | Preventive Action                                                                 | PA₁   | PA₂   | PA₃   | PA₄   |
|------|----------------------------------------------------------------------------------|-------|-------|-------|-------|
| A13  | There is no standard guideline of Fire Protection System                           | 9     | 1     | 3     |       |
| A12  | There is no Fire Protection System maintenance planning                            | 3     | 9     | 1     |       |
| A1   | Asset owner has no asset management policy                                         |       |       | 9     |       |
| A27  | Not implemented Fire Risk Assessment                                               | 9     | 9     |       |       |
| A23  | No Unit management policy                                                          | 1     | 9     |       | 9     |
| A3   | Asset owner does not have long term planning                                      | 1     | 9     |       |       |
| A16  | Fire pump is in manual operated mode                                               | 9     | 3     | 9     |       |
| A7   | Asset owner does not have asset management plan                                   | 1     | 9     |       |       |
| A2   | SWOT analysis is not accurate                                                      |       |       | 9     |       |
| A17  | Fire protection system mode manually activated                                     | 9     | 3     | 9     |       |
| A5   | Limitations of asset historical data                                               |       |       |       |       |
| A6   | Focusing on short-term problems                                                    |       | 9     | 9     |       |
| A10  | Risk Management Document not made                                                 | 1     | 3     | 3     |       |
| A14  | Not yet handed over Fire Protection System assets                                   |       |       |       | 1     |
| A15  | The fire alarm system is not integrated with plant DCS (Distributed Control System)|       |       |       |       |
| A24  | Understanding of generating business processes is lacking                          |       |       |       | 9     |
| A18  | Water source capacity is limited                                                   | 9     |       | 9     |       |
| Total effectiveness of action (TE)                                                | 2277.94 | 3197.04 | 1554.7 | 1076.74 |
| Priority of TE                                                                     | 2     | 1     | 4     | 8     |
| Degree of difficulty performing action (D)                                         | 3     | 5     | 3     | 4     |
| Effectiveness to difficulty ratio (ETD)                                            | 759.31 | 639.41 | 518.23 | 269.19 |
Table 5. House of Risk 2 (cont.)

| Code | Preventive Action | Utilization of CMMS | Employee training in preparing the Risk Management document | Formally propose to asset owner to hand over the asset | Upgrading Fire Protection System of generating unit |
|------|-------------------|---------------------|----------------------------------------------------------|-----------------------------------------------------|---------------------------------------------------|
|      |                   | PA₅  PA₆  PA₇  PA₈  ARP |                                                  |                                                      |                                                   |
| A13  | There is no standard guideline of Fire Protection System | 9 | 67.62 |
| A12  | There is no Fire Protection System maintenance planning | 9 | 61.6 |
| A1   | Asset owner has no asset management policy | 9 | 51.94 |
| A27  | Not implemented Fire Risk Assessment | 0 | 9 | 44.94 |
| A23  | No Unit management policy | 3 | 41.58 |
| A3   | Asset owner does not have long term planning | 3 9 3 | 39.9 |
| A16  | Fire pump is in manual operated mode | 1 3 9 | 38.36 |
| A7   | Asset owner does not have asset management plan | 3 9 3 | 38.22 |
| A2   | SWOT analysis is not accurate | 3 | 37.66 |
| A17  | Fire protection system mode manually activated | 1 9 | 36.12 |
| A5   | Limitations of asset historical data | 9 1 3 | 34.3 |
| A6   | Focusing on short-term problems | 3 9 | 34.02 |
| A10  | Risk Management Document not made | 1 9 3 | 33.04 |
| A14  | Not yet handed over Fire Protection System assets | 1 3 | 32.2 |
| A15  | The fire alarm system is not integrated with plant DCS (Distributed Control System) | 1 3 9 | 32.2 |
| A24  | Understanding of generating business processes is lacking | 1 | 31.78 |
| A18  | Water source capacity is limited | | 9 | 28.56 |

Total effectiveness of action (TE) 1887.48 1404.9 1467.06 1217.16

Priority of TE 3 6 5 7

Degree of difficulty performing action (D) 4 3 5 5

Effectiveness to difficulty ratio (ETD) 471.87 468.30 293.41 243.43
Table 7. Selected Preventive Action Priority.

| Priority Ranking | Code  | Chosen Preventive Action                                              | ETD   |
|------------------|-------|-----------------------------------------------------------------------|-------|
| 1                | PA₁   | Preparation of standard Fire Protection System                        | 759.31|
| 2                | PA₂   | Capacity building of power plant business processes                   | 639.41|
| 3                | PA₃   | Implementation of Fire Risk Assessment                                 | 518.23|
| 4                | PA₅   | Utilization of Computerized Maintenance Management System             | 471.87|
| 5                | PA₆   | Employee training in preparing the Risk Management document           | 468.30|
| 6                | PA₇   | Formally propose to asset owner to hand over the asset                | 293.41|
| 7                | PA₄   | Setting the Fire Protection System in Automatic Mode                  | 269.19|
| 8                | PA₈   | Upgrading Fire Protection System of generating unit                   | 243.43|

The eight selected preventive action work programs as shown in table 6 may constitute a collaborative program of inter-related activities in the electricity generation business process with the primary objective of addressing and mitigating the impacts of risk events and reducing the likelihood of occurrence of risk agents. Implementation of standard fire protection system arrangement can be realized in a company manual (private standard) which contains a policy guide fire protection system asset management system. The contents of this manual should describe the general system and manual fire protection system, reviews of fire protection system inspection procedures, testing and maintenance, and reviews of certain types of fire protection that must be provided at certain locations within the plant, based on the area and the dangers. The fire protection system manual is developed under the applicable NFPA standards and FMDS Standards, with specific insights from experienced personnel, where it will some aspects to consider in this fire protection system manual may include hazards of the area/process, the critical level of area/process, the budget that will arise in connection with the application of fire protection system, how to implement recommendations, and local regulations.

4. Conclusion
The use of the HoR method to evaluate fire risk at the power plant proved to be very effective by presenting a series of fire prevention programs. The establishment of a risk agent in the HoR will help find out which risk events have a high degree of occurrence and contain a high potential impact that will interrupt business through fire incidents. Combined with business process activities that refer to ISO 55001 (asset management) standards, company management will find it easy to determine the prioritization of the pre-incentive program to reduce the level of fire risk. Based on data analysis and calculations in this study, 17 risk agents set 8 risk mitigation as preventive action work programs aimed for asset operators. Further research is still needed in the context of being the owner and manager of the related asset. Referring to ISO 55001, asset owners have more power in determining objective strategies and investment policies both in the long term and in the range of annual intervals. Meanwhile, when acting as an asset manager, management has the flexibility to plan operations and maintenance and manage to budget.
5. References

[1] Falcon R M 1986 Spontaneous combustion of the organic matter in discards from the Witbank coalfield. Journal of the Southern African Institute of Mining and Metallurgy 86.7 p 243-250

[2] Furness A and Muckett M 2007 Introduction to fire safety management (Routledge) Ch.14 p.328

[3] Pujawan I N and Geraldin L H 2009 House of risk: a model for proactive supply chain risk management. Business Process Management Journal 15(6) p 953-967.

[4] Stollard P 1984 The development of a points scheme to assess fire safety in hospitals. Fire Safety Journal, 7(2) p 145-153

[5] Kaiser J 1980 Experiences of the Gretener method. Fire Safety Journal 2(3) p 213-222

[6] Benjamin I A 1979 A fire safety evaluation system for health care facilities. Fire Safety Journal 73.2 p 52-53.

[7] Dow Chemical Company 1966 Process Safety Manual, Chemical Engineering Progress, 62(6)

[8] Kazarians M, Siu N O and Apostolakis G 1985 Fire risk analysis for nuclear power plants: Methodological developments and applications. Risk Analysis 5.1 p 33-51

[9] Parks L L, Kushler B D, Serapiglia M J, McKenna L A, Budnick E K, and Watts J M 1998 Fire Risk Assessment for Telecommunications Central Offices. Fire Technology 34 p 156–176

[10] Watts J M 1995 Software review. Fire Technology 31 p 369–371

[11] Watts J M 1997 Analysis of the NFPA Fire Safety Evaluation System for Business Occupancies. Fire Technology 33, p 276–282

[12] Brown R E and Humphrey B G 2005 Asset management for transmission and distribution. IEEE power and energy magazine 3(3) p 39-45

[13] Global Forum on Maintenance and Asset Management (GFMAM) 2014 The asset Management Landscape 2nd edition p 12

[14] Anggrahini D, Karningsih P D, and Sulistiyono M 2015 Managing quality risk in a frozen shrimp supply chain: a case study. Procedia Manufacturing 4 p 252-260.