Volume 1 Issue 1 (2025)
Page. 54 - 71

Risk assessment of factors causing production delays in precast housing panel production

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ABSTRACT

Production delays are a common issue in the use of precast technology in construction. An evaluation of the completed production process indicates that delays occur at each stage of the precast housing panel production activities. The aim of this research is to conduct a risk assessment of the factors causing production delays in precast housing panel production. The research object of this study is precast housing panels. This study is designed using a mixed-methods approach and will be conducted in two main phases: identifying risk factors causing production delays and assessing these risks. The risk factors identification process will involve experts providing expert judgment. Subsequently, a respondent survey will be conducted to assess the impact of each variable on production delays. Following the initial risk identification phase, the second phase involves a risk assessment analyzed using the Probability Impact Matrix (PIM). Ten risk variables have been identified as factors influencing production delays in precast housing panels. Among these, nine are categorized as high-risk variables, while one is classified as moderate risk. The identified risk variables include design, materials, equipment, human resources, management, finance, administration, weather, accidents, and force majeure, all of which impact production delays in precast housing panels. Based on the analysis using the Probability Impact Matrix (PIM), the high-risk variables, in descending order, are human resources, weather, force majeure, design, accidents, materials, equipment, finance, and administration. The moderate-risk variable, ranked last, is management.

KEYWORDS

Precast House Panel, Delay Risk, Risk Management

ARTICLE INFO
Received: November 18, 2024
Accepted: February 10, 2025
Published: February 28, 2025
How to cite: *Saputra, P. D., Ichsan, M., & Pambudi, W. (2025). Risk assessment of factors causing production delays in precast housing panel production. Journal of Project Management Research, 1(1), 54-71*

1. INTRODUCTION

The Indonesian government is currently focused on improving public welfare. The "3 Million Homes" program, launched by the government, will be implemented over five years through the Ministry of Housing and Settlements. This initiative continues the accelerated housing development efforts from the previous period.

Beyond promoting public welfare, the Indonesian government aims for growth and development within the construction industry. A thriving construction sector contributes directly to economic growth, as construction is one of the primary drivers of economic expansion (Mattar, et. al., 2024; Khoso, et al., 2019). The adoption of sustainable technologies is also integral to fostering growth in the construction industry, with technological innovation playing a critical role in accelerating construction implementation.

Figure 1. Precast Houses

The use of precast technology in construction has emerged as a viable innovation for achieving housing development targets. One state-owned housing company has successfully applied precast technology in residential construction, achieving significant benefits in terms of rapid implementation and high production volumes (Pambudi, et. al., 2023).

However, the use of precast technology does present certain challenges. Precast fabricators face high and varied demand (Widiantoro, et. al., 2020), often under tight timelines (Ballard & Arbulu, 2004). This demand results in a highly complex and challenging design and production process (Widiantoro, et. al., 2021; Saputra & Latief, 2020a; Saputra & Latief, 2020b; Khoso, et. al., 2019). Additionally, timely delivery is crucial, as it significantly impacts customer satisfaction, particularly for construction contractors on-site (Bilec, et al., 2006). Therefore, any production delays are unacceptable, as even minor setbacks could cause delays in the entire project timeline (Widiantoro, et. al., 2023).

Production delays remain a key issue in the use of precast technology in construction (Widiantoro, et. al., 2021; Pambudi, et. al., 2023). Previous studies evaluating production have found delays in each stage of the precast housing panel production process (Pambudi, et. al., 2023). Observations of 100 selected samples across four precast plants in Java from 2017 to 2018 showed an average production time of 26.99 hours per panel, with an additional delay of 4.8 hours, bringing the total to 31.79 hours. The fastest production time was 23.42 hours with a delay of 1.42 hours, while the longest took 31.67 hours, with a 10.75-hour delay (Pambudi, et. al., 2023).

Similarly, production delays have also been observed in other types of precast products, such as bridge box girders, where each stage experienced delays. The average production time reached 32.67 hours, with a delay of 6.28 hours, totaling 38.95 hours (Widiantoro, et. al., 2020). The longest production time recorded was 45.67 hours, with a delay of 12.42 hours, while the shortest was 17.42 hours with a 2-hour delay (Widiantoro, et. al., 2020).

Figure 2. Precast House Panel Production

Production delays in precast technology stem from various factors, including resources, management, financial aspects, materials, equipment, design, administrative processes, documentation completeness, weather, accidents, and force majeure events (Widiantoro, et. al., 2023). Kurniawan, et. al. (2021) noted similar factors, identifying resources, management, equipment, material characteristics, site conditions, physical infrastructure, design, documentation, government policy, financial constraints, weather, unexpected events, and force majeure as risk factors affecting delays. In Safapour, et. al. (2019) research on affordable housing projects, time performance was found to be influenced by legal, design, and technology factors, project characteristics, project management, material resources, human resources, financial conditions, and project location.

Widiantoro, et. al. (2023) identified the causes of delay specifically in box girder production without conducting a risk assessment, categorizing risk factors descriptively as low, moderate, and high impact (Widiantoro, et. al., 2023). To expand upon this research, the current study will focus on conducting a risk assessment of production delays for a different type of precast product: housing panels. This risk assessment will be qualitative, utilizing the Probability Impact Matrix (PIM) method (PMI, 2017).

This study aims to provide a basis for further evaluation of precast fabricators in managing production delays effectively and to serve as a foundation for developing strategic approaches to time management in precast production. Ultimately, the findings are expected to support the Indonesian government's objectives for accelerating housing and infrastructure development.

2. LITERATURE REVIEW

2.1 Precast

The rapid development of technology in the construction industry has driven the emergence of various innovations focused on enhancing project efficiency, quality, cost, and timelines. One of the significant innovations in this sector is the use of precast concrete. Precast or prefabricated concrete has gained popularity as a practical and efficient construction solution. In this context, prefabricated buildings refer to structures built using precast concrete components manufactured in a factory. This technique offers numerous benefits, including resource and energy savings, as well as reduced pollution during the construction process (Sulistianto & Simanjuntak, 2020). Additionally, the integration of information technology with industrialization in prefabrication methods can improve workforce productivity, quality, and safety levels in construction projects (Liang et. al., 2024).

Compared to traditional construction methods that rely on on-site concrete pouring, precast concrete construction offers several advantages. On-site pouring often faces challenges related to suboptimal quality control, material waste, and low productivity (Sirajudeen & Krishnan, 2022). In contrast, prefabrication enables concrete structural components to be cast in a factory under stricter quality control, thus addressing these issues. The precast concrete components are then transported and installed at the project site, shortening construction times and reducing waste in the project area (Sirajudeen & Krishnan, 2022). Furthermore, this method enhances site safety, as most tasks are performed in the factory, away from the risks associated with construction sites.

An additional benefit of prefabrication is its potential to reduce environmental impact. This technology not only decreases material waste but also reduces carbon emissions generated during the construction process (Liu et. al., 2021). Moreover, with the flexibility offered in producing prefabricated components, construction processes can be adapted to changes in the project schedule, facilitating adjustments in workflow (Jiang et. al., 2020). Therefore, with these advantages, precast concrete methods offer a more efficient and environmentally friendly solution compared to traditional construction methods that rely on on-site pouring.

2.2 Precast House

Off-site construction has gained significant popularity in recent times due to the numerous advantages it offers over traditional construction methods (Kuragu, et. al., 2022). The utilization of off-site construction has been implemented in the residential housing sector (Kuragu et al., 2022). One example is the use of precast technology. Precast houses are constructed using precast concrete components fabricated in a concrete plant (Aquiese, 2021; Kayemba, 2021). The elements of precast houses are generally similar to conventional houses, consisting of foundations, beams, columns, walls, and roofs (Aquiese, 2021). However, precast panel houses do not use columns and beams because their structural walls are designed to bear loads. Figure 3. below is an illustration of the elements in precast panel houses from one of best precast concrete manufacturer in Indonesia (Wika Beton, 2024).

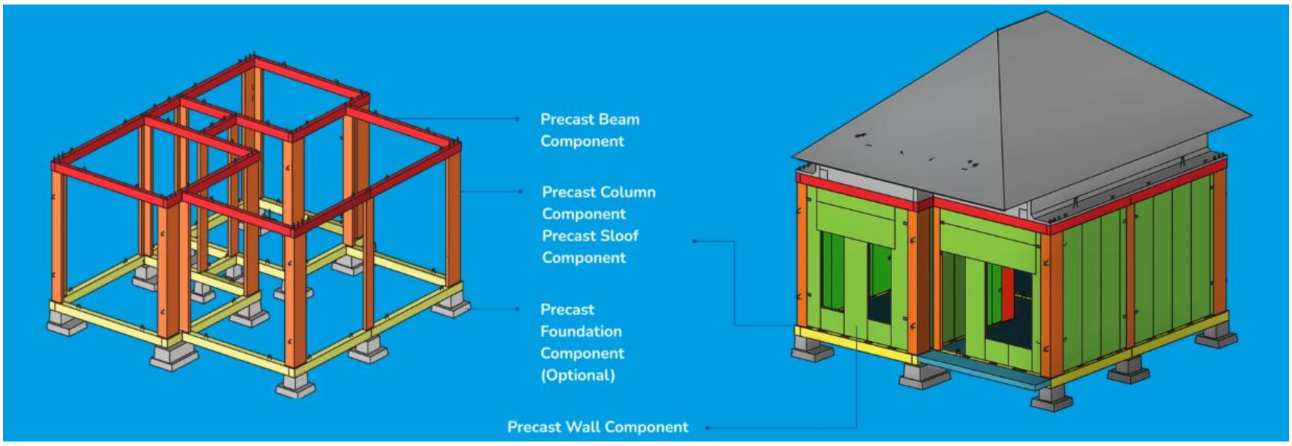


Figure 3. Precast House Panel

2.3 Delay Time

A successful construction project must be completed on time, meet the specified quality standards, and stay within the established budget to satisfy the client's needs (Arantes & Ferreira, 2020). However, delays in construction projects are a common issue worldwide (Prasad, et. al., 2018; Sambasivan & Soon, 2007). In reality, many projects face delays that result in work disruptions, reduced productivity, missed deadlines, increased time-related costs, and even contract terminations or cancellations (Rahman, et. al., 2006). Delays are a primary cause of claims within the construction industry and occur frequently regardless of the type of project (Rahman, et al., 2006; Arantes & Ferreira, 2020).

Construction project delays can be defined as events that lead to an extension of the time required to complete all or part of a specific project (Wepari, et. al., 2024). A delay in a construction project refers to a situation where the project is not completed within the time agreed upon in the contract or the predetermined handover date (Assaf & Al-Hejji, 2006). This condition results in slower progress than planned, causing tasks or actions to be performed later than scheduled, thus hindering the overall completion of the project (Assaf & Al-Hejji, 2006; Trauner, et. al., 2009).

Delays in construction projects can also be caused by late precast production at the concrete plant (Pambudi et al., 2023; Widiantoro et al., 2021). This represents a major issue, as it leads to shifts in the project's execution timeline (Pambudi et al., 2023; Widiantoro et al., 2021). Previous research indicates that the average production time for precast house panels is 26.99 hours per panel, with an additional delay of 4.8 hours, totaling 31.79 hours. The fastest production time recorded was 23.42 hours with a delay of 1.42 hours, while the longest production time was 31.67 hours, with a delay of 10.75 hours (Pambudi et al., 2023). This variability in production time is attributed to several risk factors.

2.4 Risks Cause Delay

Delays in construction projects are a complex issue involving various factors from the parties involved and the project's environment. According to Taffazoli & Shrestha (2017), the causes of delays can be categorized based on the roles of different stakeholders, such as contractors, owners, and designers, as well as external factors beyond control. Subsequent studies have expanded this view by identifying key elements contributing to delays from various aspects of the project. Ramli et. al. (2018) highlighted that communication, management, time estimation, resource availability, and timely procurement of materials are high-risk factors contributing to delays. Additionally, site conditions, weather, and uncertainties in the field are considered significant factors affecting schedules (Ramli et. al., 2018).

Furthermore, Safapour, et. al. (2019) developed delay indicators encompassing legal aspects, design, and technology, project characteristics, as well as management and resources. These factors show that construction delays often result from a combination of operational factors, such as material and labor availability, and external influences like regulations and project finances. Asmi, et. al. (2019) identified ten key factors, including frequent design changes, financial constraints from owners, payment delays, subcontractor incapacity, and material delivery delays. These factors emphasize the importance of financial stability and careful design planning to maintain the project schedule.

A more comprehensive approach was proposed by Kurniawan et. al. (2021), who added external factors such as government policies, work accidents, and unforeseen events or force majeure. These factors broaden the understanding of how conditions outside direct project management control can lead to delays. In subsequent years, Tahmasebinia et. al. (2022) and Widiantoro et. al. (2023) also mentioned the significance of quality project management and quick decision-making in addressing challenges such as design errors, low worker productivity, and unexpected weather conditions. In the context of precast production, Widiantoro et. al. (2023) emphasized that managerial factors, document completeness, and resource readiness play a crucial role in preventing delays. Overall, construction delays result from various factors requiring cross-disciplinary collaboration to effectively manage and mitigate risks.

2.5 Risk Management

Risk management is a systematic process that begins with the stages of planning, identification, analysis, response, and control of risks that may impact the project (PMI, 2017). Risk management is essential in construction to mitigate the impact of risks (Taljapurkar & Tiwari, 2024). It is useful in predicting the potential impact of hazards on infrastructure projects (Gholitabar et. al., 2016).

Risk management is a routine procedure for identifying and managing hazards throughout the project and controlling them promptly (Taljapurkar & Tiwari, 2024).

The goal of risk management is to recognize potential risks related to the project and respond accordingly. This process includes efforts to maximize the outcomes of positive events and minimize the impact of negative events. According to the PMI (2017), the key elements of risk management include setting objectives, risk identification, risk analysis, risk evaluation, risk treatment, and risk monitoring and review.

Risk assessment is crucial in construction because it directly affects capital costs (Taljapurkar & Tiwari, 2024). Risk assessment can be conducted through qualitative and quantitative analysis (PMI, 2017). Qualitative analysis is most commonly used in risk management. A qualitative risk analysis is a process of prioritizing risks for further analysis or action by evaluating the likelihood and impact of various combinations of risks (PMI, 2017). This analysis can be supported by various tools and techniques, such as Risk Probability and Impact Assessment and the Probability Impact Matrix (PMI, 2017).

Risk Probability and Impact Assessment is a method used to assess the likelihood of each specific risk and its impact on the project's performance, including time, cost, scope, and quality. This assessment can be conducted through interviews or consultations with experienced project team members. On the other hand, the Probability and Impact Matrix aims to prioritize risks for further analysis and response (action) based on the magnitude of the risk, which is measured by the likelihood and impact of the risk.

3. METHODOLOGY

3.1 Research Design

This study is an applied research project that utilizes the Probability and Impact Matrix to assess risk factors causing time delays in the production of precast house panels. This study is planned to use a mixed methods approach that combines quantitative and qualitative approaches (Creswell, 2014). The quantitative approach involves data collection through surveys and descriptive statistical analysis (Creswell, 2014). The research is a survey-based study aimed at obtaining risk values. Meanwhile, the qualitative approach requires experts to validate the risk factor variables in alignment with PMI (2017), which identifies expert judgment as one of the tools and techniques in project risk management.

3.2 Research Object.

The object of this research is precast house panels. This object was selected because it is one of the technologies that can accelerate the housing construction process within a short period, thus supporting government programs. The production of precast panel houses examined in this study is carried out by a state-owned enterprise specializing in the development of national housing. The company focuses on advancing precast concrete technology in the production of high-quality housing products.

3.3 Research Process.

The research process is divided into three main stages. The first stage involves identifying the risk factors contributing to time delays in the production of precast panel houses by validating the risk factor variables through expert judgment. The second stage assesses the impact levels of these risk factor variables on production delays using a series of respondent surveys. The final stage involves conducting a risk assessment to determine the risk value, risk category, and risk ranking.

3.4 Research Variables

This study involves several variables that influence the production time of precast house panels. A total of 10 variables will be examined in this research, derived from various references. The research variables are presented in Table 1 below.

Table 1. Research Variables

No	Variable		Reference
	Name of Variable	Code	
1	Design	X1	Kurniawan (2021); Bux et al (2019); Ramli et al (2018); Durdyev, et al (2017)
2	Material	X2	Kurniawan (2021); Asmi, et al (2019)
3	Equipment	X3	Kurniawan (2021); Alsuliman et al (2019); Asmi, et al (2019); Ramli et al (2018); Durdyev, et al (2017)
4	Human Resources	X4	Kurniawan (2021); Alsuliman et al (2019) Bux et al (2019); Asmi et al (2019); Islam et al (2018); Ramli et al (2018); Durdyev, et al (2017)
5	Management	X5	Kurniawan (2021); Asmi, et al (2019); Ramli et al (2018); Durdyev, et al (2017); Masood et al (2015)
6	Financial	X6	Kurniawan (2021); Safapour, et al (2019); Asmi, et al (2019)
7	Administration	X7	Kurniawan (2021); Safapour et al (2019); Asmi et al (2019); Alsuliman (2019)
8	Weather	X11	Kurniawan (2021); Perez et al (2015); Ramli et al (2017); Safapour, et al (2019)
9	Accident	X13	Kurniawan (2021); Durdyev, et al (2017); Safapour, et al (2019)
10	Force Majeur	X12	Kurniawan (2021); Perez et al (2015)

Source: Compiled from various references, 2024

3.5 Experts and Samples

The study involved three experts who acted as representatives from a precast house panel company. These experts were selected based on their roles within the company, which are deemed critical to the operational production and installation of precast house panels, with a minimum position of manager. Additionally, the experts were chosen based on their extensive work experience in the precast industry, with a minimum of 15 years, demonstrating their professionalism and expertise. Educational qualifications were also a key requirement, with a minimum of a bachelor’s degree in civil engineering or management.

The population in this study comprises engineers in the production and construction units of the precast house panel company, which is relatively limited in number. A non-probability sampling technique was employed, meaning that the selected samples had to meet specific criteria. Similar to the expert selection criteria, the samples were required to meet certain qualifications based on their positions, work experience, and educational background. The sample positions had to be department heads, unit heads, or senior engineers. The minimum work experience required was five years, and the educational background required was a diploma in civil engineering. Due to these strict criteria and the limited number of engineers spread across production and construction units throughout Indonesia, the sample size was relatively small. Therefore, 30 samples were selected to meet the minimum statistical analysis requirements (Morrisan et al., 2012).

3.6 Research Instrument

This study employs a closed-ended questionnaire for survey data collection. Data collection for the identification of risk factors by experts utilizes the Guttman scale. The experts will be asked to indicate their agreement or disagreement ("yes" or "no") with the identified risks factors, based on the scale provided in Table 2.

Table 2. Scale for Expert Judgement

Scale	Grade	Explanation
1	Yes	These variables are risk factors that cause delays in precast production.
0	No	These variables are not risk factors that cause delays in precast production.

After the risk factors causing delays in the precast panel production are validated, the next step is to survey assessing the extent to which each of these variables affects the delay time. The scale used is a Likert scale, which is commonly used to measure the influence of one variable on another. The scale for determining the level of influence is presented in Table 3.

Table 3. Scale for Influence Level

Scale	Grade	Explanation
1	No Influence at All	The variable does not influence all the delays in precast production.
2	No Influence	The variable does not influence the delay in precast production.
3	Influential	The variable influences the delay in precast production.
4	Highly Influential	The variable has a significant influence on the delay in precast production.
5	Extremely Influential	The variable has an extremely significant influence on the delay in precast production.

Subsequently, the assessment of risk factors will be conducted through a respondent survey. The assessments performed include probability assessment and impact assessment. For data collection through the survey, a Likert scale is utilized in the questionnaire. The Likert scale used for probability assessment is presented in Table 4, while the scale for impact assessment is provided in Table 5.

Table 4. Scale of Risk Probability

Scale	Explanation
1	Very unlikely to occur
2	Unlikely to occur
3	Somewhat likely to occur
4	Likely to occur
5	Very likely to occur

Table 5. Scale of Risk Impact

Scale	Explanation
1	Causes a production delay of precast products by less than 1 hour
2	Causes a production delay of precast products between 1 to 3 hours
3	Causes a production delay of precast products between 3 to 7 hours
4	Causes a production delay of precast products between 7 to 10 hours
5	Causes a production delay of precast materials exceeding 10 hours

Source: Modified based on the production time researched by Pambudi et al. (2023)

3.7 Research Analysis

The identification of risk factors involving experts will be analyzed using descriptive statistics. Conclusions will be drawn based on the mode of the experts' responses. The frequency of responses will then be summarized and presented as percentages. Since only three experts are involved, a "yes" response mode with a frequency exceeding 67% will validate the identified risk factors.

To assess the influence of the risk factors, descriptive statistical analysis will be employed. The descriptive analysis will include metrics such as the total number of data points as a control, maximum value, minimum value, mean, median, and mode. These values will serve as the basis for drawing conclusions regarding the influence level of the risk factors.

Table 6. Scale Conversion of Risk Probability

Scale	PMI Scale (2017)	Grade
1	0.10	Very low
2	0.30	Low
3	0.50	Moderate
4	0.70	High
5	0.90	Very High

Source: PMI, 2017

The risk assessment conducted in this study is a qualitative risk assessment to determine the risk value and risk category based on the Probability Impact Matrix (PIM) (PMI, 2017). Although the method is qualitative, the data collection approach will use a quantitative method, namely a survey, and the analysis will be descriptive statistics. Thus, the measurement scales used will also follow the Likert scale presented in Table 4. for the probability scale and Table 5. for the impact scale. The results will then be converted according to the risk scale established by PMI (2017) shown in Table 6. For Probability and Table 7. For Risk Impact.

Table 7. Scale Conversion of Risk Impact

Scale	PMI Scale (2017)	Grade
1	0.05	Very low
2	0.10	Low
3	0.20	Moderate
4	0.40	High
5	0.80	Very High

Source: PMI, 2017

After the scale conversion is carried out according to PMI (2017) which has been explained previously, then the value of the risk factors is calculated based on the multiplication of the probability value and the impact value. The results of the analysis involving the multiplication of probability and impact to determine the risk value will be categorized based on the PIM and categorization made by PMI (2017). The PIM is presented in Table 8, and the risk categories are presented in Table 9. Furthermore, a ranking is carried out to determine which risk factors need more control.

Table 8. Probability Impact Matrix

PIM			Impact				
			Very Low	Low	Moderate	High	Very High
			0.05	0.10	0.20	0.40	0.80
Probability	Very High	0.90	0.05	0.09	0.18	0.36	0.72
	High	0.70	0.04	0.07	0.14	0.28	0.56
	Medium	0.50	0.03	0.05	0.10	0.20	0.40
	Low	0.30	0.02	0.03	0.06	0.12	0.24
	Very Low	0.10	0.01	0.01	0.02	0.04	0.08

Source: PMI, 2017

Table 9. Risk Category

Grade	Risk Value	Color
High	0.24 - 0.72	
Moderate	0.08 - 0.20	
Low	0.01 - 0.07	

Source: PMI, 2017

4. RESULTS & DISCUSSION

4.1 Expert Judgement

Expert judgment was conducted by three experts who are directly involved in the production of precast house panels. The experts hold positions at the managerial level, including project manager and general manager. Their experience ranges from 19 to 27 years. The educational background of the experts is a minimum of a bachelor's degree in civil engineering, with some having a master's degree in construction management. A complete profile of the experts involved in this study can be seen in Table 10.

Table 10. Expert Profile

No	Code	Position	Experience	Education
1	E1	General Manager	27 Years	Master's Degree in Construction Management
2	E2	Project Manager	22 Years	Bachelor's Degree in Civil Engineering
3	E3	Manager	19 Years	Bachelor's Degree in Civil Engineering

Source: Data Analysis, 2024

Expert judgment was conducted to validate the risk variables causing delays, which included design, material, equipment, human resources, management, finances, administration, weather, accidents, and force majeure. Out of the 10 variables validated through expert judgment, 8 variables were unanimously approved by the experts (100%), including design (X1), material (X2), equipment (X3), human resources (X4), management (X5), financial (X6), accidents (X9), and force majeure (X10). Meanwhile, 2 other risk variables—administration (X7) and weather (X8)—received only 67% approval from the experts, while 33% disagreed. However, since more than 50% of the experts agreed, all risk variables were considered valid. The results of the expert judgment analysis are shown in Table 11.

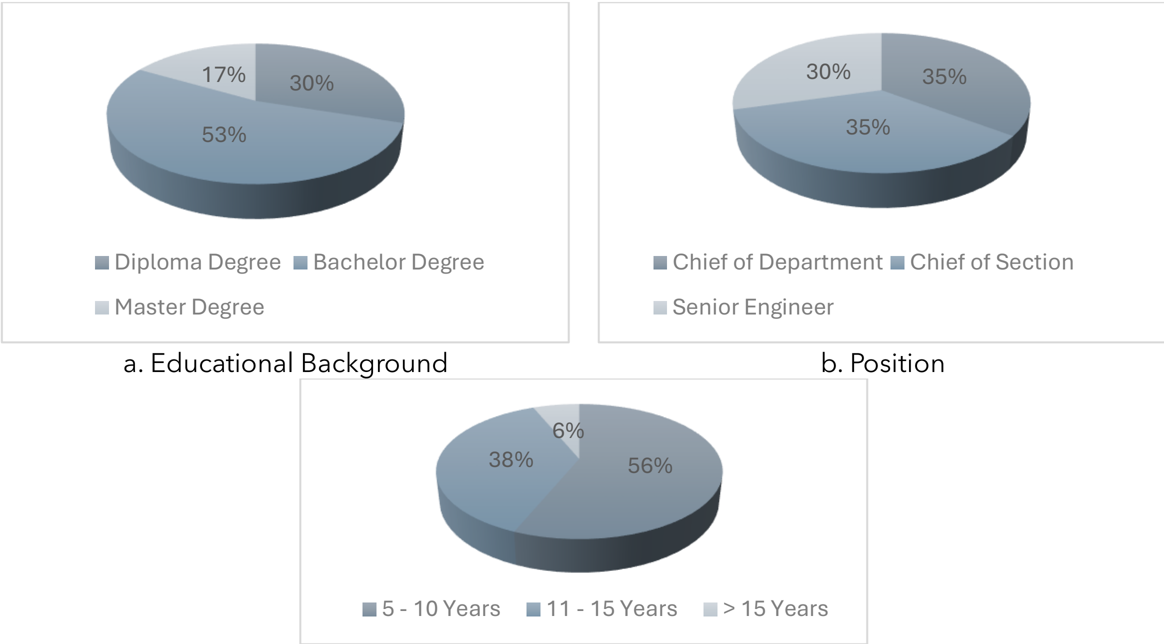
Table 11. Expert Judgement Results

No	Variable		Expert Opinion			Expert Judgement Result			
	Name of Variable	Code	1	2	3	Mode	Agree	Disagree	Conclusion
1	Design	X1	1	1	1	1	100%	0%	Valid
2	Material	X2	1	1	1	1	100%	0%	Valid
3	Equipment	X3	1	1	1	1	100%	0%	Valid
4	Human Resources	X4	1	1	1	1	100%	0%	Valid
5	Management	X5	1	1	1	1	100%	0%	Valid
6	Financial	X6	1	1	1	1	100%	0%	Valid
7	Administration	X7	1	1	0	1	67%	33%	Valid
8	Weather	X11	1	0	1	1	67%	33%	Valid
9	Accident	X13	1	1	1	1	100%	0%	Valid
10	Force Majeur	X12	1	1	1	1	100%	0%	Valid

Source: Data Analysis, 2024

4.2 Respondent Survey

Due to the limited population available at the research location, only 30 respondent samples were asked to provide their opinions regarding the influence of risk variables on the delay in the production of precast house panels. Of these, 30% of the respondents had the lowest education level, which was a diploma degree, 53% had a bachelor’s degree, and 17% had a master’s degree. The respondents held mid-to-senior strategic positions, with 35% being chief of department, 35% chief of section, and the remaining 30% being senior engineers. The respondents’ work experience varied, with 56% having 5-10 years of experience, 38% with 11-15 years, and 6% with more than 15 years of experience. The characteristics of the respondents, based on educational background, position, and work experience, are presented in Figure 4.



a. Educational Background
b. Position
c. Working Experience

Figure 4. Respondent Characteristic

Table 12. Respondent Survey Result

No	Variable		Respondent Opinion							
	Name of Variable	Code	N	Min	Max	Mean	Median	Mo	Level	Conclusion
1	Design	X1	30	3	5	3.70	3.50	3.00	4.00	High Influential
2	Material	X2	30	2	3	2.63	3.00	3.00	3.00	Influential
3	Equipment	X3	30	2	3	2.90	3.00	3.00	3.00	Influential
4	Human Resources	X4	30	2	3	2.90	3.00	3.00	3.00	Influential
5	Management	X5	30	2	3	2.50	2.50	2.00	3.00	Influential
6	Financial	X6	30	3	4	3.40	3.00	3.00	3.00	Influential
7	Administration	X7	30	3	4	3.27	3.00	3.00	3.00	Influential
8	Weather	X8	30	3	5	3.97	4.00	4.00	4.00	High Influential
9	Accident	X9	30	3	3	3.00	3.00	3.00	3.00	Influential
10	Force Majeure	X10	30	4	4	4.00	4.00	4.00	4.00	High Influential

Source: Data Analysis, 2024

The results of the survey analysis show that the risk variables are categorized as either influential or highly influential toward the delay in the production of precast house panels. A total of 7 risk variables, including material (X2), equipment (X3), human resources (X4), management (X5), financial (X6), administration (X7), and accident (X9), were found to be influential on the delay in the production process. Meanwhile, the remaining 3 risk variables—design (X1), weather (X8), and force majeure (X10)—were identified as highly influential on the production time of precast house panels. The descriptive analysis results from the survey respondents are presented in Table 12.

4.3 Probability Impact Matrix

The respondents were also asked to assess the risk variables, and based on their assessments, the risk variables were categorized according to their impact on delays. The variables with high-risk categories, ranked in order, include: Human resources (X4) with a risk value of 0.72, Weather (X8) with a risk value of 0.72, Force majeure (X10) with a risk value of 0.72, Design (X1) with a risk value of 0.56, Accident (X9) with a risk value of 0.56, Material (X2) with a risk value of 0.28, Equipment (X3) with a risk value of 0.28, Financial (X6) with a risk value of 0.28, Administration (X7) with a risk value of 0.28. The risk variable categorized as moderate, ranking last, is management (X5) with a risk value of 0.10. The results from the survey respondents, which are in the form of Probability and Impact Matrix (PIM), are presented in Table 13.

Table 13. Respondent Survey Result

No	Variable		Probability	Impact	Risk		
	Name of Variable	Code	Value	Value	Value	Category	Ranking
1	Design	X1	0.70	0.80	0.56	High	4
2	Material	X2	0.70	0.40	0.28	High	6
3	Equipment	X3	0.70	0.40	0.28	High	7
4	Human Resources	X4	0.90	0.80	0.72	High	1
5	Management	X5	0.50	0.20	0.10	Moderate	10
6	Financial	X6	0.70	0.40	0.28	High	8
7	Administration	X7	0.70	0.40	0.28	High	9
8	Weather	X8	0.90	0.80	0.72	High	2
9	Accident	X9	0.70	0.80	0.56	High	5
10	Force Majeur	X10	0.90	0.80	0.72	High	3

Source: Data Analysis, 2024

4.4 Discussion

Delays in precast production are often associated with human resource issues (Widiantoro, et. al., 2023). A shortage of labor is identified as a major risk, as limited workforce availability can hinder the production process and increase the likelihood of delays (AlGheth & Ishak, 2022; Tahmasebinia & Song, 2022). Additionally, low skill levels among the workforce exacerbate the situation by reducing production efficiency and increasing the potential for errors (AlGheth & Ishak, 2022; Tahmasebinia & Song, 2022). An incompetent project team is also a significant factor, as the success of a project relies heavily on effective collaboration and problem-solving abilities (AlGheth & Ishak, 2022). Other factors, such as weak project resource management and poor staff management, further aggravate the delay risk by creating an imbalance between HR needs and effective management (Mahamid, et. al., 2012; Tafazzoli & Shrestha, 2017). Low worker productivity, often influenced by environmental factors, motivation, or working conditions, also directly impacts production time (Asmi, et. al., 2019; Yap, et. al., 2020; Tahmasebinia & Song, 2022). Lastly, inadequate qualifications of technical staff add to the challenge, as undertrained personnel are unable to handle the technical complexities involved in precast production (Mahamid, et. al., 2012).

Weather conditions are one of the key external factors affecting delays in precast production (Widiantoro, et. al., 2023). Precast production, which relies on field activities, is vulnerable to adverse weather conditions such as extreme heat and heavy rain, which can hinder construction, logistics, and material handling (AlGheth & Ishak, 2022; Mahamid, et. al., 2012; Apipattanavis, et. al., 2010; Yap, et. al., 2020). The impact of heat in the field is a significant obstacle, particularly in high-temperature regions. Exposure to extreme temperatures can lead to reduced labor productivity, degradation of certain materials, and potential cracking of precast components during the curing process (Tahmasebinia & Song, 2022). Conversely, the effects of rain present another major challenge. Heavy rainfall can disrupt outdoor work, affect the molding and drying processes of precast, and delay the transportation of materials to the project site. Rain also introduces additional safety risks, such as slippery surfaces and water pooling, which slow down logistics and work activities (Tahmasebinia & Song, 2022). These unpredictable weather conditions require project management to have a robust contingency plan, including flexible scheduling, the use of weather-resistant technologies, and dynamic resource management to mitigate weather-related risks.

Force majeure refers to events beyond human control that are often unpredictable and result in significant disruptions to precast production (Widiantoro, et. al., 2023). These risks include natural disasters, pandemics, political instability, and issues related to peace and order. Such events directly impact project operations by creating barriers to logistics, site access, labor, and material procurement (Mahamid, et. al., 2012; Yap, et. al., 2020; Rivera, et. al., 2020). Natural disasters such as earthquakes, floods, or hurricanes can damage infrastructure, halt production activities, and increase recovery costs. In construction contexts, natural disasters can damage equipment or production facilities, requiring time for repairs before operations can resume (Mahamid, et. al., 2012; Yap, et. al., 2020). Pandemics, such as COVID-19, significantly affect the continuity of construction projects (Larasati, et. al., 2021). They can cause labor shortages due to mobility restrictions or worker health issues, and disruptions to global supply chains slow down material procurement for precast production. Political instability, such as sudden policy changes, political conflicts, or government instability, also poses a significant threat. This uncertainty can affect investment, material access, or the smooth administration of projects (Rivera, et. al., 2020). Peace and order issues, including security and social conflicts, can create an unfavorable working environment, slow operations, or even force temporary suspension of the project (Rivera, et. al., 2020).

Design is a critical factor influencing delays in precast production, especially in projects with high technical complexity (Widiantoro, et. al., 2023). Complex designs often require additional time for planning, fabrication, and installation, thereby increasing the risk of delays (Rivera, et. al., 2020; AlGheth & Ishak, 2022; Tahmasebinia & Song, 2022). Moreover, design errors and poor design quality can result in discrepancies between technical specifications and field requirements, necessitating time-consuming and resource-intensive revisions (Mahamid, et. al., 2012; Tafazzoli & Shrestha, 2017; Asmi, et. al., 2019). Design errors, incomplete drawings, and conflicts between specifications and drawings further complicate the situation by creating confusion during the construction and production stages, disrupting an otherwise efficient workflow (AlGheth & Ishak, 2022). Changes to drawings and design specifications, whether due to technical requirements or client demands, add to the challenge by delaying the production process and causing inconsistencies in project execution (Rivera, et. al., 2020; AlGheth & Ishak, 2022). Design delays often occur due to inadequate planning or lack of coordination among teams, which significantly impacts the overall production schedule (Mahamid, et. al., 2012; Asmi, et. al., 2019). Therefore, a well-prepared, detailed, and error-free design is key to ensuring smooth precast production, reducing potential delays, and enhancing overall project efficiency.

Accidents are a significant risk factor that can lead to delays in precast production (Widiantoro, et. al., 2023). Poor safety management on-site is often the primary cause of accidents, resulting from inadequate supervision, insufficient safety procedures, or non-compliance with workplace safety standards (AlGheth & Ishak, 2022). Workplace accidents, such as material falls or equipment failures, not only disrupt operations but can also damage production equipment and project infrastructure, necessitating additional time for repairs (Rivera, et. al., 2020; Tahmasebinia & Song, 2022). Moreover, injured workers reduce overall team productivity, both due to the loss of direct labor and the psychological impact on other workers (AlGheth & Ishak, 2022). With poor safety management, accident frequency increases, ultimately extending the overall project timeline. Therefore, strict safety management, regular training, and proactive supervision are essential to minimize accidents and ensure smooth precast production.

Materials are a primary risk factor influencing precast production delays (Widiantoro, et. al., 2023), particularly due to the high dependency on timely and specification-compliant supply. Material shortages in the market pose a significant challenge, as material scarcity can slow down the production process and force the project to seek time-consuming alternatives (Mahamid, et. al., 2012; Yap, et. al., 2020; AlGheth & Ishak, 2022). Additionally, delays in material supply by the owner or other stakeholders in the supply chain can cause significant gaps in the project schedule (AlGheth & Ishak, 2022). Failing to define the materials to be used, or situations where materials are not specified, creates uncertainty and affects production planning (AlGheth & Ishak, 2022). Changes in material types and specifications often require design and production adjustments, ultimately extending the work duration (Mahamid, et. al., 2012). Other factors, such as material price fluctuations and cost escalation, can also have a significant impact, as material cost fluctuations affect the budget and the ability to procure materials on time (AlGheth & Ishak, 2022; Yap, et. al., 2020). Finally, delays in material delivery, whether due to inefficient logistics or external factors such as bad weather, further increase the risk of production delays (Asmi, et. al., 2019; Tahmasebinia & Song, 2022). Overall, effective material management, including careful supply planning, risk mitigation for price fluctuations, and effective communication with suppliers, is critical to ensuring smooth precast production and minimizing delays.

Equipment is another significant risk factor contributing to delays in precast production (Widiantoro, et. al., 2023). The process heavily relies on the availability and optimal performance of equipment. Delays in equipment ordering or shortages in the market are often the result of poor planning or supply chain issues, causing delays in the production schedule (AlGheth & Ishak, 2022). Furthermore, delays in equipment delivery can extend project timelines, particularly when specialized equipment is needed and requires complex logistics (Asmi, et. al., 2019). During operations, equipment breakdowns represent a major barrier, whether due to mechanical failure or lack of maintenance, leading to temporary production halts for repairs (Tahmasebinia & Song, 2022; Widiantoro, et. al., 2023). Low equipment efficiency and the selection of inappropriate or inadequate equipment also contribute to reduced productivity and longer work durations (Mahamid, et. al., 2012; Yap, et. al., 2020). Other factors, such as fuel shortages, can affect operations, especially in remote locations or areas with limited fuel distribution (Rivera, et. al., 2020). Thus, effective equipment management, including procurement planning, regular maintenance, and the selection of equipment suited to project needs, is essential to ensuring smooth precast production and minimizing delays.

Financial factors are one of the primary risks affecting delays in precast production (Widiantoro, et. al., 2023), as financial stability plays a crucial role in ensuring the smooth execution of construction projects. Financial difficulties on the part of the client or project owner often serve as the initial cause, leading to an inability to meet payment obligations to contractors or vendors in a timely manner (Mahamid, et. al., 2012; Asmi, et. al., 2019; Yap, et. al., 2020; Rivera, et. al., 2020; AlGheth & Ishak, 2022). This issue is exacerbated by delays in advance payments or progress payments, which directly impact the contractor's and subcontractor's cash flow, thereby hindering operations (Asmi, et. al., 2019; Rivera, et. al., 2020; AlGheth & Ishak, 2022). Furthermore, contractors or subcontractors experiencing financial shortages face difficulties in financing material purchases, paying labor, and completing work on time (Yap, et. al., 2020; Tahmasebinia & Song, 2022). Financial struggles on the part of contractors may also lead to delays in payments to subcontractors and vendors, ultimately slowing down the supply chain and production process (Mahamid, et. al., 2012; AlGheth & Ishak, 2022). Additionally, price escalations, such as increases in material costs or fuel prices, further compound the situation by adding pressure to the project's budget (Yap, et. al., 2020). Therefore, effective financial management, including budgeting, cash flow monitoring, and price negotiation, is crucial to mitigate the risk of delays. Improving transparency and communication between all involved parties can also help mitigate the impact of these financial challenges.

Administration is another significant risk factor affecting construction delays (Rivera, et. al., 2020), as it directly relates to the management of documents, contracts, and permits that are essential for the smooth progression of the project. The completeness of documentation often presents an initial challenge, as incomplete or non-compliant documents can obstruct operational processes (Widiantoro, et. al., 2023). Non-standard contract formats and errors in contract documentation can also lead to conflicts or uncertainties in project execution, thereby slowing progress (AlGheth & Ishak, 2022). Delays in approval processes, including both work-related and design revision documents, are common issues that hinder production phases. These delays often stem from a lack of coordination among the parties involved or the time required for thorough verification of technical documents (Mahamid, et. al., 2012; Asmi, et. al., 2019; Rivera, et. al., 2020; AlGheth & Ishak, 2022; Tahmasebinia & Song, 2022). Furthermore, delays in the resolution of contractor claims can cause financial strain and further delay the execution of subsequent tasks (AlGheth & Ishak, 2022). Other factors, such as delays in obtaining permits or land acquisition, are often the result of complex bureaucratic procedures or legal issues, affecting the overall project timeline (Tafazzoli & Shrestha, 2017). Therefore, efficient administrative management, a systematic approach, and strong communication among stakeholders are essential to minimizing delays caused by administrative issues.

Management is a critical risk factor that influences delays in precast production, as ineffective management can disrupt various aspects of the project, from planning to execution (Safapour, et. al., 2019; Widiantoro, et. al., 2023). The lack of experience on the part of the client or project owner in managing construction projects often leads to slow decision-making and mismanagement of resources, ultimately delaying project progress (AlGheth & Ishak, 2022). Limited experience on the part of the contractor also contributes to challenges in efficiently managing the work and anticipating field challenges (Tahmasebinia & Song, 2022). Poor or ineffective communication among stakeholders often results in misunderstandings and misalignments in conveying project objectives and progress, thus hindering operational flow (Mahamid, et. al., 2012; Yap, et. al., 2020; AlGheth & Ishak, 2022; Tahmasebinia & Song, 2022). Additionally, inadequate coordination among the involved parties complicates task execution and timely problem resolution (Tafazzoli & Shrestha, 2017). Delays in decision-making also play a significant role, as delayed decisions create uncertainty, disrupting the project schedule (Mahamid, et. al., 2012; Yap, et. al., 2020; AlGheth & Ishak, 2022). Complicated organizational structures, whether on the owner's side or the contractor's side, can create bureaucracy that slows down processes, while weak field management and oversight result in ineffective project execution (AlGheth & Ishak, 2022; Tafazzoli & Shrestha, 2017). Furthermore, poor progress control and unstable leadership and management styles can lead to a failure in monitoring and directing the project effectively (AlGheth & Ishak, 2022). Overall, effective management requires experience, clear communication, and coordination among all stakeholders, along with a well-defined organizational structure and stringent oversight to ensure that the project is completed within the established timeline.

5. CONCLUSION

Based on the analysis and discussion, the following conclusions can be drawn:

- Ten risk variables were successfully identified and their influence on the delay time in the production of precast house panels was observed. These variables include design, material, equipment, human resources, management, financial, administration, weather, accident, and force majeure, all of which affect the production delay time.
- Nine variables were categorized as high risk based on the Probability and Impact Matrix (PIM). These variables, ranked in order, include human resources, weather, force majeure, design, accident, material, equipment, financial, and administration. The risk variable categorized as moderate and ranked last is management.

The results of this research can be used as a reference for construction projects using precast products. However, these findings cannot be entirely generalized due to the unique nature of each project and the different precast products used. The risk factors causing production delays can be further detailed by breaking them down into indicators for each variable and analyzed more thoroughly using structural equation modelling for more precise insights. This will enable more effective risk control measures and strategies to be implemented, ultimately reducing the risk values and preventing production delays.

6. ACKNOWLEDGEMENT

The researchers would like to express their deepest gratitude and appreciation to the state-owned enterprise in the housing sector for granting permission to conduct this research. The researchers also express their sincere thanks for the support provided by the expert personnel and engineers from the company, including their valuable opinions, comments, and involvement in this study.

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