Jurnal Inovasi Teknologi dan Rekayasa
Vol. 9, No. 2, July-December 2024, pp. 551-557
ISSN: 2581-1274

Analysis of Material Supply Chain Risk Weight Using Severity Index Method

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ARTICLE INFO

Article history:
Published

Keywords:
Supply chain material in construction
risk analysis material
material construction delays
severity index
planning materials

ABSTRACT

Material delay is a vital problem in the completion of construction work, this is closely related to the understanding of the flow of material supply. So it takes risk weight analysis from the internal side (supply, control, process, demand) and external (disaster factor). This study began with a literature study to obtain a list of risks, then data collection using a questionnaire method to 50 respondents who are experts in construction material procurement. Furthermore, a risk analysis was carried out using the severity index method. From this analysis, the average risk from the supply side was 16.40%, the control risk was 16.29%, the process risk was 11%, the demand risk was 16.11% and the disaster risk was 13.79%. There are two most dominant delay risks, namely material delays due to constraints in the factory process to material limitations at the supplier and late payments from the main contractor to the subcontractor so that material orders are late. To mitigate this risk there needs to be careful planning and preparation regarding material suppliers and a contract agreement that must be made with the supplier to ensure the availability of materials in the field and needs commitment to timely payment to subcontractors and on-site material calculations.

I. Introduction

The construction sector needs to be active in encouraging more effective, efficient, and productive development to increase the added value of construction products. Delays in projects are a classic problem that often arises and can be detrimental to many parties. This delay makes the owner or end user unable to immediately utilize the facilities that have been built. On the other hand, the contractor must pay a fine for the delay, which is an unnecessary additional cost and can damage the company's reputation. Project delays can be caused by the contractor, project owner, or other external factors.

Kaliba [1] identified that factors such as late payments, financial problems on the part of contractors and clients, contract changes, economic issues, material procurement, design changes, staffing problems, equipment availability, poor supervision, construction errors, ineffective coordination on site, specification changes, and labor disputes and strikes are the main causes of delays in road construction projects. On the other hand, factors that cause project delays in the construction industry include [2]: incompetence of contractor management, challenges faced by subcontractors, deficiencies in design quality, contract-related issues, and disruptions in the supply chain affecting the availability of labor and construction material. An integrated supply chain system manages the flow of goods, money, and information from point of origin to destination, focusing on procurement, production, and distribution so that products are delivered on time. In the construction context, the supply chain transforms raw materials into finished products, such as roads or buildings, and involves collaboration between general contractors, subcontractors, planners, and suppliers [3].

Supply chain management in construction projects is challenged by the temporary nature of the organization, short-term relationships, and the difficulty of managing complex networks. Therefore,

DOI: 10.31572/inotera.Vol9.Iss2.2024.ID423 W : http://inotera.poltas.ac.id | E : inotera@poltas.ac.id

material management is crucial; shortages can stop work and cause losses. An understanding of the techniques for procurement, storage, distribution, and risk analysis of material delays is essential, as failure to manage risk can result in higher construction costs than budgeted.[4], [5].

Based on the background that has been explained above, the purpose of this study is analysing the risk (supply, control, process, demand) and external (disaster factor) sides using Severity Index simulation, determine the most dominant risk category for material delays in Medan City and explain the risk mitigation strategy to reduce dominant risks.

II. Method

A. Risk identification

Risk identification is a process to find, describe, and record risks that hinder a target as a basis for carrying out further analysis to determine the level of threats and opportunities [6]. According to Ghasemi, risk identification is a series of actions with the main objective of detecting the uncertainty of an event that if it occurs has a positive or negative effect on the target set [7]. Risk identification does not only make a list of risks but also needs to review related factors to get a complete picture of the risk. The requirement in the risk identification process is based on good quality information.

The first step in the risk identification process is to collect historical information related to risks from previous work. If historical information or data is not available, information can be used from other companies that have the same work which is then refined through discussions with related parties regarding historical[8], current and ever-evolving information, such as: Information from structured interviews, Local and international experience, Information from experts, Company Long-Term Plan, Company Work Plan and Budget, Risk management reports, Auditor and other examiner reports, Self-assessment results, Historical data, Incident database, failure analysis. To help identify risks, several methods can be used, namely compiling a risk list, interviews with experts, through brainstorming (exchange of ideas/discussions) with competent parties, and by collecting data sources in the form of recording minutes or minutes of a project [9], [10]

Risk identification includes risks in supply, process, control, demand, and disaster factors. Supply risks arise from various sources such as suppliers, manufacturers, and distributors, and are important to ensure the availability of goods or raw materials on time and in sufficient quantities. Control risks relate to operational management, including inventory management, production scheduling, and efficient flow of goods. This includes the use of technology and management processes to ensure the smoothness and coordination of each stage in the supply chain. Process risks relate to the steps taken to transform raw materials into finished products or provide services to customers. This process includes production, packaging, distribution, and shipping, where efficiency and coordination are essential to optimize supply chain performance. Demand risks relate to the number of products or services desired by the company as a customer. Demand management is important to predict and anticipate market needs so that the supply chain can respond appropriately and efficiently.

B. Risk Analysis with Likert Scale

After obtaining a list of risks in the data collection process, the next stage is to process and analyze the data using the severity index method using Likert scales. To determine the scale of possibility/probability this research refers to the *Table 1* below:

Table 1. Probability criteria [6]

Scale	Frequency	Description
1	Material delay (0.5 days or 4 hours)	Almost impossible
2	1-2 times in one period	Less likely to happen
3	3-4 times in one period	Equal chance of happening and not happening
4	4-5 times in one period	Most likely to happen
5	>5 times in one period	Almost certain to happen

The scale of impact based on the table below:

Table 2. Impact criteria

Scale	Frequency	Description of delay
1	Not Significant	0.5 days / 4 hours
2	Small	1 day
3	Medium	2 days
4	Large	4 days
5	Catastrophe	>6 days

After the data are collected, data analysis will be carried out using Skala liker simulation to obtain risk weight. Calculating the magnitude of the Risk value, the risk factor equation is as follows:

$$Risk(R) = Probability\ Value(P)_{(e)}\ x\ Impact\ Value(I)_{(e)} \quad (1)$$

The next step is to create a risk categorization. Risk categories are grouped based on color codes from very low, low, medium, high and very high levels. Each risk category grouping depends on the risk treatment to be given. The form of this risk level can be illustrated in the table below:

Table 3. Risk Matrix

Probability	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
				Impact		

Table 4. Risk category

Scale	Level	Priority	Response
1-3	Very Low	5	Acceptance
4-6	Low	4	Mitigate
8-10	Medium	3	Transfer
12-16	High	2	Allocation
20-25	Very High	1	Avoidance

Each risk category is obtained from very low to very high risk which will then be treated based on the level of risk. Based on Susilo and Kaho, risk tolerance based on risk level is explained as follows: Very low risk level, risk that can be accepted without special treatment, but only needs to be monitored by the risk owner. Maintain existing controls and monitor whether the risk increases to be given special treatment. Low risk level, risk is unacceptable but tolerable, control treatment (preventive) is given if the benefits outweigh the costs. Medium risk level, risk is unacceptable and requires preventive control treatment. High risk level, risk is unacceptable and requires preventive and responsive control. Very high-risk level, risk is unacceptable and requires responsive control

C. Risk Analysis with Severity Index

Risk analysis is used to determine the level of probability and impact of risk on cost, quality, and time. The processing of this risk analysis data first uses the severity index which will then be categorized based on impact and probability. Calculations using the Severity index are calculated based on the following equation;

$$SI = \frac{\sum_{i=0}^{4} ai\ xi}{4\sum_{i=0}^{4}\ xi}\ x\ (100\%) \quad (2)$$

Where :
ai = constant assessor
xi = frequency of respondents

I = 0,1,2,3,4,... n
x0, x1, x2,x3, x4 = frequency value of respondents
a0 = 0 , a1 = 1, a2 = 3, a4 = 4
x0 = frequency of "very small/low" then a0 = 0
x1 = frequency of "small/low" then a1 = 1
x2 = frequency of "medium" then a1 = 2
x3 = frequency of "large" then a1 = 3
x4 = frequency of "very large" then a1 = 4

The criteria for determining the scale of possibility and impact are determined by the researcher himself based on discussions and agreements with the respondents, where the agreement states that the level of possibility of risk and impact due to very large risks is 100%, this is considered based on time, quality, and cost. After obtaining the results of the risk category based on the scale above, the probability and impact categories are converted into numbers as follows: very small is worth 1, small is worth 2, medium is worth 3, large is worth 4, and very large risk is worth 5.

Table 5. Severity index value categories for probability frequency and impact

No	Category	SI	Value
1	Very small/low	0% < SI < 20%	1
2	Small/low	20% < SI < 40%	2
3	Medium	40% < SI < 60%	3
4	Large	60% < SI < 80%	4
5	Very large	80% < SI < 100%	5

III. Results and Discussion

Risk identification is the first thing to do to get a list of risks that will then be used as something that needs to be reviewed. Risk identification is obtained from various sources including interviews and literature studies. The results of the risk identification that affect the supply chain can be seen in the following table:

Table 6. Material supply chain risk weight analysis

Risk code	Occurrence / Risk	Impact	Impact category	Probability	Prob. category	Risk Weight	Mean
S1	Materials are sent repeatedly because the material is damaged / does not meet the quality of the specified specifications	50,00%	3	30,77%	2	15,38%	16,40%
S2	Material delays due to obstacles in the factory process to material limitations at the supplier	82,69%	5	62,50%	4	51,68%	
S3	Cancellation of shipments due to transportation problems / lack of transportation equipment	36,54%	2	25,00%	2	9,13%	
S4	For each material, only focus on 1 supplier	86,54%	5	30,77%	2	26,63%	
S5	Long waiting time because material delivery is carried out in stages	67,31%	4	40,38%	3	27,18%	
C1	Inefficient inventory management system so that materials are reduced or piled up in the warehouse	30,77%	2	34,62%	2	10,65%	16,29%
C2	Changes in material needs due to changes in the material usage schedule and project implementation schedule from the contractor	34,62%	2	44,87%	3	15,53%	
C3	Lack of material storage capacity by the contractor resulting in re-supply	30,77%	2	28,85%	2	8,88%	

C4	Late payment from the main contractor to the subcontractor resulting in late material orders	84,62%	5	84,62%	5	71,60%	
C5	Delayed orders due to lack of information related to the work to be carried out	40,38%	3	46,15%	3	18,64%	
P1	Delay in material arrival due to traffic problems	26,92%	2	42,31%	3	11,39%	11,00%
P2	Inability to fulfill orders	38,46%	2	33,33%	2	12,82%	
P3	Lack of detailed information about the quantity of materials ordered, requiring reordering of materials	30,77%	2	30,77%	2	9,47%	
P4	Damage and loss of materials in the storage warehouse	34,62%	2	33,33%	2	11,54%	
P5	Delay in material delivery due to inadequate storage warehouse	34,62%	2	28,21%	2	9,76%	
D1	Difficulty in finding materials	38,46%	2	38,46%	2	14,79%	16,11%
D2	Changes in material orders due to sudden changes in specifications or designs from the owner	44,23%	3	37,18%	2	16,44%	
D3	Additional materials due to changes in room function	61,54%	4	46,15%	3	28,40%	
D4	Delays in material delivery due to financial problems that are not running smoothly	40,38%	3	44,87%	3	18,12%	
E1	Bad Weather during delivery	46,15%	3	41,03%	3	18,93%	13,79%
E2	Country conditions (inflation, politics, culture)	36,54%	2	26,92%	2	9,84%	
E3	Geographical characteristics of the location	36,54%	2	33,33%	2	12,18%	

Based on Table 6, the category of risk can describe below:

Table 7. Risk Category

Scale	Category	Code of Risk
1-3	Very Low	-
4-6	Low	S1. S3, C1,C2, C3, P1,P2, P3, P4, P5,D1, D2, E2, E3, E4
8-10	Medium	S4, C5, D4, E1
12-16	High	S5, D3
20-25	Very High	S2, C4

The very high risks element consists of two sub-risks consisting of S2 and C4. Based on the table above, the values of S2 and C4 are 51.68% and 71.60%. The main priority that must be considered is the risk of late payment of the main contractor to the subcontractor so that the ordering of materials is late with a weight of 0.716 or 71.60%. which means that the C4 risk has an effect of 71.60% on the control risk. The C4 risk category based on table 4-28 is categorized as a very high risk, which has a high impact and level of possibility of occurrence. The other very high risks level is S2, Material delays due to obstacles in the factory process to material limitations at the supplier, with weight 51,68% that means S2 risk has an effect of 51.68% on the supply risk. Risk C4 and S2 should be considered to be mitigate prioritize risk, the recommendation from respondent to mitigate the risk Accuracy and commitment to timely payment to subcontractors and on-site material calculations and the contractors have sufficient project funds.

The second prioritize risk is the high categorizes in scale 12 – 16 that are S5 and D3. Long waiting time because material delivery is carried out in stages (S5) has weight 27,18% or 0,2718 that means S5 risk has an effect of 27,18% on the supply risk. To mitigate this risk there needs to be careful planning and preparation regarding material suppliers and a contract agreement must be made with the supplier to ensure the availability of materials in the field and ensure the volume and specifications of material requirements and look for several suppliers so that alternatives can be found if there are problems with one of the suppliers. The second risk in the high-risk category is D3, additional materials due to changes in room function with weight 28,40% that means D3 risk has an effect of 28,14% on the demand risk. To mitigate this risk there needs to be careful planning and preparation regarding suppliers and contractors in design changes so that materials can be adjusted to the contractual agreement with suppliers so that the availability of materials in the field is guaranteed.

The third prioritize risk is the medium risk with scale 8 -1 10, that is S4, C5, D4, E1, from the Table 6 the range weight 18,12% until 26,63 % that means S4, C5, D4, E1 have effects of 18,12% until 26,63 % on each sub risks. To mitigate the risk, the company should take note for some recommendation such as the company do not rely on 1 supplier, material orders must be controlled before use (S4), Create a measurable material supply plan that is tailored to field needs (C5). Have a material time schedule that can be used as a reference by suppliers in supplying materials (C5), commitment to timely payment (D4), Take advantage of the summer season before the rainy season arrives (E1).

The low risk is the category risk with scale 4 -6, that is S1. S3, C1, C2, C3, P1, P2, P3, P4, P5,D1, D2, E2, E3, E4 with weights risk from 9,13% until 16,44% that means these risks have effects of 9,13% until 16,44% on each sub risks.

IV. Conclusion

The risk weight analyzed using the severity index method shows that the average risk from the supply side is 16.40%, the control risk is 16.29%, the process risk is 11%, the demand risk is 16.11% and the disaster risk is 13.79%. The very high risks element consists of two sub-risks consisting of S2 and C4. Based on the table above, the values of S2 and C4 are 51.68% and 71.60%. The main priority that must be considered is the risk of late payment of the main contractor to the subcontractor and obstacles in the factory process to material limitations at the supplier. The very low risk in this study is nothing so the contractors should focus on the low risk until very high risk

Acknowledgment

The authors would like to thank the financial support provided by DIPA Medan State Polytechnic in 2024 in accordance with the research contract Number: B/159/PL5/PT.01.05/2024.

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