House of Risk Approach for Assessing Supply Chain Risk Management of Material Procurement in Construction Industry

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Abstract. The purpose of this study is to identify the potential risk events in material procurement supply chain and to arrange risk agents priority using House of Risk (HOR) approach where priority can be the basis to create mitigation strategies. The approach started with HOR Phase 1 by mapping supply chain activities using Supply Chain Operation Reference (SCOR) model and risk assessment. There are 30 risk events in supply chain are adapted from several previous studies, but after the preliminary studies by deep interview with the Manager and the Purchasing Supervisor of Accounting Division obtained 23 valid risk events with 17 risk agents. Using the Aggregate Risk Potential (ARP) values and Pareto 80:20 principle, obtained 3 selected risk agents needs immediate handling with mitigation strategies. HOR Phase 2 with the mitigation strategies arrangement will be performed in the further study.

1. Introduction
The complexity of a supply chain network that involves many parties and uncertainty is a challenging Supply Chain Management (SCM) in a company. This is in line with the factors that cause the risk of supply chain activities: a very complex supply chain networks, high dependence on suppliers, organizational interactions, and short life cycle of a product [1]. There are two types of supply chain risk: risks from internal supply chain networks and risks from the external environments [2].

As well as PT Samudera Rekso Asri (SRA), a branch of the property business line of PT Samudera Indonesia, Tbk. based in Jakarta, established in 2011 and effective in 2014, has projects in several cities in Indonesia in the field of construction or civil engineering such as Container Depot construction. This time, PT SRA doesn't have structured risk management to identify and mitigate risks that may occur in the supply chain function. The upstream supply chain activities is started from material supply from selected suppliers and the downstream is project operational. The supply process can not be separated from a complex procurement risks, starts from the supplier selection process based on the comparison of the quality of material samples previously sent from some candidates for laboratory test to obtain the best quality results, price comparison and distance of suppliers to the project site.

The causes that affect the completion of construction projects are related to financial problems, changes in contracts, material procurement, lack of coordination, changes in specifications and designs, and lack of tools [3]. The influence due to the supply chain can also be derived from the flow of informations, materials, tools and human resources quality, where materials has the greatest impact, including delays in material delivery, materials limited availability in the market, poor quality of
Based on the data within the last 6 months, material deliveries were carried out using dump truck types with an average of 5% per day of the total material ordered, so the material lead time becomes long due to the limited unit by the supplier. Dump trucks usage affect the quality of the material during the unloading process, it causes a defect material of 0.6% of each delivery, so material redelivery is needed. Supplier's material delivery capacity in a day is quite limited, the supplier's production capacity unable to meet the company's demands with 42% frequencies of the planned material sent, so that the project's operational activities are late and delayed. High intensity of rainfall also affects the speed of delivery and the arrival materials accuracy with a frequency of 4 times each month. In the project's operational activities found several obstacles or risks from these impacts, such as material that is not in accordance with the specifications ordered by 0.1% and material damage during usage by 0.01%.

PT SRA has the potential to face other risks that can cause the failure of company goals, including on time projects completion, maintained quality, minimizing rework and efficiency of operational costs. The study needed to identify, analyze the risks that may occur in the PT SRA supply chain as well as to mitigate those risks. The method used is the House of Risk (HOR), which has been widely applied to assess the risks, as well as to formulate an integrated risk mitigation strategies [5]. The proposed method of House of Risk Approach for Assessing Supply Chain Risk Management of Material Procurement is very practical and useful.

2. Literature Review

2.1. Supply Chain Risk Management

Risk is a function of the uncertainty rate and impact of an event [6]. Risk is always associated with uncertainty that the probability of reality is not in line with expectations [7]. Where risk is defined as the probability of loss from an event, while uncertainty is expressed as an exogenous disturbance. The risks in supply chain divided into three categories [8] namely Internal Risk, where supplier companies have control, including process risk (disruption of a process) and control risk (errors in applying rules set by the company). Then External Risks of the company but still in the supply chain network, including demand risk (disruption of product flow and information related to downstream process) and supply risk. The last is External Supply Chain Risks, including environmental risk that affects the downstream and upstream processes.

Many studies have reported the application of risk analysis in construction supply chain [9], such as engineering project based on route analysis [10], logistics simulation modelling across construction supply chains [11], Augustine [12], Sharma [13], and Jaśkowski [14]. Several methods such as Analytic Hierarchy Process (AHP), fuzzy AHP, Logistics Simulation Modeling, FMEA, have been widely used in the risk analysis, due to their accuracy results [13], [14], [11], [4]. For example, [13] used the Analytical Hierarchy Process (AHP) and Risk Map methods for risk management in construction projects and obtained risk variables: material availability, human resource skills, delivery units availability, material quality, credit facilities, and weather conditions. Thus, [9] proposed a Supply Chain Risk Management Process (SCRMP) for assessing and managing risks, obtained ten risk categories: demand, delay, disruption, inventory, manufacturing, capacity, supply, system, sovereign and transportation. To find the level of risk determination in the supply chain, [4] proposes to mitigate supply chain risk by involving the process of identifying, assessing, planning and implementing solutions by applying Failure Mode and Effect Analysis (FMEA) and doing continuous improvement. In line with HOR method that developed by [5] which is an integrated model between the FMEA model and the House of Quality (HOQ) model.

The HOR approach aims to identify risks and design treatment strategies to reduce the probability of occurrence of risk agents by providing preventive actions to risk agents. Risk agents are a contributing factor that creates risk. This HOR model places the probability of the occurrence of risks related to the cause of the risk, and the severity is related to the risk event. Based on the ARP value, the decision is
taken to choose the risk agents with the highest priority for mitigation action. HOR consists of phase 1 and phase 2. First phase, mapping supply chain activity and risk identification. Then risk assessment using FMEA method. This phase is used to determine priority risk agents for risk mitigations. HOR Phase 2 is the mitigation strategy planning stage. The mitigation strategy was arranged based on the correlation between the mitigation strategy and risk agent. Table 1 below is a HOR Phase 1 template.

| Process | Risk Event (Ei) | Risk Agent (Ai) | Severity of Risk Event I (Si) |
|---------|-----------------|-----------------|-----------------------------|
| Plan    | E1              | R11             | Rnn                         | S1  |
|         | E2              | R12             |                             | S2  |
|         | E3              | R21             |                             | S3  |
| Source  |                 |                 |                             |     |
| Make    |                 |                 |                             |     |
| Deliver |                 |                 |                             |     |
| Return  |                 |                 |                             |     |
| Occurance of Agent j | O1           | O2              | O3              | On  |
| Aggregate Risk Potential j | ARP1       | ARP2            | ARP3            |     |
| Priority Rank of Agent j | P1           | P2              | P3              | Pn  |

Information:
A1, A2, A3...An = Risk Agent
E1, E2, E3...En = Risk Event
O1, O2, O3...On = Occurrence value of the risk agent (Ai)
S1, S2, S3...Sn = Severity value of risk event (Ei)
ARP1, ARP2, ...ARPn = Aggregate Risk Priority
P1, P2, P3...Pn = Ranking of risk agents based on ARP values

3. Research Method

3.1. Population and Sample
Population of this research is Accounting Division which handles taxation and billing as well as bills payment to vendor/supplier which included a Purchasing section that handles material procurement. Sampling method used is a nonprobability sampling with a purposive sampling technique, considering that the selected sample meet certain criteria based on the research objectives. Sampling objects are the Manager of Accounting Division and the Purchasing Supervisor of Accounting Division which both already worked in PT SRA for 6 years.

3.2. Data Collection Procedure
Primary data were collected by deep interview about supply chain activities of material procurement by using Supply Chain Operation Reference (SCOR) model with sampling objects defined in face to face with duration 30 minutes per object. And also questionnaire fulfillment for risk assessment distributed directly to the objects. Secondary data were collected from historical data of project progress report from January 2018 - December 2018.

3.3. Research Variables
Variables of this research are adapted from risk events of several previous studies such as transportation mode [9], [15], delivery units availability [11], [13], material placement area availability [12], [14],
material specification and quality [14], [12], [13], [9], etc. Obtained 30 risk events in supply chain, but based on the result of preliminary studies, 23 valid risk events can be seen in Table 2.

3.4. Data Processing

The risk events and risk agents identification were started from the supply chain activities of material procurement using SCOR model that grouped by plan, source, make, and deliver. Then it will be performed a risk assessment using FMEA approach including severity from each risk event, probability risk agents may happen (occurrence), and correlation between severity and occurrence. Thus, performed calculation of ARP values to determine risk prioritization which rank priority of risk agents that will be mitigated first based on its biggest values. Below is the formulation for ARP calculation.

\[ ARP_j = O_j \sum_i S_i R_{ij} \]  

\( O_j \) : probability risk agents j may happen  
\( S_i \) : severity if risk events i happen  
\( R_{ij} \) : correlation between risk agents j and risk events i

4. Result and Discussion

4.1. Result of Risk Assessment

FMEA approach is used for risk events and risk agents assessment. This approach assess based on severity and occurrence. Severity (of risk events) states the severity when a failure mode occurs. Occurrence (of risk agents) assess the probability of a failure mode. This assessment performed by interview with the sampling objects, historical data of project progress report and questionnaire that valued using the scale 1-10 based on their significance effect. For example, risk event the material specifications and qualifications that come are not as ordered have 9 severity scale, means that the risk event happened affect project’s activities significantly. Risk agent limited availability of transportation modes have 8 occurrence scale, means that this risk agent have high probability to happen. The details can be seen in Table 2 and Table 3 below.

The next step is correlation level assessment which purpose is to find out the correlation between risk events and risk agents. This assessment uses the data from the questionnaire, the correlation level is divided into the scale of 0 (no correlation), 1 (low correlation), 3 (medium correlation), and 9 (high correlation). If the risk event caused the appearance of a risk agent, it means there is a correlation between the two of them.

**Table 2. Risk Events**

| Process          | Sub Process                  | Risk Events                                                                 | Code | Severity |
|------------------|------------------------------|----------------------------------------------------------------------------|------|----------|
| Plan             | Delivery strategy planning   | Transportation mode selection smaller or greater than the capacity transported | E1   | 5        |
|                  |                              | The number of delivery units less than needed                               | E2   | 7        |
| Planning and area preparation | Field technical planning is not ready                                 | E3   | 8        |
|                  |                              | Area unavailability for material placement                                | E4   | 7        |
| Material ordering planning | Poor material storage methods                               | E5   | 8        |
|                  |                              | The material specifications that come are not as ordered                    | E6   | 9        |
|                  |                              | The material quality that come are not as ordered                           | E7   | 9        |
| Process | Sub Process                                      | Risk Events                                                                 | Code | Severity |
|---------|-------------------------------------------------|-----------------------------------------------------------------------------|------|----------|
| Source  | Supplier evaluation and development             | Less collaborative of partner relationships                                 | E8   | 5        |
|         |                                                 | Miscommunication due to lack of coordination                                 | E9   | 6        |
|         |                                                 | Important information hidden by the supplier                                 | E10  | 7        |
|         |                                                 | Supplier contracts are not specific                                        | E11  | 7        |
|         |                                                 | Less integrated of supply chains                                           | E12  | 4        |
|         |                                                 | Less skills of worker                                                      | E13  | 3        |
|         |                                                 | Supplier production capacity does not correspond to the amount needed       | E14  | 4        |
|         |                                                 | Supplier's machine breakdown                                               | E15  | 3        |
|         |                                                 | Defect caused by poor material handling                                     | E16  | 8        |
|         |                                                 | Suppliers can't afford raw materials due to poor company's financial performance | E17  | 3        |
|         |                                                 | Material delivery delays                                                   | E18  | 4        |
|         |                                                 | Imprecision delivery time                                                  | E19  | 6        |
|         |                                                 | Breakdown of delivery unit                                                 | E20  | 6        |
|         |                                                 | Long order processing time                                                 | E21  | 3        |
|         |                                                 | Bad weather conditions                                                     | E22  | 6        |
|         |                                                 | Natural disasters                                                          | E23  | 1        |

4.2. House of Risk

After data of risk identification and risk assessment are collected, then data processing using HOR is performed. In this HOR Phase 1, determined the rank of risk agents by ARP value obtained from severity value multiplied with occurrence and correlation value in the previous step. This value shows the level of risk agent in relation to its appearance frequency. The result of ARP values of each risk agent can be seen in Table 3.

Table 3. Risk Agents Assessment with ARP Value and Ranking

| Risk Agents                                                                 | Code (Aj) | Occurrence | ARP    | Pj  |
|-----------------------------------------------------------------------------|-----------|------------|--------|-----|
| Limited availability of transportation modes                                 | A1        | 8          | 1920   | 2   |
| Wet construction area due to bad weather                                    | A2        | 8          | 1136   | 5   |
| Unbalanced project progress with material delivery                          | A3        | 7          | 2240   | 1   |
| Unavailability of supporting tools for material handling activities         | A4        | 8          | 1080   | 7   |
| No quality control during the manufacturing process of materials            | A5        | 8          | 752    | 12  |
| Supplier receives orders from more than one company                          | A6        | 7          | 1113   | 6   |
| The supplier in fluctuant producing                                         | A7        | 6          | 1536   | 3   |
| Supplier not fulfill a promise                                              | A8        | 6          | 846    | 10  |
| Supplier is unable to meet orders                                           | A9        | 5          | 885    | 9   |
| Limited machine capacity                                                    | A10       | 5          | 570    | 15  |
| Unilateral supplier decision for material delivery                          | A11       | 7          | 917    | 8   |
The company's inaccuracy when making contracts
Accident occurs transportation
Material loading unit exceeds capacity (overload)
Imprecise inspection acceptance of materials
 Interruption along the way
Unpredictable weather

The table above shows 17 risk agents with each ARP value and ranks that obtained from the HOR Phase 1, then determined the dominant risk agents with Pareto diagram created using the cumulative percentage of each ARP value from the risk agents. The Pareto risk agents diagram can be seen in Figure 1 below.

Figure 1 above identified 7 dominant risk agents, namely unbalanced project progress with material delivery (A3), limited availability of transportation modes (A1), the supplier in fluctuating production (A7), the company's inaccuracy when making contracts (A12), wet construction area due to bad weather (A2), supplier receives orders from more than one company (A6) and unavailability of supporting tools for material handling activities (A4).

With Pareto 80:20 principle from previous research [16] that 80% of risk events can be caused by 20% of the risk agents, three risk agents priority was selected to be mitigated. They are can be seen in Table 4 below.

| Code (Aj) | Risk Agents                                | ARP  | Pj |
|-----------|--------------------------------------------|------|----|
| A3        | Unbalanced project progress with material delivery | 2240 | 1  |
| A1        | Limited availability of transportation modes | 1920 | 2  |
| A7        | The supplier in fluctuating producing      | 1536 | 3  |

The risk agents A3 with ARP value of 2240, A1 with ARP value of 1920 and A7 with ARP value of 1536 have high affect to the risk events up to 24% from total risk agents and needs immediate handling.
with mitigation strategies. The mitigation strategy planning of HOR phase 2 arranged based on the correlation between the mitigation strategies and risk agents to determine the priority of the strategies need to be done. The HOR phase 2 will be performed in the further study.

5. Conclusion
Based on the results of the assessment using HOR approach, it was concluded that supply chain of material procurement at PT. SRA were identified 23 risk events that may appear. In plan activity, there are 7 risk agents about delivery strategy and material ordering planning, also planning and area preparation. In source activity, there are 6 risk agents about supplier evaluation and development. In make activity, there are 4 risk agents about execution and production control. In delivery activity, there are 6 risk agents about delays, breakdown of delivery unit, bad weather and natural disasters.

There were identified 17 risk agents and three were selected as the risk that needs immediate handling based on Pareto 80:20 principle. Those risks were unbalanced project progress with material delivery (A3), limited availability of transportation modes (A1) and the supplier in fluctuating production (A7) with each ARP value of 2240, 1920 and 1536. The results of this study provided the priority of risk agents that the mitigation strategies will be performed in the further study.

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