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Risk Analysis in the Procurement Process of Goods and Services for Steam Power Plant Overhaul

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Abstract:- Power plant overhaul activities aim to maintain the reliability of power plants. All parties involved in this overhaul activity must be able to work dynamically to support the achievement of overhaul performance that is on time, on cost, on quality, on scope, on clean, and on safety (6 ON). Therefore, risk analysis and mitigation are needed in the process of procurement of goods and services for power plant overhaul so that it can assist companies in making decisions. Multi-Criteria Decision-Making (MCDM) method, especially the Analytic Network Process (ANP) method to obtain the weight of risk agents that affect the occurrence of a risk (risk event). House of Risk (HOR) method for risk identification, analysis and mitigation. The results of this study show that there are 12 types of risks with 18 risks caused by 20 risk causes.

Keywords:- *Analytic Network Process (ANP); House of Risk (HOR); Risk Management; Overhaul.*

I. INTRODUCTION

A reliable and stable supply of electric power is a major and fundamental need, as a driver of economic development in a country. Market competition in the power industry is forcing power plants to become more aware of the role of maintenance management.

The number of power plants in Indonesia in 2020 was 3,339 power plants, including power plants owned by State-Owned Enterprises (SOEs) and Independent Power Producers (IPPs) [1].

In managing the large number of power plants in Indonesia, efforts are needed to increase the availability, reliability and efficiency of power plants by carrying out proper maintenance.

One way to do proper maintenance is to perform Maintenance, Repair and Overhaul (MRO) periodically. MRO includes all inspection, repair and maintenance activities to keep facilities and equipment in good operating condition.

Power plant overhaul activities aim to maintain the reliability of power plants so that they can operate optimally and can minimize the number of force outages.

All parties involved in this overhaul activity must be able to work dynamically according to existing conditions to support the achievement of overhaul performance on time, on cost, on quality, on scope, on clean, and on safety (6 ON).

There are delays in the completion of service work and delivery of goods that can hamper the duration of the overhaul of the power plant. This is caused by the sudden procurement process of goods and services, so it is risky in the selection of suppliers.

Determining business partners is not an easy thing for every company, the right and fast strategy is needed in order to get the right supplier so that it can maintain company performance [2].

This study aims to conduct a risk analysis in the supplier selection process for power plant overhaul through a risk management approach, so that risk mitigation can be carried out and provide recommendations for companies in making decisions to choose competent suppliers.

II. LITERATURE REVIEW

A. Maintenance, Repair dan Overhaul (MRO)

The term MRO stands for Maintenance, Repair and Operations or Maintenance, Repair and Overhaul. MRO is a set of all the actions necessary to return equipment, machinery, or systems to their original state in which they operate at the required level of performance [3].

Physical assets such as plant, machinery, and equipment will decrease in their usage capacity over time. To maintain, restore and/or increase this capacity requires appropriate MRO and MRO management (MROM) activities [4].

B. Maintenance

Maintenance is a combination of all technical and administrative measures intended to maintain equipment or return it to a state in which it can perform the necessary functions [5].

Management of equipment maintenance at power plants involves a rather complicated process. This includes routine, preventive, predictive, emergency and corrective maintenance used in mechanical, electrical, and instrumentation and control fields. There are 3 (three) types of maintenance approaches, namely: breakdown maintenance, corrective maintenance, preventive maintenance [6].

C. Overhaul

Overhaul is a large scheduled package of work for extensive inspection and repair of a large item or equipment to achieve proper condition [7].

Basically, the implementation of Overhaul / Inspection of the Generating Unit during Unit Outage, is a collection of various other types of maintenance activities such as Preventive Maintenance, Corrective Maintenance, Predictive Maintenance and Engineering / Project which are carried out simultaneously during Unit Outage.

D. Supply Chain Management (SCM)

A supply chain is a network of companies that work together to make and deliver products to end customers [8]. These companies include suppliers, factories, distributors, stores or retailers, and logistics service companies.

Supply chain management is a method or approach to centrally manage the flow of products, information, and money involving many parties ranging from upstream to downstream consisting of suppliers, factories, distribution networks and logistics services [8]. The purpose of supply chain management is to improve supply chain performance on the supplier and buyer side [9].

E. Procurement Management

Procurement management is one part of supply chain management that systematically processes the procurement of goods and services from source to destination based on the right quality, right quantity, right price, on time to meet customer needs [10].

Procurement management is one of the main components in supply chain management that provides inputs needed in production activities in the form of goods and services [8].

F. Risk Management

The company must have a way that can be used to overcome the risks that may arise. Risk is the effect of uncertainty on the target or uncertainty that has an impact (effect) on the target [11].

Risk management as a coordinated activity to direct and control the organization related to risk [11]. The purpose of risk management is to improve performance, encourage innovation and support the achievement of objectives.

G. House of Risk (HOR)

The House of Risk (HOR) method is an integration of models developed as a tool to proactively handle risks [12]. This method combines two models, namely Failure Mode and Effect Analysis (FMEA) and House of Quality (HOQ).

HOR is carried out through 2 stages, namely HOR phase 1 and HOR phase 2. HOR phase 1 is used to rank each risk agent based on the Aggregate Risk Potential (ARP) value. HOR phase 2 is used to facilitate management in prioritizing risk handling that has been identified [12].

HOR phase 1 is developed through the following steps [12]:

- Identify activities in the business process then identify risk events that occur in the business process.
- Assess the impact that occurs (severity) on the risk event if the risk occurs. The assessment was carried out on a scale range of 1-10 [13].
- Identify risk agents and assess the chances of occurrence in each identified risk agent. The rating scale given is 1-10 [13].
- Assess the correlation between risk agents and risk events notated with R_{ij} with values of 0, 1, 3 and 9.
- Perform ARP_j calculations.
- Sort risk agents after getting ARP values from largest to smallest.

HOR phase 2 is developed through the following steps [12]:

- Choose a risk agent that is included in the highest ARP value and can be obtained from pareto diagram.
- Identify preventive measures that are considered effective to handle and prevent risk agents.
- Determine the amount of correlation between risk prevention measures and each risk agent.
- Calculates the total value of the effectiveness of each preventive measure.
- Assess the level of difficulty to take each preventive action.
- Calculates the total value of the difficulty effectiveness ratio.
- Ranking the priorities of each preventive action.

H. Analytic Network Process (ANP)

The procedures of decision-making through ANP are set as follows [14]:

- Arrange problem structures and develop linkage models
- This procedure states the objectives set to achieve.
- Develop a paired comparison matrix.
- The paired comparison matrix is conducted by using ANP scale which is from 1 to 9.
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- The paired comparison matrix is conducted by using ANP scale which is from 1 to 9.
- Calculate consistency ratio.
- Consistency ratio is used to examine the consistency of assessment given by expertise.
- Develop supermatrix.

III. RESEARCH METHODOLOGY

In this research, there are three major steps regarding data gathering and data processing. The first step carries out the process of identifying risk types, risks (risk events) and risk causes (risk agents) in the process of selecting power plant overhaul suppliers based on literature references and interviews with experts.

The second step determines the value of the impact that occurs (severity) on each risk (risk event) and determines the value of the opportunity of occurrence (occurrence) in each risk cause (risk agent) that has been identified. After that, identify and assess the correlation between the risk and the cause of the risk. Then the next step is to create a linkage model and calculate the weight of each risk and the cause of risk using the ANP method. The ANP calculation is conducted with Super

Decision software. The weight of the result of ANP will be the new severity and occurrence values used as input in the HOR method. This HOR method is divided into 2 phases, namely phase 1 is carried out to rank each risk agent based on the value of Aggregate Risk Potential (ARP) and phase 2 is carried out to determine risk mitigation priorities.

In the third step, the results of the ARP value ranking are mapped through a pareto diagram and used as input in the phase 2 HOR method. The next step is to identify risk mitigation measures. After that, assess the correlation between risk mitigation actions and each risk agent. Then, calculate the effectiveness of each risk mitigation action and calculate the value of the level of difficulty to perform each risk mitigation action. The next step is to calculate the difficulty ratio and rank the priority of each risk mitigation action based on the difficulty ratio.

IV. RESULTS AND DISCUSSION

The author conducted a literature study and interviews with experts to identify the type of risk, risk (risk event) and risk cause (risk agent) in the process of selecting suppliers for power plant overhaul. The identification results can be seen in Table 1.

Table 1. Results of Identification of Risk Type, Risk (Risk Event) and Risk Cause (Risk Agent)

No.	Risk Type	Risk (Risk Event)	Code	Causes of Risk (Risk Agent)	Code
1	Quality	The quality of the goods sent is not appropriate	RE1	The specifications of the goods requested by the user are unclear	RA1
		The quality of the service work is not appropriate	RE2	Details of the scope of service work listed in the TOR (Term of Reference) document are unclear	RA2
2	Delivery	Delays in the delivery of goods	RE3	There is a delay in production from the manufacturer	RA3
				Goods held up at customs	RA4
		Delay in completion of work	RE4	Non-optimal division of work schedules	RA5
3	Flexibility	Failure to fulfill changes in the number of orders requested by the company	RE5	The supplier does not have inventory of goods	RA6
		Failure to meet the time change requested by the company	RE6	Lack of resources (man power, cost) to complete the requested work	RA7
4	Occupational Health and Safety System	There was a work accident during the overhaul of the power plant	RE7	Incomplete PPE in accordance with K3 regulations	RA8
				Lack of supervision and awareness related to K3	RA9
5	Performance History	Poor supplier performance	RE8	The practice of collusion and nepotism in choosing suppliers	RA10
6	Warranties and Claim Policies	Failure in the warranty claim process	RE9	Suppliers no longer get support from principals	RA11
7	Price	Increase in the price of goods on the market	RE10	There is a scarcity of goods on the market	RA12
		Increase (Regional Minimum Wage)	RE11	The occurrence of inflation	RA13
8	Mutual Trust and Easy Communication	The emergence of business suspicion	RE12	Business ethics are not well executed	RA14
		Ineffective communication	RE13	Long and convoluted bureaucracy	RA15
9	Supplier's Profile	There was falsification of company data by suppliers	RE14	Lack of supplier integrity	RA16
		Required documents expired	RE15	Haven't updated the required documents	RA17
10	Repair Service	Re-work by suppliers	RE16	The supplier was unable to fulfill the agreement in the contract	RA18
11	Attitude	Breach of contractual agreements by suppliers	RE17	The supplier does not understand the content of the contract agreement	RA19
12	Geographical Location	Geographical location of suppliers away from power generation units	RE18	There is no branch office / representative office around the power generation unit	RA20

The next stage determines the value of the impact that occurs (severity) on each risk (risk event), determines the value of the chance of occurrence (occurrence) in each cause of risk (risk agent) and assesses the correlation between risk and risk causes. This assessment will be used to calculate the Aggregate Risk Potential (ARP) value.

Data processing in this study uses the ANP method because in this study it allows for a relationship between risk (risk event) and between risk causes (risk agent). This relationship is not supported by the HOR method because it only considers the relationship between risk (risk event) and the cause of risk (risk agent) only.

The calculation of the Aggregate Risk Potential (ARP) value uses the following formula:

$$ARP_j = O_j \sum i\, S_i R_{ij}$$

The results of calculating the Aggregate Risk Potential (ARP) value can be seen in Table 2.

Table 2. Results of Aggregate Risk Potential (ARP) Value Calculation

Causes of Risk (Risk Agent)	Code	ARP Value
The specifications of the goods requested by the user are unclear	RA1	720
Details of the scope of service work listed in the TOR (Term of Reference) document are unclear	RA2	990
There is a delay in production from the manufacturer	RA3	408
Goods held up at customs	RA4	324
Non-optimal division of work schedules	RA5	588
The supplier does not have inventory of goods	RA6	432
Lack of resources (man power, cost) to complete the requested work	RA7	470
Incomplete PPE in accordance with K3 regulations	RA8	567
Lack of supervision and awareness related to K3	RA9	189
The practice of collusion and nepotism in choosing suppliers	RA10	395
Suppliers no longer get support from principals	RA11	207
There is a scarcity of goods on the market	RA12	288
The occurrence of inflation	RA13	144
Business ethics are not well executed	RA14	396
Long and convoluted bureaucracy	RA15	873
Lack of supplier integrity	RA16	2208
Haven't updated the required documents	RA17	164
The supplier was unable to fulfill the agreement in the contract	RA18	1848
The supplier does not understand the content of the contract agreement	RA19	1536
There is no branch office / representative office around the power generation unit	RA20	388

After obtaining the Aggregate Risk Potential (ARP) value, the next step is to rank the risk agent based on the ARP value. The higher the ARP value obtained by the risk agent, the more important it is to mitigate the risk against the risk agent.

The results of the ARP value ranking for risk agents can be seen at Table 3.

Table 3. Aggregate Risk Potential (ARP) Value Ranking

Causes of Risk (Risk Agent)	Code	ARP Value	Ranking
Lack of supplier integrity	RA16	2208	1
The supplier was unable to fulfill the agreement in the contract	RA18	1848	2
The supplier does not understand the content of the contract agreement	RA19	1536	3
Details of the scope of service work listed in the TOR (Term of Reference) document are unclear	RA2	990	4
Long and convoluted bureaucracy	RA15	873	5
The specifications of the goods requested by the user are unclear	RA1	720	6
Non-optimal division of work schedules	RA5	588	7
Incomplete PPE in accordance with K3 regulations	RA8	567	8
Lack of resources (man power, cost) to complete the requested work	RA7	470	9
The supplier does not have inventory of goods	RA6	432	10
There is a delay in production from the manufacturer	RA3	408	11
Business ethics are not well executed	RA14	396	12
The practice of collusion and nepotism in choosing suppliers	RA10	395	13
There is no branch office / representative office around the power generation unit	RA20	388	14
Goods held up at customs	RA4	324	15
There is a scarcity of goods on the market	RA12	288	16
Suppliers no longer get support from principals	RA11	207	17
Lack of supervision and awareness related to K3	RA9	189	18
Haven't updated the required documents	RA17	164	19
The occurrence of inflation	RA13	144	20

The next step is to map ARP values using a Pareto Chart. Pareto diagrams are used to assist the process of selecting a number of risk causes that will be prioritized for risk mitigation. The Pareto diagram of risk agents can be seen in Figure 1.

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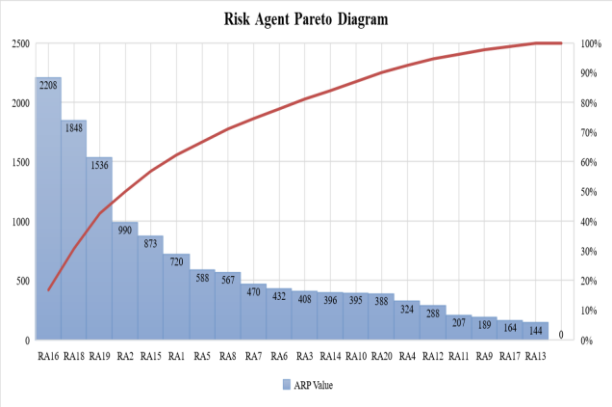

Fig 1. Risk Agent Pareto Diagram

Based on Figure 1, there are 11 risk agents that have the largest ARP values, namely RA16, RA18, RA19, RA2, RA15, RA1, RA5, RA8, RA7, RA6 and RA3. These 11 risk agents must be addressed immediately and a risk mitigation strategy design is made. The results of the identification of risk mitigation actions can be seen in Table 4.

Table 4. Risk Mitigation Action

No.	Causes of Risk (Risk Agent)	Code	Risk Mitigation Action
1.	Lack of supplier integrity	RA16	Conduct the process of signing an integrity pact (TM1)
			Implement a supplier blacklist system (TM2)
			Implement a supplier coaching system (TM3)
2.	The supplier was unable to fulfill the agreement in the contract	RA18	Implement a supplier blacklist system (TM2)
			Implement a supplier coaching system (TM3)
			Conduct a Contract Discussion Agreement (TM4)
3.	The supplier does not understand the content of the contract agreement	RA19	Conduct a Contract Discussion Agreement (TM4)
			Improve coordination between PICs related to suppliers (TM5)
4.	Details of the scope of service work listed in the TOR (Term of Reference) document are unclear	RA2	Standardization of goods / services request specification forms (TM6)
			Create historical data on the scope of similar work (TM7)
5.	Long and convoluted bureaucracy	RA15	Create integrated and accessible smart digital supply chain management applications (TM8)
6.	The specifications of the goods requested by the user are unclear	RA1	Standardization of goods / services request specification forms (TM6)
7.	Non-optimal division of work schedules	RA5	Optimize outage management meeting schedules so that information related to overhauls is not biased (TM9)
8.	Incomplete PPE in accordance with K3 regulations	RA8	Implement CSMS (Contractor Safety Management System) system (TM10)
			Implement a supplier coaching system (TM3)
9.	Lack of resources (man power, cost) to complete the requested work	RA7	Make estimates of resource needs and scope of work with a long-term contract system (TM11)
10.	The supplier does not have inventory of goods	RA6	Make an estimate of the minimum amount of demand for goods with a long-term contract system (TM12)
11.	There is a delay in production from the manufacturer	RA3	Make an estimate of the minimum amount of demand for goods with a long-term contract system (TM12)

The next step is to assess the correlation between risk mitigation actions and each risk agent, calculate the effectiveness of each risk mitigation action, calculate the value of the difficulty level to perform each risk mitigation action and calculate the difficulty ratio and rank the priority of each risk mitigation action.

The results of the calculation of the effectiveness, difficulty and difficulty effectiveness ratio of risk mitigation measures can be seen in Table 5.

Table 5. Effectiveness, Difficulty and Difficulty Effectiveness Ratio

Criteria	TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8	TM9	TM10	TM11	TM12
Total Effectiveness of Actions (TE_k)	19872	23256	28359	30456	4608	15390	8910	7857	5292	5103	4230	7560
Difficulty Level (D_k)	3	3	3	3	3	4	3	5	4	4	4	3
Difficulty Effectiveness Ratio (ETD_k)	6624	7752	9453	10152	1536	3848	2970	1571	1323	1276	1058	2520
Mitigation Action Ranking	4	3	2	1	9	5	6	8	10	11	12	7

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Ranking of risk mitigation actions based on the results of the calculation of the level of effectiveness, level of difficulty and effectiveness ratio of difficulty can be seen in Table 6.

Table 6. Risk Mitigation Action Ranking

Ranking	Code	Risk Mitigation Acton
1	TM4	Conduct a Contract Discussion Agreement
2	TM3	Implement a supplier coaching system
3	TM2	Implement a supplier blacklist system
4	TM1	Conduct the process of signing an integrity pact
5	TM6	Standardization of goods / services request specification forms
6	TM7	Create historical data on the scope of similar work
7	TM12	Make an estimate of the minimum amount of demand for goods with a long-term contract system
8	TM8	Create integrated and accessible smart digital supply chain management applications
9	TM5	Improve coordination between PICs related to suppliers
10	TM9	Optimize outage management meeting schedules so that information related to overhauls is not biased
11	TM10	Implement CSMS (Contractor Safety Management System) system
12	TM11	Make estimates of resource needs and scope of work with a long-term contract system

V. CONCLUSION

There are 12 types of risks, 18 risks (risk events) and 20 risk causes (risk agents) that have the possibility to arise in the procurement process of goods and services for steam power plant overhaul, especially in the supplier selection process.

Based on the Aggregate Risk Potential (ARP) value and pareto diagram analysis, 11 risk agents with the largest ARP value are obtained that must be addressed immediately and a risk mitigation strategy design is made.

Based on the calculation of the difficulty effectiveness ratio of each risk mitigation action, 2 risk mitigation actions with the highest difficulty effectiveness ratio were obtained, namely Conducting a Contract Discussion Agreement (TM4) and Implementing a Supplier Coaching System (TM3).

These two risk mitigation actions need to be carried out immediately to minimize the opportunity for the occurrence and impact of the causes of risk on the procurement process of goods and services for the overhaul of the steam power plant.

This study has considered the relationship between risk events and risk agents through the integration of the Analytic Network Process (ANP) and House of Risk (HOR) methods where the HOR method only considers the relationship between risk (risk event) and the cause of risk (risk agent).

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