International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 7, Issue 11, pp 567-575, November-2023

https://doi.org/10.47001/IRJIET/2023.711074

Supply Chain Risk Management in Precast Concrete Industry

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***Abstract* - Supply chain risk management is very important to implement, because companies often do not realize that risks arise and become problems for the company. This research aims to conduct a supply chain risk analysis for precast concrete companies. The data collection techniques used was observation, interviews, questionnaires, literature studies and documentation studies. The analysis method uses Failure mode and effect analysis (FMEA). The research results showed that there were 14 risks with details of 2 very high risk, 3 high risk and 2 low risks. After controlling with the right strategy, the 7 priority risks that can be controlled become low category risks. Risk of storage delays due to high production of new products, risk of high customer demand and production spikes, risk of unexpected material prices, risk of product fraud to customers, risk of late delivery to the project site, risk of fire at production sites and shipping facilities and risk of machine damage production and damage to transportation equipment is a priority risk that must be controlled so that it becomes a risk that does not endanger the company's reputation. The results of this research provide input to companies to always implement risk management in their companies so that they can achieve the set goals.**

Keywords: Risk management, Supply chain, Industry, Precast concrete, FMEA method.

I. INTRODUCTION

Precast construction projects are associated with many activities, many parties, enormous efforts, and diverse processes. For effective communication, this requires conveying appropriate and up-to-date information to enhance collaboration and increase integration, [1]. The precast construction industry is often characterized by complexity, a non-integrated environment, and fragmentation. For 150 years, the on-site precast construction industry has been one of the core elements of the construction supply chain consisting of the efficient management of various activities that contribute to the flow of services, products and materials, [2] between suppliers, clients, manufacturers, architects/engineers, general contractors, consultants, subcontractors, and developers. As one component of the construction supply chain, the precast concrete industry contributes to improving the supply chain and there is a high demand for skilled and semi-skilled labour required, [3]. Therefore, systems that support efficient labor allocation will support overall construction supply chain improvements.

In general, a supply chain consists of similar agents. However, the risks for two similar chains may vary depending on various factors such as the activities in which they are located, the agents participating in them, the place where they are developed or the number of customers they encounter. It is therefore difficult to assume that a particular risk in one supply chain has the same importance and value as the same risk in another supply chain. The greatest disadvantage of these risks is based on their great diversity, their many origins and their varied consequences. and complex relationships with others. Risk identification involves naming the risk without explaining or measuring it. Logically, people who work in a part of the supply chain have a greater facility to identify risks in that part. That is why the definition and functional separation of the parts of the supply chain is critical to successful risk identification. Knowledge is an important resource in the supply chain and an important determinant of supply chain competitiveness, [4]. This is developed both at the organizational level and at the individual level. While some authors focus on knowledge as an attribute, others point to the individual as the site of knowledge creation. When using an individual-level knowledge-based vision perspective, a company's ability to manage supply chain risks will depend on the risk mitigation competencies of its supply chain managers. Therefore, it has become imperative to strive to better understand the factors that influence managers' risk mitigation competence. Supply chain risks may also include, for example, supplier risks (delays in receipt of raw materials or poor quality of materials). Within an organization, internal risk factors, such as those related to forecast errors, failures, capacity issues, and inventory problems, should also not be ignored. Another example is operational risks related to the organization's internal activities, [5].

ISSN (online): 2581-3048
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https://doi.org/10.47001/IRJIET/2023.711074

A study shows that prefabricated building projects (PBP) have made a significant contribution to addressing Hong Kong's serious housing shortage and house nearly half of the population in this densely populated city. The PBP supply chain involves a large number of stakeholders, including clients, designers, prime contractors, carriers, and assembly subcontractors, all of whom need to interact with each other through frequent exchanges of information. However, cross-border supply chains are quite complex, giving rise to risks that have a significant impact on PBP's performance. Supply chain risk (SCR) is closely related to the stakeholders involved and has high interdependence with each other. This paper adopts social network analysis (SNA) to develop a PBP supply chain risk network in Hong Kong to prioritize stakeholder-related SCRs. Research findings show that poor resource and schedule planning, poor workflow control, and poor information exchange between stakeholders are the main challenges for PBP supply chains. This is the first study to consider the dynamic interdependence of risks and related stakeholders in SCR. By providing a better understanding of the risks that exist across the PBP supply chain in Hong Kong, this research can help practitioners address these risks more effectively and efficiently, [6]. Identifying and analyzing the risks of supply chain disruption is critical to preventing disaster scenarios, [7]. Recent studies analyze the impact of supply risk on firms' optimal purchasing decisions, [8] and the importance of correctly identifying sources of supply risk, [9].

The implementation of risk management must be an inseparable part of the company's management system. The risk management process is one of the steps that can be taken to create continuous improvement. The risk management process is also often associated with the decision-making process in a company. This process can be applied to any activity, position, project, product or asset. Integrated risk management is a process where various risks are identified, measured and controlled throughout an organization or company, [10]. One of the precast concrete companies in East Nusa Tenggara Province is PT. Sinar Bangun Mandiri-Tugu Beton Semesta Abadi Precast Kupang. This company produces precast concrete such as: Udith, Kanstein, Paving, Buis and others. This precast concrete production was established with the aim of providing material for infrastructure development, especially in the Kupang area and its surroundings. One of the product distributions is the second phase of the Napan Village Cross Border Post (PLBN) Infrastructure Improvement Development Project, construction of which will begin in May-December 2023. The Napan PLBN project requires a number of precast concrete including 450 units of Udith, 2570 kansteins whose needs are distributed by PT. Sinar Bangun Mandiri-Tugu Semesta Abadi Precast Kupang. So the production supply chain system up to the project location is very interesting to study for risks in this research.

Based on the background description above and previous research and considering the many possible risks that occur in companies, especially in the precast concrete supply chain sector, researchers are currently interested in conducting research on risk analysis in the precast concrete supply chain. The difference between current research and previous research lies in the focus of supply chain risk analysis carried out in companies. To identify risks that may occur, find out what risks are important categories to control, and analyze efforts to overcome risks that can occur in the precast concrete supply chain. Risk analysis in this research uses the methodRisk Failure Mode and Effect Analysis (FMEA) so that the level of possibility of risk occurring (Occurrence), the magnitude of the risk impact (Saverity) and the level of detection (Detection) can be known.

II. RESEARCH METHODS

2.1 Data sources

Based on the source, the data used in this research are:

1) Primary data in this research are the results of observations, interviews and questionnaires distributed regarding supply chain risks in the precast concrete industry.
2) Secondary data in this research was obtained from literature reviews, literature and previous research related to supply chain risk analysis in the precast concrete industry.

2.2 Research sites

This research was conducted at a precast concrete industrial company located at PT. Sinar Bangun Mandiri-Tugu Beton Semesta Abadi Precast Kupang.Jl. Prof. Dr. Herman Johanes, Lasiana, Kec. Kelapa Lima, Kupang City, East Nusa Tenggara 85228.

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Figure 1: Research Location

2.3 Population and Sample

The population in this study was all workers in the precast concrete industry at PT. Sinar Bangun Mandiri-Tugu Beton Semesta Abadi Precast Kupang numbers 31 people, consisting of 5 foremen and 26 workers. The sample in the study was the same as the population, namely 31 people. This is in accordance with the opinion that in determining the number of samples used, the recommended sample size for research is as follows: the appropriate sample size in research is between 30 to 500, if the sample is divided into categories then the number of sample members for each category minimum 30.

2.4 Data collection techniques

The data collection technique in this research uses a questionnaire. In this study, a modified Likert scale method was used, namely that the respondent's answers would be scored on a 5-point scale for the highest score and a 1-point scale for the lowest score. The questionnaire in this study was used to determine the risk assessment in the precast concrete industry supply chain carried out by respondents in this study. The questionnaire in this research contains identification of any supply chain risks that occur at the research location. Next, a risk identification group was carried out based on the results of a questionnaire that had been filled in using a 1-5 Likert scale to determine the probability value and risk impact.

2.5 Data analysis techniques

The data in this research was collected through a questionnaire. The questionnaire contains identification of any supply chain risks that occur at the research location. Next, a risk identification group was carried out based on the results of a questionnaire that had been filled in using a 1-5 Likert scale to determine the probability value and risk impact. Then proceed with the risk analysis stage using the Risk Failure Mode and Effect Analysis (FMEA) method, namely calculating risks on a scale of probability and risk impact to obtain a risk index value. The next stage of risk analysis is to carry out risk mapping, by placing risk values at the risk mapping and management level. In risk mapping, risk levels are classified into four, namely minor, moderate, major and critical. The supply chain stages of the make to order system at the research location are divided into five activities, namely planning, raw material procurement (source), production, product delivery and return. At each stage of the supply chain, the number of risks that arise or may arise is known and then a risk analysis is carried out using the FMEA method. After carrying out risk analysis using the FMEA method, the risk level for each type and stage of risk is known, namely minor, moderate, major and critical levels. Next, a risk management analysis is carried out with the following strategy:

1) Accept risk, is a risk strategy at a small level by accepting the risks that occur and maintaining the risks as they are
2) Mitigate risk, is a risk strategy at a moderate level by reducing the impact and frequency of risk occurrence that has the potential to harm the risk owner.
3) Share risk, is a risk strategy at a large level by sharing risks among the parties involved in a mutually agreed Cooperation agreement.
4) Avoiding risk is a risk strategy at a critical level by accepting risk with extraordinary actions to minimize risk.

The assessment stages using FMEA are as follows:

1) Identify systems and system elements and their failures and impacts.
2) Determining the severity of the impact of a failure (severity).
3) Determine the frequency of risk occurrence.
4) Determine the level of detection that has been carried out to prevent risk (Detection).
5) Calculate the Risk Priority Number (RPN) which states the risk level of a failure. The RPN number ranges from 1 – 1000, the higher the RPN number, the higher the risk of potential failure of the system, design, process or service. RPN = Severity x Occurrence x Detection.
6) Provide recommendations for actions that can be implemented to reduce the level of risk of failure.

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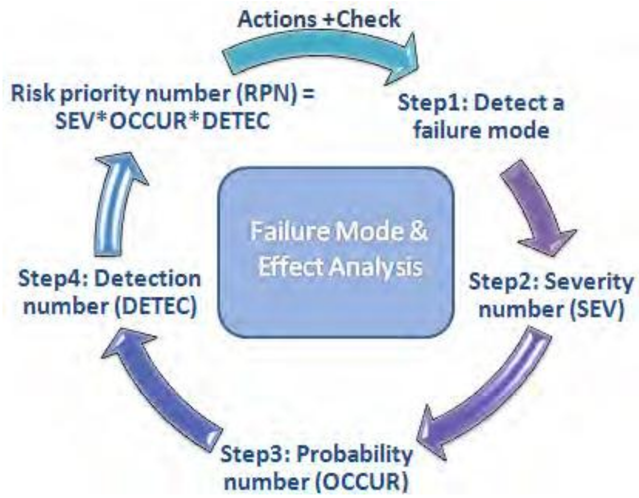

Figure 2: FMEA Method Chart

Failure Mode Effect Analysis (FMEA) is a method that can be used to measure risk. In this research, measurements are carried out by identifying risks, assessing risks and controlling risks work risks at PT. Sinar Bangun Mandiri-Tugu Beton Semesta Abadi Precast Kupang in the risk assessment process using FMEA, the assessment components are divided into 3 components, namely Frequency Level (Event) in Table 1, Risk Impact (Severity) in Table 2, and Risk Detection (Detection) in Table 3.

Next, it will be multiplied to get the Risk Priority Number (RPN) used to determine the level of risk as in Table 4. The assessment standards (rating) used to determine the score for each component are as follows:

Table 1: Probability Level (Occurrance)

Level	Frequency
1-2	Rare
2-4	Less likely to happen (unlikely to happen)
5-6	Possible (possible)
7-8	Very likely to happen (probably)
8-10	Almost certain to happen (almost certain)

Table 2: Level of Impact (Saverity)

Level	Impact
1-2	Very insignificant (minimal)
2-4	Not significant (small)
5-6	*Currently*
7-8	Significant (major)
8-10	Very significant (critical)

Table 3: Detection Level

Level	Detect
1-2	Very insignificant (minimal)
2-4	Not significant (small)
5-6	*Currently*
7-8	Significant (major)
8-10	Very significant (critical)

Table 4: Risk Priority Number (RPN)

Risk Level	Risk Priority Number (RPN)
Very low	x<20
Low	20≤x<80
Currently	80≤x<120
Tall	120≤x<200
Very high	x>200

2.6 Research variables

The research variables used are based on research literature studies related to concrete supply chain risks. The risks identified in the supply chain were obtained from their own elaboration list for a first assessment of their impact using sources such as Iowa State University College, International Journal of Logistics Research and Applications, [11] and International Journal of Production Research [12],. The identified risks are presented in the table5. These have been sorted by their meaning and have derived a total of five risk groups: operational, production processes, suppliers, safety, and workers.

Table 5: Supply Chain Risk Factors

NO	Sources of Risk	Risk factors	Researcher
1	Operational	1. Unexpected volume peaks 2. New products save delay products 3. Inventory 4. Travel breaks and packing	Hermoso et al., 2021 Amling et al., 2020 Rogers et al., 2016 Blos et al., 2016
2	Direct Process to Product Service	1. The final product is of poor quality 2. Bad customer service	
3	Supplier	1. Commodity Prices 2. Supply Fraud 3. Default shipping	
4	Security	1. Fire 2. Machine failure	
5	Labor Rights	3. Work accident 4. Poor staff training 5. Poor working conditions	

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2.7 Research stages

Stages of research flow in supply chain risk analysis studies in the precast concrete industry.

1) Problem and Goal Formulation: As a first step in research, the problem you want to research must be clearly identified. To assist the research study, observations and literature studies were carried out to identify problems that occur in precast concrete companies related to supply chain risks.
2) Literature Review or Literature Study: At this stage, literature studies and surveys are carried out simultaneously. At the literature study stage, learning was carried out regarding literature that supports the implementation of research, namely regarding supply chain risk analysis in the precast concrete industry. This is done to clarify existing problems by studying various journals, scientific studies and related books.
3) Data collection: At this stage, this research requires supporting data to be processed in order to obtain assessment results which can ultimately produce recommendations. This data was obtained through observation, interviews and questionnaires.
4) Data analysis: The supply chain stages at the research location are divided into five parts, namely operations, production processes, suppliers, security and workers. At each stage of the supply chain, the number of risks that arise or may arise is known and then a risk analysis is carried out using the FMEA method. After carrying out risk analysis using the FMEA method, the risk level for each type and stage of risk is known, namely very high, high, medium, low and very low.
5) Research results and discussion: At this stage, the results of the data analysis that have been obtained are then compared with several literature and interview results regarding supply chain risks in the precast concrete industry.
6) Conclusions and recommendations: This stage contains conclusions and suggestions that cover the essence of the entire process and results of the supply chain risk study in the precast concrete industry.

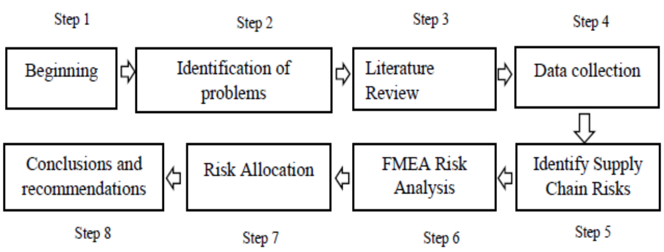

Figure 3: Research Process

III. RESULTS AND DISCUSSION

3.1 Risk Identification

In general, a supply chain consists of similar agents. However, the risks for two similar chains may vary depending on various factors such as the activities in which they are located, the agents participating in them, the place where they are developed or the number of customers they encounter. It is therefore difficult to assume that a particular risk in one supply chain has the same importance and value as the same risk in another supply chain. The greatest disadvantage of these risks is based on their great diversity, diverse origins, varied consequences, and complex interrelationships with other risks. Risk identification involves naming the risk without explaining or measuring it. Logically, people working in one part of the supply chain have a greater facility to identify risks in that part. That is why the definition and functional separation of the parts of the supply chain is critical to successful risk identification. Supply chain risks identified at PT. Sinar Bangun Mandiri-Tugu Beton Semesta Abadi Precast Kupang according to table 6.

Table 6: Factors precast concrete supply chain risks

Risk Factors	
R1	Risk of high customer demand and production spikes
R2	The risk of storage delays due to new product production is high
R3	Risk of failure to record production
R4	Product packaging and shipping risks
R5	Risk of poor final production quality
R6	Risk of poor customer service
R7	Risk of unexpected material prices
R8	Risk of product fraud to customers
R9	Risk of late delivery to the project location
R10	Risk of fire at production sites and shipping facilities
R11	Risk of damage to production machines and damage to transportation equipment
R12	Health risks and work accidents
R13	Risk of poor job training for employees
R14	Put risks and poor working conditions at the production site

3.2 Risk analysis and assessment using the FMEA Method

The aim of risk analysis is to obtain a prioritized list of chain risks, which determines the relevance that should be given to each of the elements mentioned. With this prioritization, it is easier to visualize the importance of each risk in the supply chain. Therefore, we request that each risk from the 14 identified risks be given a probability of

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ISSN (online): 2581-3048

Volume 7, Issue 11, pp 567-575, November-2023

https://doi.org/10.47001/IRJIET/2023.711074

occurrence between four categories, namely very low, low, medium, high, very high and its impact on the organization in the categories very small, small, medium, large and very large,[13].After testing the research instrument, namely the questionnaire, and it has been declared valid and reliable, the questionnaire can then be used to carry out an analysis of the level of supply chain risk identified in the precast concrete industry based on probability (Occurrence) and impact (Saverity) and level of detection (Detection). Regarding supply chain risks in the precast concrete industry, an assessment was carried out by the 31 respondents used in this research regarding the 14 risks that had been previously identified. A recapitulation of the results of respondents' perceptions regarding probability (Occurrence) and impact (Saverity) and detection (Detection) in this research is presented in Table 7.

Table 7: Risk level

Risk Sources	Risk		Saverity (S)	Occurrence (O)	Detection (D)	RPN	Category
Operational	R1	Risk of high customer demand and production spikes	5	4	7	140	High
	R2	The risk of storage delays due to new product production is high	4	6	9	216	Very high
	R3	Risk of failure to record production	3	4	3	36	Low
	R4	Product packaging and shipping risks	2	5	3	30	Low
Direct Process to Product Service	R5	Risk of poor final production quality	4	3	2	24	Low
	R6	Risk of poor customer service	5	2	2	20	Low
Supplier	R7	Risk of unexpected material prices	7	9	6	138	High
	R8	Risk of product fraud to customers	5	4	4	80	Medium
	R9	Risk of late delivery to the project location	7	4	3	84	Medium
Security	R10	Risk of fire at production sites and shipping facilities	6	5	6	180	High
	R11	Risk of damage to production machines and damage to transportation equipment	5	7	9	315	Very high
Labor Rights	R12	Health risks and work accidents	4	6	3	72	Low
	R13	Risk of poor job training for employees	3	5	2	30	Low
	R14	Put risks and poor working conditions at the production site	2	6	4	48	Low

Based on table 7, to determine the risk value based on the size of the RPN value. The RPN value is obtained from multiplying the saverity (S), accuracy (O) and detection (D) values. Risk level for each job at the concrete production company PT. Semesta Bangun Mandiri-Tugu Beton Semesta Abadi Precast Kupang. Seven low category risks were identified, namely: risk of recording failure (R3), risk of product packaging and delivery (R4), risk of poor final production quality (R5), risk of poor customer service (R6), occupational health and safety. risk (R12), risk of job training for employees (R13) and risk of poor working places and conditions at production sites (R14). Two risks were identified in the medium category, namely: the risk of product fraud to customers (R8) and the risk of late delivery to the project location (R9). High category risks identified are: risk of high customer demand and production spikes (R1), risk of unexpected material prices (R7). Two very high risks were identified, namely: the risk of storage delays due to high production of new products (R2) and the risk of damage to production machines and

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damage to transportation equipment (R11). This shows that high category risks (H) and very high category risks (VH) receive priority treatment from management.

Based on the risk level previously determined in table 5 regarding supply chain risks in precast concrete companies, an analysis is then carried out regarding risk control efforts based on this risk level. This risk control is carried out based on interviews with respondents (leaders, employees, workers) of PT. Mandiri Bangun Semesta-Tugu Beton Semesta Abadi Precast Kupang is in accordance with the experience while working for the company. Based on this, the risks that need to be controlled by the company are obtained according to five parts, namely operational, production processes, suppliers, safety, and workers to anticipate emerging risks. Regarding supply chain risk control, each risk factor is in accordance with table 8.

Table 8: Risk control

Risk	Strategy	Severity (S)	Occurrence (O)	Detection (D)	RPN	Category
R1	Adding precast concrete production equipment	2	4	3	48	Low
R2	Carrying out additional storage warehouses	4	5	2	40	Low
R3	Recording is done using a digital system	3	4	4	36	Low
R4	Packaging of production materials uses heavy equipment and delivery is carried out early	2	5	3	30	Low
R5	The company strictly implements quality standards	4	3	2	24	Low
R6	Implement a disciplined work culture and ensure customers come first	5	2	2	20	Low
R7	Providing reserve raw materials to anticipate increases in material prices	4	3	3	36	Low
R8	Carry out strict inspection of the materials when packing	2	5	4	40	Low
R9	Adding transportation equipment and increasing labor for packing production goods	6	4	2	48	Low
R10	Prepare fire extinguishers and trained officers	5	3	3	45	Low
R11	Prepare production machines and spare transportation equipment	3	5	4	60	Low
R12	Prepare personal protective equipment and provide regular occupational health and safety training	4	6	3	72	Low
R13	Prepare employee training methods according to the field of work and experienced officers	3	5	2	30	Low
R14	Prepare comfortable and clean employee workplace facilities	2	6	4	48	Low

Based on table 7 and table 8, it can be explained that the priority risks that need to be controlled are very high risk, high risk and medium risk as follows:

1) The risk of high customer demand and a surge in production (R1) after controlling by adding precast concrete production equipment, the RPN value from 140 in the high category to 48 in the low category.
2) The risk of storage delays due to the production of new products is high (R2) after control has been carried out by increasing the storage warehouse for the RPN value from 216 in the very high category to 48 in the low category.
3) The risk of unexpected material prices (R7) after being controlled by providing reserve raw materials to anticipate material prices increased the RPN value from 138 high categories to 36 low categories.

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4) Risk of product fraud to customers (R8) after controlling by carrying out strict inspection of materials during packing, RPN value from 80 medium category to 40 low category.
5) Risk of late delivery to the project location (R9) after control is carried out by adding transportation facilities and adding workers to pack production goods. RPN value from 84 in the medium category to 48 in the low category.
6) Risk of fire at production sites and shipping facilities (R10) after controlling by preparing fire extinguishers and trained officers RPN value from 180 high category to 45 low category.
7) The risk of damage to production machines and damage to transportation equipment (R11) after controlling with preparation of production machines and spare transportation equipment, the RPN value from 315 in the very high category to 60 in the low category.

IV.CONCLUSION

Risk management in supply chains is becoming increasingly important not only for the activities carried out within them but also for their managers. It is important to remember that the risk management process should not be haphazard, but should be created and prepared carefully. The main tool to carry out this entire process is the creation of departments used to analyze risk management and determine the scope of each situation and the actions to be taken, realizing that the crucial element is strong communication between all departments and the various links within them. All of this will provide the ability to confront, avoid, move or eliminate impactful risks. In this way, we will start the road to a strong, flexible and competitive process. Looking at the case study of this research, it can be seen that many factors that influence risk quality have been identified, so that the actions taken will be directed at risks that affect quality. In this way, the probability and impact will be reduced and the possibility of major risks occurring will be reduced. Risk of storage delays due to high production of new products, risk of high customer demand and production spikes, risk of unexpected material prices, risk of product fraud to customers, risk of late delivery to the project site, risk of fire at production sites and shipping facilities and risk of machine damage production and damage to transportation equipment is a priority risk that must be controlled so that it becomes a risk that does not endanger the company's reputation.

ACKNOWLEDGMENTS

Thank you to the Directors of PT. Bangun Semesta Mandiri-Tugu Beton Semesta Abadi Precast Kupang for their cooperation and for helping provide data and facilities so that this research can be completed.

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ISSN (online): 2581-3048

Volume 7, Issue 11, pp 567-575, November-2023

https://doi.org/10.47001/IRJIET/2023.711074

Citation of this Article:

I Wayan Muka, Putu Ika Wahyuni, "Supply Chain Risk Management in Precast Concrete Industry" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET,* Volume 7, Issue 11, pp 567-575, November 2023. Article DOI https://doi.org/10.47001/IRJIET/2023.711074

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