Risk study on supply chain management in construction (Case study: Building projects in Indonesia)

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Abstract. The concept of supply chain in construction is very influential on the improvement of projects performance. In outlining the problems in the supply chain, it need to be identified the risks therein related to the smoothness of the supply chain process. Risk is an event / uncertainty condition, when it happens may lead to positive or negative impact [1]. The purpose of this study are to determine the identification of risks on supply chain in construction projects, analyze the risks, and analyze the response of risks. Primary data obtained through a questionnaire and interview methods. Data processing method that used in this research were Promethee method for risk analysis, and descriptive statistical methods at risk response. From this research, it is known that the identification of risks at supply chain in construction projects can be seen from the potential failure of achievement of Key Performance Indicators in Supply Chain Management (SCM). From risk analysis with Promethee method, it is known that the highest risk in SCM is the change of price from sub-contractors. Based on the analysis for risk response, it is known that the contractor has developed mitigation measures to risk response.

1. Introduction

The construction industry has become the center of attention of the government in the last period. Recorded in 2019, the Ministry of PUPR received a ceiling of Rp. 102.01 trillion for infrastructure development, including allocations for the Water Resources (SDA) sector of Rp. 38.9 trillion, Bina Marga of Rp. 39.2 trillion, Cipta Karya of Rp. 13.4 trillion, and Housing Provision of Rp. 7.8 trillion. From data of BPS, it also showed that the value of construction projects has increased from year to year. It indicates that the position of the infrastructure is already regarded as a strategic action in the development of a country.

Various aspects in the construction project is currently receiving more attention. The goal is to unravel the problems that can cause poor performance of the project. One aspect that often studied is the Supply Chain Management (SCM).

The concept of supply chain in the construction is very influential on performance improvement at projects. By the appropriate design patterns of supply chain, it is expected that each supply chain actors can make a major contribution to the efficiency and productivity of its own activities [2]. Basically supply chain is a set of supplier and customer that are connected, each customer are the supplier for further downstream organization [3].

From the research on Supply Chain Performance Analysis at Building Construction Projects, it can be concluded that the pattern of supply chain network design is influenced by: method contract that used, scope of business by owner, and procurement strategy by the contractor. Recommendations are
offered in improving supply chain performance by implementing information systems and better coordination between the parties involved in the production process, by establishment the long-term cooperation relationship between the contractor, subcontractors, and suppliers [4].

From the research on Supply Chain Structure Analysis Bridge Construction at Work, the results conducted on contractors, subcontractors and suppliers in the construction of bridges with some of the key aspects like relationships with subcontractors and suppliers such as, the type of procurement, contract type, payment systems, and the interaction between the two companies, shows the relationship between the cooperative relationship and the effectiveness of the implementation of construction work [5]. This can be used as a reference to identify risks in construction projects.

Supply chain performance affects the availability of materials, tools, and labor in construction projects, that are factors to achieve good project performance. In outlining the problems in the supply chain, it needs to be identified the risks therein that related to the process in it. Risk is an event / uncertainty condition, when it happens may lead to positive or negative impact in terms of the scope of work, cost, quality and time [1]. This identification of risks can be analyzed to determine the impact on the performance of the project, that are the cost, quality and time.

The purpose of this study is to determine the identification of risks on supply chain in construction projects, analyze risks on supply chain in construction projects, and analyze the response of risks at supply chain in construction projects.

2. Literature review

In the process of writing of this article, several literature studies were carried out on the research topics related to supply chain and risk management in construction projects.

2.1. State of the art of research about supply chain

Supply Chain is an item of network activity or cooperative procurement of goods or services that work together and intertwined with each other to create and distribute goods or services. Meanwhile, supply chain structure is the arrangement of an item or networking activity procurement of goods or services that work together and intertwined with each other to create and distribute goods or services [5].

The concept of supply chain in the construction is very influential on performance improvement projects. By the appropriate design patterns of supply chain, it is expected that each supply chain actors can make a major contribution to the efficiency and productivity of its own activities [2].

The characters of Supply Chain Management are as follows: Inventory Management Approach, Cost Efficiencies, Time Horizon, Amount of Mutual Information Sharing and Monitoring, Amount of Coordination of Multiple Levels of The Channel, Joint Planning, Compatibility of Corporate Philosophies, Breadth of Supplier Base, Channel Leadership, Sharing of Risk and Reward, Speed of Operations [6].

There are two patterns of supply chain in construction projects, particularly in building projects. The pattern is a general pattern and specific patterns [7]. The general pattern is a pattern of relationships that occur in stages in accordance with the hierarchy in a contractual relationship pattern. The specific pattern is a pattern of relationships that have different properties to the general pattern. The general pattern and specific patterns are described as Figure 1.

2.2. State of the art of research about risk management

Risk is an uncertain event, and this event will allow a positive or negative impact to the goals and objectives of the project. Risks in construction projects must be managed properly so the result of the project will be good and safe for stakeholders, and will generate profits for the interested parties in project [1]. Group process on risk management according to PMBOK are as follows: Plan Risk Management, Risk Identification, Qualitative Risk Analysis, Quantitative Risk Analysis, Risk Action Plan, Monitoring and Control Risks [8].
In construction projects, research on risk management has been widely performed. An effective risk management is to correctly identify the important risks and allocate these risks in the contract. The risk identification is performed by classifying the risks that exist [9].

![General Pattern of Supply Chain in Construction](image1)

![Specific pattern of supply chain in construction](image2)

![Specific pattern of supply chain in construction](image3)

**Figure 1.** (a) General Pattern of Supply Chain in Construction, (b) Specific pattern of supply chain in construction - a direct relationship between the owner and specialist/subcontractors, (c) Specific pattern of supply chain in construction - a direct relationship between the owner and specialist/subcontractors in the procurement of certain materials

The risk categories on highway projects from owner perception are in seven categories: Political risk, such as changes in policy, tax increases, tariff setting is not appropriate, the rate increase is not appropriate, and changes in the structure of governance; Construction Risk, such as improper design, land acquisition, project delays, conditions on the ground, and the failure of the construction; Operation and Maintenance Risk; Legal Risk and Contracts; Risk of Revenue Generation; Financial Risk; Risk of Force Majeure [10]. Categories of risk in construction projects is the external risks, the risks of economic and financial, technical and contractual risks, and risk management [11]. While the risk categories of highway projects, according to the perception of various stakeholders that are contractor, owner, consultant of planning, supervisory consultants, and the society are construction risk; political, legal, and contractual risk; and economic risk [12].

2.3. State of the art of research about promethee

Promethee is one of the models in the system of Multi Criteria Decision Making (MCDM). Promethee is able to analyze a problem that has complex criteria.

Promethee (Preference Ranking Organization Method for Enrichment Evaluation) is one method of determining the priority that using the value of dominance criterion in relation outrangking [13]. In Promethee, there are six (6) criteria: insensitive, indifference, linear, criterion, linear with indifferent and gaussian.
After deciding the specified criteria, these criteria must be given a value (weights) so that these criteria can be operationalized. Scoring for each criterion is solved by weighting. If each criterion has the value or weight, then the analysis can be implemented using Promethee. The most ideal alternative can be seen in accordance with the ranking from this analysis [14].

3. Research methods
This research object is Supply Chain Management in construction, particularly in building projects. In this case, researchers analyzed risks in the Supply Chain Management, then be analyzed using Promethee methods. Stages in this study can be described as Figure 2:

![Flowchart of research](image)

In the first stage (risk identification), researchers conducted an analysis of the implementation of Key Performance Index in the SCM on the terms of a previous study. Risks were identified if the Key Performance Index in SCM not achieved, which is obtained through the interview method. The Key Performance Index in SCM at construction were a perfect order fulfillment, order fulfillment cycle time, upside supply chain flexibility, upside supply chain adaptability, downside supply chain adaptability, overall value at risk, supply chain management cost, cost of goods sold, cash to cash cycle time, supply chain return on fixed assets, return on working capital, the utilization of information technology, and the behaviour of suppliers [15].

In the second phase (risk analysis), risks was measured by the method Promethee to get the risks ranking. This method was chosen to review the ranking of risk that is influenced by the factors of cost, quality, and project time. The data for probability and impact of risks that was to assess the risk ranking, obtained through interviews and questionnaires. In this questionnaire also included a response strategy for each risk.

Respondents in this study were the contractor on the building project. The respondents were the decision maker on the project. Data retrieval to respondents was conducted through questionnaires and interviews.

4. Data processing and discussion
Based on interviews and questionnaires in the first phase, the identification of risks based on the Key Performance Index on SCM are as Table 1:
Table 1. Identification of risk at SCM in construction

| No. | KPI                                    | Identification of Risk                                                                                     | Exist or not? |
|-----|----------------------------------------|-----------------------------------------------------------------------------------------------------------|---------------|
|     | Technical Risk (Supply Chain with Subcontractors) |                                                                                                           |               |
| 1   | Perfect order fulfillment               | Works of sub-contractor was not implemented in full (sub-contractor does not finish the job)              | √             |
| 2   | Perfect order fulfillment               | Works of sub contractors defective or not in accordance with specifications                                 | √             |
| 3   | Order fulfillment cycle time            | Works of sub-contractor does not start on time in accordance to SPK or letter of agreement between the contractor and sub-contractor | √             |
| 4   | Upside supply chain flexibility        | Sub-contractors are not flexible to the number of days required to meet the design changes.                | √             |
| 5   | Upside supply chain adaptability       | Sub-contractors are not adaptive to additional work                                                       | √             |
| 6   | Downside supply chain adaptability     | Sub-contractors are not adaptable to job reductions                                                        | √             |
| 7   | Overall value at risk                  | Imprecision in the selection of sub-contractors                                                             | √             |
| 8   | Return on working capital              | Inadequacy of existing workers in sub contractors                                                           | √             |
| 9   | Utilization of Information Technology  | The lack of use of technology by sub contractors                                                            | √             |
|     | Economic and Financial Risks (Supply Chain with Subcontractors) |                                                                                                           |               |
| 10  | Cost of goods sold                     | There were changes in Price from sub-contractors that are different with the previous offer price          | √             |
| 11  | Supply chain management cost           | Payment of the owner has been synchronized with the needs on the project                                    | √             |
|     | Technical Risk (Supply Chain with the Supplier) |                                                                                                           |               |
| 12  | Perfect order fulfillment               | The material sent is not full                                                                               | √             |
| 13  | Perfect order fulfillment               | The material sent is not in accordance with specifications                                                  | √             |
| 14  | Order fulfillment cycle time            | Late delivery of materials                                                                                   | √             |
| 15  | Upside supply chain flexibility        | Supplier inflexible with the number of days that needed to meet the changing demand                          | √             |
| 16  | Upside supply chain adaptability       | Supplier is not adaptive to additional work                                                                  | √             |
| 17  | Downside supply chain adaptability     | Supplier is not adaptive to the reduction of jobs                                                            | √             |
| 18  | Overall value at risk                  | Inaccuracy in supplier selection                                                                             | √             |
| 19  | Return on working capital              | Incompence supplier                                                                                         | √             |
| 20  | Utilization of Information Technology  | The lack of use of technology by suppliers                                                                  | √             |
|     | Economic and Financial Risks (Supply Chain with the Supplier) |                                                                                                           |               |
| 21  | Cost of goods sold                     | There were changes in the price of materials from suppliers                                                | √             |

Risk identification in the supply chain in construction projects derived from the possibility of wasn't achieved the KPI in SCM, where the KPI on construction projects there are 13 kinds [15]. Risk identification in the supply chain is obtained through interviews with the respondents' (contractor). From
interviews, it is obtained the identification of risks in the supply chain in construction. There are 21 risk, where the eight among these risks are not occur in the project, according to some respondents.

Furthermore, from the risks that were identified, there were the value of probability and risk impact. The impact of risk grouped into three, there are the impact on cost, quality, and time.

| No | Risk                                                                 | Value of Risk | Risk Response |
|----|----------------------------------------------------------------------|---------------|---------------|
|    |                                                                      | Cost | Quality | Time |
| R1 | Works of sub-contractor was not implemented in full (sub-contractor does not finish the job) | 15,75 | 12,25 | 10,50 | Mitigation |
| R2 | Works of sub contractors defective or not in accordance with specifications | 6,00  | 12,00 | 9,00  | Mitigation |
| R3 | Works of sub-contractor does not start on time in accordance to SPK or letter of agreement between the contractor and sub-contractor | 10,50 | 14,00 | 7,00  | Mitigation |
| R4 | Sub-contractors are not flexible to the number of days required to meet the design changes. | 12,00 | 16,00 | 8,00  | Mitigation |
| R5 | Imprecision in the selection of sub-contractors | 10,00 | 14,00 | 8,00  | Mitigation |
| R6 | The lack of use of technology by sub contractors | 10,50 | 7,50  | 7,50  | Mitigation |
| R7 | There were changes in price from sub-contractors that are different with the previous offer Price | 20,25 | 11,25 | 15,75 | Mitigation |
| R8 | Payment of the owner has been synchronized with the needs on the project | 25,00 | 22,50 | 15,00 | Mitigation |
| R9 | The material sent is not full | 25,00 | 22,50 | 17,50 | Mitigation |
| R10| The material sent is not in accordance with specifications | 12,00 | 10,50 | 10,50 | Mitigation |
| R11| Late delivery of materials | 16,00 | 16,00 | 12,00 | Mitigation |
| R12| The lack of use of technology by suppliers | 15,75 | 8,75  | 8,75  | Mitigation |
| R13| There were changes in the price of materials from suppliers | 20,25 | 20,25 | 4,50  | Mitigation |
|    | Average                                                               | 15,31 | 14,42 | 10,31 |

From the value of the probability and impact of these risks, then it was searched the risk value from the multiplication of these two variables. Risk values are obtained by processing the data using Promethee methods. The results of data processing with Promethee method are presented in Table 2.

Table 2 shows the value of risk that are divided into the impact categories to the cost, quality and time. The high-impact risk in project cost is risks R8 and R9; high-impact risk in project quality is risks R8 and R9; while the high-impact risk in project duration is the risk R9.

Of all the risks that have been identified, these risks 38% impacted to the project cost. Then, 36% risks impacted to quality of the project, and 26% risks impacted to duration of the project.
From the above results, then the risks were processed using Promethee methods to determine risk values and the ranking of risk in the supply chain at construction. The results of processing using Promethee methode are as follows (Table 3).

**Table 3. Risk ranking of SCM in construction**

| Rank | Code | Risk                                                                 | Score |
|------|------|----------------------------------------------------------------------|-------|
| 1    | R7   | There were changes in Price from sub-contractors that are different with the previous offer Price | 7,667 |
| 2    | R9   | The material sent is not full                                       | 6,667 |
| 3    | R12  | The lack of use of technology by suppliers                          | 3,000 |
| 4    | R8   | Payment of the owner has been synchronized with the needs on the project | 3,000 |
| 5    | R1   | Works of sub-contractor was not implemented in full (sub-contractor does not finish the job) | 2,000 |
| 6    | R10  | The material sent is not in accordance with specifications           | 1,667 |
| 7    | R11  | Late delivery of materials                                           | 1,667 |
| 8    | R2   | Works of sub contractors defective or not in accordance with specifications | -2,667 |
| 9    | R6   | The lack of use of technology by sub contractors                     | -4,000|
| 10   | R5   | Imprecision in the selection of sub-contractors                      | -4,333|
| 11   | R13  | There were changes in the price of materials from suppliers          | -4,333|
| 12   | R4   | Sub-contractors are not flexible to the number of days required to meet the design changes. | -4,333|
| 13   | R3   | Works of sub-contractor does not start on time in accordance to SPK or letter of agreement between the contractor and sub-contractor | -6,000|

From the data processing using Promethee method, it is known that the risk in the first rank in the supply chain activity is risk R7, and risk at the lowest ranking is the risk R3.

The advantages of using Promethee method to processing data is that it can be learned the ranking of risks according to three variables impact of risk, that are cost, quality, and time. Whereas from the other methods of risk analysis, it only can be known the impact of risk in general.

**5. Conclusions and recommendations**

The conclusion that can be drawn from this research is the identification of risks in the supply chain is derived from the possibility of weren't achieved the KPI in the supply chain. The identification of risks in the supply chain on a building project there are 13 kinds.
The highest risk that is impacted to the project cost is the payment of the owner that is difficult to synchronized with the needs on the project, and the risk of shipping materials that are not full or not appropriate. The highest risk that is impacted to the project quality is the payment from the owner that is difficult to synchronized with the needs on the project, and the risk of shipping materials that are not full or is not appropriate. While the highest risk that is impacted to the duration of the project is the delivery of materials that are not full. Based on the risk analysis using Promethee method, it is known that the highest risk in the supply chain at building projects is the risk of the price changes from sub-contractors that are different from the previous offer price.

Based on the analysis of the risk response of supply chain at building projects, it is known that there are risk mitigation on each risks and the measures to against the possible risks.

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