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Risk Analysis in the Construction Industry Using Project Management Life Cycle and House of Risk

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ABSTRACT

This study aims to identify risks arising in housing construction projects, particularly those related to budget overruns, and to develop mitigation strategies to ensure that projects run according to plan in terms of cost, time, and resources. The methods used are the Project Management Life Cycle (PMLC) to map the project stages from initiation to closure, and the House of Risk (HoR) to identify risk events and risk agents. The novelty of this study lies in the development of difficulty analysis in HoR, which focuses on three main aspects —cost, time, and resources — that have not been explicitly described in previous studies. The results show that the project experienced a cost increase from IDR 150 million to IDR 165 million due to dominant risks, including misinterpretation of design drawings, fluctuations in material prices, and work delays. Through HoR analysis, priority risks were successfully identified, and mitigation strategies were developed in the form of team training to improve design understanding, control of material usage, and the implementation of contingency planning. This research contributes academically by modifying the HoR method with difficulty analysis based on cost, time, and resources, and integrating it with PMLC. It also provides practical guidance to contractors and project managers on anticipating and managing risks more effectively, thereby improving cost efficiency, timeliness, and resource optimization in housing construction projects.

Keywords: Construction Services Industry, House of Risk, Project Management Life Cycle, Risk Agent, Risk Event

INTRODUCTION

Project management life cycle is a skill, tool, and management process that is needed to run a project successfully in planning and completing the project (Westland, 2006). Project management life The cycle has five phases in its stages, namely the initial phase , planning phase , execution phase, monitoring phase and project closing phase project (Omakwu & Chen, 2023). One of the industries used is the construction services industry. The construction services industry is a sector that involves various parties involved in the construction process, including professional workers, construction implementers, and suppliers who together support the needs of industry players. Construction services include the provision of infrastructure and physical facilities, which involve activities such as studies, technical planning, implementation, supervision, and maintenance (Hillebrandt, 1974).

The success of running a project cannot be separated from the risks that occur; it is therefore necessary to identify this plan as well, so that the required actions can be taken to prevent each risk from happening and to mitigate the impact of the risk if it does occur. The initial step in identifying risk is to use the Failure Mode and Effects Analysis (FMEA) method. Furthermore, (Nyoman Pujawan & Geraldin, 2009) initiated the development of a risk identification model that integrates the House of Quality (HoQ). This development is based on the success of HoQ in identifying customer needs, thus the birth of the House of Risk (HoR) model. The House of Risk model is used as a method to identify and analyze risks by determining risk priorities using the latest approaches in risk analysis. This approach combines the principles of Failure Mode and Effects Analysis (FMEA) with the House of Quality (HoQ) model to measure risk quantitatively, allowing for the prioritization of risk agents and the selection of practical actions to mitigate potential risks (Purwaningsih et al., 2021).

The risk of the limitations of the house of risk in its application for mitigation is limited [5]. Data collection still relies on subjective assessments of individuals involved in the process. This can result in variations in data accuracy and consistency, which can affect the results of risk analysis [6]. The success of a project is not only seen from its risk reduction, but the success of the project can also be assessed from the earned value parameter. The earned value parameter is a project management technique that emphasizes project control, making it possible to identify project implementation for project managers regarding variances that can affect the project so that they can take the necessary corrective actions (Proaño-narváez et al., 2022).

The object of research is engaged in the construction sector. The flow of this housing project starts from project preparation and licensing, pre-project implementation, project implementation, evaluation and monitoring, project closing. The stages of the housing project's implementation certainly pose risks, including over budget. The initial budget of 150 million increases to 165 million, and then experiences a deficit. The increase in the budget is due to the risk of over budget.

This research focuses on identifying the risks that occur at the construction project stages starting from the initial phase, planning phase, execution phase, monitoring phase to the project closing phase project. Then, determine the causes of risk in the construction project stages by using the house of risk. After that, a mitigation plan is carried out to avoid the risks in the construction project.

Until now, research related to the house of risk has not been explained in more detail regarding the difficulty, particularly in relation to case studies on projects that are over budget, which is an obstacle in project development. The house of risk does not describe this problem. The use of the house of risk in this problem is one way to minimize the risks that occur. Determining the difficulty in the house of risk is still limited in its definition, ignores aspects such as time, costs, resources, and often influences the determination of problems in building housing projects (A.P., Hari Purnomo, 2021). Therefore, this research is expected to contribute to overcoming the problem of overspending in construction projects by identifying the risks that occur and minimizing them.

The novelty of this study lies in the development of difficulty analysis in the House of Risk (HoR) method. In previous studies, the difficulty aspect was only described in general terms. It was subjective, whereas this study made modifications using more specific and measurable indicators based on the elements of cost, time, and resources. This approach provides a more objective quantitative basis, making the analysis results more accurate and relevant to the actual conditions of construction projects. In addition, this study also integrates HoR with the Project Management Life Cycle (PMLC) and Earned Value Management (EVM), so that it not only identifies risks but also links them to construction project performance, particularly in terms of cost and schedule parameters. The contribution of this research can be seen from two sides. Academically, this research enriches the construction risk management literature through the modification of the HoR method with a more detailed and integrative difficulty analysis. Meanwhile, practically, this research provides guidance for contractors and project managers in developing more effective risk mitigation strategies.

LITERATURE REVIEW

Construction Services Industry

The construction services industry in general is a comprehensive activity related to land preparation and activities that include construction, modification, and repair of buildings, structures, and other related facilities. The construction industry has a primary characteristic where work is carried out based on contracts with employers. Company activities in this industry often last more than one normal operating cycle of the company. Each contract generally produces unique and non-uniform products (Sartono & Ak, 2023)

Project Management

Project management is the application of knowledge, skills, as tools and techniques that are carried out in working on the needs of project activities. Project management is carried out using applications, and in project management, there are stages, namely initiating, planning, executing, and monitoring. And controlling. And ends with closing overall on project activities. Every project is always limited by mutually influencing constraints known as the project constraint triangle, namely, project scope, time, and cost. The balance of the three constraints will determine the quality of the project. A project is an activity that is carried out with the aim of achieving a result within a certain time period. A project can also be said to be a human activity in carrying out a series of activities with a certain purpose. Of course, a project has important characteristics in it as follows (Ir. Iman Soeharto, 1999)

Project Management Life Cycle

Project management life cycle is a structure used in project management from the beginning to the end of the process. The cycle consists of several stages to ensure the implementation, planning, and closing of the project. Important stages in the project management life cycle are namely initial, planning, execution, monitoring, and closing the project. (Omakwu & Chen, 2023) The following is a more detailed explanation regarding the stages of the project management life cycle :

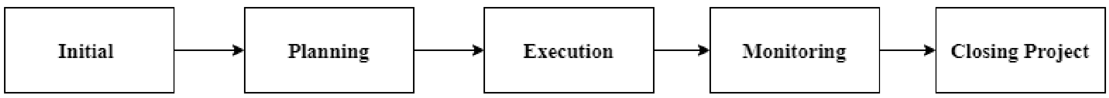

Figure 1. Project management life flow

Initial is the first phase in the project flow stages. Management life in this cycle, business problems or opportunities are identified, and a business study that offers various solutions is prepared. Planning is the stage that explains the planning of the project. The planning includes resources, namely labor, materials, and equipment needed. Execution is the longest phase in the project. This stage is for the final physical results to be made and then submitted to the customer, then the project manager supervises and regulates the activities, resources and costs required. Monitoring is a monitoring stage or evaluation stage of project work results. This activity involves several project teams to run according to plan.
Closing a project is a handover project on the provider's task.

House of Risk

House of Risk Stage 1 is the process of identifying possible risks that occur in the business process. House of risk Stage 1 focuses on identification to risk level based on that is level incident, how much big the impact is, and how reciprocal relationship risk agents and risk event. House of risk stage 1 is used for identify incident risk and agent potential risks arise so that output results in the form of grouping agent risks classified to agents risk priority based on mark aggregate risk potential.

House of Risk Stage 2 is the selection of risk agents based on the highest priority, based on the results of the Pareto diagram. Stage 2 focuses on determining the right mitigation steps to assess the effectiveness of the resources used and the level of performance of its objects. House of Risk stage 2 is intended for mitigation design strategies carried out to handle risk agents in priority categories. Output house of Stage 1 risk will be used as input to the house of risk Stage 2 (Chairani & Siregar, 2021)

Construction Risk Management

Construction Risk Management. The first step in construction risk management is risk identification. This is necessary so that all project stakeholders can determine the specific risks, assess their potential, and analyze their impact. Once the impact has been identified, a process can be carried out to reduce the impact by developing appropriate measures. The risk identification process is similar to identifying positive opportunities so that they are easily identified (Tosun, 2024).

Risk management has several functions, as follows:
1. Identifying, assessing, and ranking risks
2. Focusing on the main risks associated with the project
3. Making the right decisions about existing constraints
4. Minimizing potential damage
5. Controlling uncertain aspects of the project
6. Explaining the roles of each party in the risk management process
7. Finding opportunities to improve project performance.

METHODOLOGY

Data Collection Stage

The data collection technique begins by determining respondents who are experts in the field of construction. After that, sub-process identification is carried out using the Project Management Life Cycle (PMLC), starting from planning to completion. These stages are carried out to ensure that all project stages are covered. The next step is to identify risk agents and risk events that correspond to the specified sub-processes. Each risk agent and risk event is analyzed to understand its potential impact on the project. This process ends with an assessment of the risk agent and risk event to determine the appropriate mitigation steps. Assessing through focus group discussion (FGD).

The FGD was conducted with a project manager selected based on specific criteria to ensure that the risk assessment results remained highly valid. The criteria for selecting respondents included more than five years of work experience in managing construction projects, direct involvement in the planning and control processes of projects, and a deep understanding of the risks that often occur in housing projects.

Data Processing Stage

The data processing technique in this study uses the house of risk stage 1 and house of risk stage 2 methods. The first step taken is to identify sub-processes at the stages in the construction project using the project management life cycle (PMLC). Then the risk assessment process is carried out on the results of the risk identification which includes aspects in each process of the housing construction project. The data analysis and processing process uses the house of risk.

House of Risk 1

- Risk assessment

The risk assessment stage is an assessment used to assess the risk of impact (severity) using a numerical value of 1 to 10, and a value of 10 is very risky. The assessment process with experts. Involvement in conducting this assessment uses the distribution of questionnaires to respondents then The scale used was taken from a literature study on FMEA (Ebrahimi et al., 2022)

Table 1. Severity scale

Scale	Severity	Description
5	Dangerous	Time increase >20% with cost increase >20% and unable to use project results properly
4	Weight	An additional 10% - 20% in time with a 10% - 20% increase in costs and a decrease in quality is not acceptable to stakeholders.
3	Medium	5% - 10% increase in time, with 5% - 10% increase in cost and decrease in quality reported to stakeholders
2	Small	Additional time <5% with cost increase <5% and quality reduction requires stakeholder approval.
1	None	The addition of time does not have a significant impact with the increase in costs not have a significant effect and the decrease in quality is not significant enough.

Then the assessment scale on occurrence has a value of 1 to 5, and a value of 5 is the highest frequency. Here is a table of occurrence assessment scales.

Table 2. Occurrence Scale

Scale	Occurrence	Description
5	Seriously	The incident occurred more than 5 times
4	Happens Often	The incident occurred 4-5 times
3	May Occur	The incident occurred 3-4 times
2	Rarely Occurs	The incident occurred 3-4 times
1	Almost impossible	The incident occurred less than 2 times

Calculating the correlation value obtained from the results of filling out the questionnaire and filled out by experts, then an aggregate risk potential (ARP) assessment is carried out. The correlation scale table is as follows.

Table 3. Correlation Scale

Scale	Occurrence	Description
0	Seriously	Correlation of risk impact on risk agents: there is no correlation
1	Happens Often	The correlation of risk impact to risk agent is weak
3	May Occurs	Correlation of risk impact on risk agents is moderate
4	Rarely Occurs	The correlation of risk impact to the agent is strong

Calculating the aggregate risk value potential (ARP) is used to calculate the risk value by determining the cause of the risk using the following formula:

$ARP_j = O_j \sum Si\ Rij$ ....(1)

Information:

ARPj = aggregate risk potential from risk source causes (j)

Oj = occurrence of risk agent (j)

Si = Magnitude of impact if risk (i) occurs.

Rij = correlation or relationship between risk (i) and risk agent (j)

- Risk Evaluation

Evaluating risk is done by presenting it in a Pareto diagram, taken from the aggregate risk value. Potential (ARP) at each risk agent. Pareto diagram uses the value of 80/20, meaning that 80 percent of the results or effects and 20 percent of the input in each job are responsible for 80 percent of it.

The evaluation stage is the stage of the housekeeping results. of risk stage 1 of each risk. The agent then carries out a risk evaluation to minimize the risk prevention process based on the risk level.

House Of Risk 2

a. After performing the correlation, the next step is to calculate the effectiveness value using the following formula.
   $\mathrm{TEk} = \sum_i \mathrm{ARPj\ Ejk}$ ....(2)
   Information :
   TEk = total effectiveness of implementation of mitigation measures (k)
   ARPj = aggregate risk potential resulting from the causes of risk sources (j)
   Ejk = level of effectiveness of mitigation steps by linking risk (i) and the cause of the risk source (j)
b. Calculating the measurement of the degree of difficulty in implementing PAk with the provisions of 3; low, 4; medium, and 5; high
c. Calculating effectiveness to difficulty ratio (ETDk) using the formula:
   $\mathrm{ETDk} = \frac{\mathrm{TEk}}{\mathrm{Dk}}$
   ....(3)
   Information:
   ETDk = ratio of effectiveness of mitigation difficulty level (k)
   TEk = total effectiveness of implementation of mitigation measures (k)
   Dk = level of difficulty of implementing mitigation steps (k)
d. Calculate PAk priority ranking based on ETDk value
e. In Dk = the level of difficulty of implementing mitigation steps (k) is not explained specifically; therefore, the focus is on time, costs, and resources.
   Dk = level of difficulty of implementing mitigation steps (k)
   Dk = $\mathrm{skala\ time\ x\ skala\ cost\ x\ skala\ resources}$

Table 4 Development Difficulty Analysis on Time, Cost, and Resources

Scale	Time	Scale	Cost	Scale	Resources	References
1	< 6 months	1	150 million – 300 million	1	≤49 employees	(Hobbs & Petit, 2017), (Kleiss & Imura, 2006)
2	6 months – 1 year	2	150 million – 300 million	2	≤49 employees	(Müller et al., 2016)
3	12 years old	3	150 million – 300 million	3	≤49 employees	(Kleiss & Imura, 2006), (Hobbs & Petit, 2017)

Scale	Time	Scale	Cost	Scale	Resources	References
4	23 years	4	300 million – 1 billion	4	50–249 employees	(Hobbs & Petit, 2017),(Kleiss & Imura, 2006)
5	3 – 5 years	5	300 million – 1 billion	5	50–249 employees	(Hobbs & Petit, 2017), (Kleiss & Imura, 2006), (Harrison et al., 2024)
6	5 – 7 years	6	300 million – 1 billion	6	50–249 employees	(Harrison et al., 2024)
7	7 – 10 years	7	1.1 billion	7	≥250 employees	(Müller et al., 2016), (Aerts et al., 2017)
8	10 – 15 years	8	1.1 billion	8	≥250 employees	(Saunders et al., 2016), (Müller et al., 2016)
9	15 – 20 years	9	> 1.2 billion	9	millions of people	(Denicol et al., 2020), (Dille et al., 2018)
10	> 20 years	10	>1.2 billion	10	millions of people	(Denicol et al., 2020), (Harrison et al., 2024)

RESULTS

Construction Project Process Flow

Project process flow construction own stages and explained in the work breakdown structure (WBS), which is a project plan that is detailed in easy-to-see levels. This can help ensure that each product and part of the work is well identified, make it easier to integrate the project with the organization, and form a strong basis for controlling project progress, and make it easier to manage as follows:

Table 5. Work Breakdown Structure

Node	Activity	Worker
1	Licensing Stage	
1.1	Market analysis and location feasibility	Project manager, legal affairs staff
1.1.1	Analysis of community interests/interests	Project Manager
1.1.2	Location survey	Project Manager
1.1.3	Conducting a comparison of alternative locations	Project Manager
1.1.4	Determine the location	Project Manager
1.1.5	Apply for licenses to the relevant institution	Legal Affairs
1.1.6	Land purchase	Project Manager
1.1.7	Project feasibility study	Project Manager

Work Breakdown Structure (WBS) is a breakdown of work at a level and focuses on the results carried out in order to obtain the desired results (Utama & Latief, 2021) . The planning stage is the process of all project activities being planned in detail. The planning stage includes preparing a project work plan, creating a project schedule, and determining project resources. The project implementation stage is the stage of implementing the plan that has been made until the final project results are achieved. The monitoring stage is the stage of continuous project monitoring carried out by the project supervision team so that the project runs according to the housing construction work plan. The project closing stage is the last phase in the project work; all project activities have been completed and approved. The sub-process at this stage is the finishing stage carried out for final project supervision. The first handover is to the buyer.

Identification of Risk Agent and Risk Event

Identifying risk agents and risk events through collecting information from interviews with related experts, and carrying out the analysis based on the stages in the project management life cycle. The stages are the initial phase, planning phase, execution phase, monitoring phase, and project closing phase.

Table 6. Risk Event

PMLC	Sub Process	Risk Event
Initial	1.1 Conduct feasibility studies and market analysis	Market analysis takes a long time from the schedule
		Market analysis requires more costs.
		Mistakes in determining market segments
	1.2 Create a site plan according to land conditions and market share	The site plan design does not match the land conditions (there is land that is too steep/prone to flooding)
		Rejection of the site plan by the authorities
	1.3 Create house designs and infrastructure plans according to market share	Delay in design completion
		Errors and deficiencies in infrastructure plans (Supporting facility plans, such as roads, water channels, or parks, are incomplete)
Planning	2.1 Prepare a project work plan	Delay in preparing project work plan
		Project work planning errors by architects/designers
	2.2 Creating a project schedule	Unreasonable time estimates
		supporting tools or software
	2.3 Determining resources (manpower, materials, equipment)	Shortage of skilled labor
		Delay in the delivery of materials
Execution	3.1 Carrying out material procurement	Materials not available as required
		Delay in the delivery of materials
	3.2 Allocating resources	Delay in project completion
		Disputes with third parties (contractors, etc.)
	3.3 Implementation of housing construction work	Delay in the completion of work
		Work accident
Monitoring	4.1 Supervision of construction work progress	Work progress is not according to schedule
		Work progress is not up to standard
	4.2 Budget monitoring	Project cost overruns
		Late payment

Closing	Finishing Stage (final project supervision) 5.2 Handover 1 (handed over to the buyer)	Defects in the finishing section Non-conformity with the initial design Property Damage before handover Delay in completing work

Table 6. explains the results of risk events in each process and each risk has been validated. Through the stages in the project management life cycle through the initial phase, planning phase, execution phase, monitoring phase and closing project phase and 33 risk events have been identified that may occur.

Table 7. Risk Agent

PMLC	Sub Process	Risk Events
Initial	1.1 Conduct feasibility studies and market analysis	Lack of competent experts Inflation or an increase in the price of consulting services Lack of understanding of local consumer demographics or preferences
	1.2 Create a site plan according to land conditions and market share	Lack of survey or analysis of soil conditions Ignorance or negligence regarding local regulations
	1.3 Create house designs and infrastructure plans according to market share	Project work is delayed. Lack of competent experts (not involving experienced professionals, such as civil engineers or urban planners, in infrastructure planning)
Planning	2.1 Prepare a project work plan	Delay of the entire project Time-consuming and costly repetition of work
	2.2 Creating a project schedule	The project schedule is challenging to implement The scheduling process becomes longer and prone to errors.
	2.3 Determining resources (workforce, materials, equipment)	The difficulty of finding workers with the skills needed Project work gets delayed
Execution	3.1 Carrying out material procurement	The supplier is out of stock, resulting in delayed delivery. Bad weather and logistical problems
	3.2 Allocating resources	Low skilled workers Inadequate quality of work
	3.3 Implementation of housing construction work	Bad weather, lack of coordination between teams, or late material supplies Inadequate use of personal protective equipment, neglected safety procedures, or worker fatigue
Monitoring	4.1 Supervision of construction work progress	Irregular supervision, material delays, or labor shortages Errors in implementation, use of materials that do not meet specifications, lack of supervision, and incompetent labor
	4.2 Budget monitoring	Miscalculation of budget, increase in material price, need for additional work and mistakes in reading design drawings Contractor financial problems, payment arrears from clients, and administrative constraints
Closing	Finishing Stage (final project supervision)	Installation errors, rushed work, or careless inspection Design changes in the middle of work without coordination, or lack of understanding of design specifications
	5.2 Handover 1 (handed over to the buyer)	Worker errors during finishing Handover is delayed

Table 7 explains the results of the risk agents in each process and each risk has been validated. Through the stages in the project management life cycle, through the initial phase, planning phase, execution phase, monitoring phase, and project closing phase. Then, the risk event that has occurred, 33 possible risk agents were identified.

Severity and Occurrence Assessment

Table 8. Severity Assessment

No	Risk Event	Code	Severity
1	Market analysis takes a long time from the schedule	A1	2
2	Market analysis requires more costs	A2	2
3	Mistakes in determining market segments	A3	1
4	The site plan design does not match the land conditions (there is land that is too steep/prone to flooding)	A4	3
5	Rejection of the site plan by the authorities	A5	1

Table 8. explains the results of the severity assessment in the construction services industry. The assessment was carried out through a forum group discussion (FGD) with the assessment being important so that the identified risks can be managed properly and reduce potential risks. The scale used in the assessment uses a scale of 1, which is none, scale 2, which is small, scale 3, which is moderate, scale 4, which is severe, and scale 5, which is dangerous. The results of the severity assessment on the incompatibility of the site plan design with soil conditions and the results of a value of 3 are categorized as having a moderate level of severity. This means that this can cause the project to be delayed and its costs will increase.

Table 9. Occurrence Assessment

No	Risk Agent	Code	Occurrence
1	Lack of competent experts	B1	2
2	Inflation or increase in the price of consulting services	B2	2
3	Lack of understanding of local consumer demographics or preferences	B3	3
4	Lack of survey or analysis of soil conditions	B4	3
5	Ignorance or negligence regarding local regulations	B5	2
6	Project work is delayed	B6	3
7	Lack of competent experts (not involving experienced professionals, such as civil engineers or urban planners, in infrastructure planning)	B7	3

Table 9. explains the occurrence assessment in the construction services industry used to assess the frequency or likelihood of risk occurrence. The assessment was carried out through a group discussion forum (FGD) with the results of the occurrence with code B7, namely the lack of competent experts in the rare category, which is around 2-3 times during the project. This has an impact on obstacles to project implementation due to limited experienced human resources. Although this is not too often, prevention is needed so that it does not happen again.

Correlation Level Assessment

Table 9. Correlation Level Assessment

Risk Events	Risk Agent					Si
	B1	B2	B3	B4	B5	
A1	9	1	3	9	3	2
A2	9	9	3	9	3	2
A3	9	1	9	3	3	1
A4	9	1	3	9	3	3
A5	9	1	3	9	9	1
Occ (Oj)	2	2	3	3	2	
ARP	1120	278	486	1071	510	
Acting	6	28	23	7	22	

Table 4.5 explains the correlation level used to measure the relationship between risk events and risk agents. Based on the risk events and risk agents that have been identified in the previous stage, then the house of risk matrix calculation is carried out on the vertical axis, namely the risk event section and the horizontal axis, namely the risk agent section. Severity (Si) shows the severity level caused by the risk event and occurrence shows the chance of a risk occurring, namely the risk agent. The matrix scale assessment uses a scale of 0, 1, 3 and 0 then, calculating ARPj is carried out to determine the value or potential of the risk.

Aggregate Results Risk Potential (ARP)

Table 10. Aggregate Results Risk Potential (ARP)

No	Risk Agent	Code	ARP	Presentation	Accumulation	Rank
1	Lack of competent experts (not involving experienced professionals, such as civil engineers or urban planners, in infrastructure planning)	B7	1770	7.7%	7.7%	1
2	Delay of the entire project	B10	1266	5.5%	13.3%	2
3	Project work gets delayed	B15	1212	5.3%	18.5%	3
4	Project work is delayed	B6	1212	5.3%	23.8%	4
5	Project schedule is difficult to implement	B12	1140	5.0%	28.8%	5
6	Lack of competent experts	B1	1120	4.9%	33.7%	6
7	Lack of a survey or analysis of soil conditions	B4	1071	4.7%	38.4%	7
8	Time-consuming and costly repetition of work	B11	1029	4.5%	42.9%	8
9	Increase in building material prices during the process	B17	916	4.0%	46.9%	9
10	Errors in implementation, use of materials that do not meet specifications, lack of supervision, incompetent labor	B25	860	3.8%	50.6%	10
11	Installation errors, rushed work, or careless inspection	B28	858	3.7%	54.4%	11

12	The difficulty of finding workers with the skills needed	B14	789	3.4%	57.8%	12
13	Design changes in the middle of work without coordination, or lack of understanding of design specifications	B29	748	3.3%	61.1%	13
14	The scheduling process becomes longer and prone to errors.	B13	724	3.2%	64.2%	14
15	Negligence in document preparation or unclear requirements	B9	694	3.0%	67.3%	15
16	Inadequate quality of work	B21	682	3.0%	70.2%	16
17	Miscalculation of budget, increase in material price, need for additional work, and mistakes in reading design drawings	B26	666	2.9%	73.1%	17
18	Unskilled workers	B20	650	2.8%	76.0%	18
19	Failure to meet technical or administrative requirements	B8	644	2.8%	78.8%	19
20	Irregular supervision, material delays or lack of labor	B24	566	2.5%	81.3%	20
21	Bad weather, lack of coordination between teams, or late material supplies	B22	522	2.3%	83.5%	21
22	Ignorance or negligence regarding local regulations	B5	510	2.2%	85.8%	22
23	Lack of understanding of local consumer demographics or preferences	B3	486	2.1%	87.9%	23
24	The supplier is out of stock, resulting in delayed delivery.	B18	471	2.1%	89.9%	24
25	Worker errors during finishing	B30	390	1.7%	91.6%	25
26	Data on material prices or workers' salaries is inaccurate or missing.	B16	330	1.4%	93.1%	26
27	Bad weather and logistical problems	B19	309	1.3%	94.4%	27
28	Inflation or increase in the price of consulting services	B2	278	1.2%	95.7%	28
29	Contractor financial problems, payment arrears from clients, and administrative constraints	B27	276	1.2%	96.9%	29
30	Ambiguity in the warranty agreement, damage that is deemed not included in the warranty coverage, and differences in perception between the developer and the buyer regarding the cause of the damage.	B33	190	0.8%	97.7%	30
31	Inadequate use of personal protective equipment, neglected safety procedures, or worker fatigue	B23	178	0.8%	98.5%	31
32	Handover is delayed	B31	176	0.8%	99.2%	32
33	Damage to paint, floors, or ceilings due to use or environmental factors.	B32	176	0.8%	100.0%	33

Table 10. explains the results of Aggregate Risk Potential (ARP) based on risk events and risk agents. The calculation of the results of Aggregate Risk Potential (ARP) consists of percentage, accumulation

and ranking on risk agents. Based on the results of the table, the accumulation value below 80% is in codes B7 to B8, and the results above 80% are in codes B24 to B32. After calculating the results of Aggregate Risk Potential (ARP), then analyze the results of the Pareto diagram on house of risk 1.

Risk Priority Determination

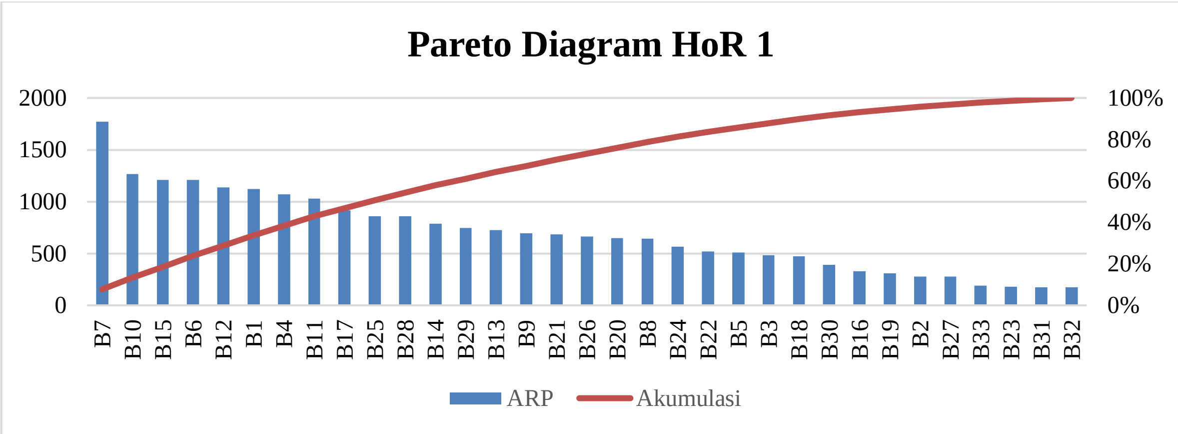

Figure 1. HoR 1 Pareto diagram

Figure 1 is the result of a Pareto diagram using the 20/80 concept, which states that 20% of causes produce 80% of events, then 80/20, which means 80% of events that occur are influenced by 20% of causes. The Pareto diagram results show a blue bar (ARP) indicating the number or frequency of events for each risk category. The orange line (accumulation) shows the cumulative total.

The research results have presented a fairly detailed identification of risks in the form of risk events and risk agents, which were then analyzed using House of Risk (HoR) stage 1 through the calculation of Aggregate Risk Potential (ARP). However, the discussion of the results should not stop at a description of the figures, but needs to be interpreted more deeply by relating the dominant risks to the actual conditions of construction projects in Indonesia. For example, the risk of misinterpretation of design drawings, which ranks high in ARP, reflects a common problem in housing projects, where coordination between the design team and the field implementers is still weak, resulting in cost overruns and delays. Similarly, the risk of material price increases is in line with the often unstable fluctuations in building material prices in Indonesia, which has a direct impact on budget overruns.

House Of Risk 2

Table 11. Risk Agent Priority Based on Pareto Diagram

No	Risk Agent	Code	ARP	Percentage	Accumulation	Rank
1	Lack of competent experts (not involving experienced professionals, such as civil engineers or urban planners, in infrastructure planning)	B7	1770	7.7%	7.7%	1
2	Delay of the entire project	B10	1266	5.5%	13.3%	2
3	Project work gets delayed	B15	1212	5.3%	18.5%	3

4	Project work is delayed	B6	1212	5.3%	23.8%	4
5	Project schedule is difficult to implement	B12	1140	5.0%	28.8%	5
6	Lack of competent experts	B1	1120	4.9%	33.7%	6
7	Lack of survey or analysis of soil conditions	B4	1071	4.7%	38.4%	7
8	Time-consuming and costly repetition of work	B11	1029	4.5%	42.9%	8
9	Increase in building material prices during the process	B17	916	4.0%	46.9%	9
10	Errors in implementation, use of materials that do not meet specifications, lack of supervision, incompetent labor	B25	860	3.8%	50.6%	10
11	Installation errors, rushed work, or careless inspection	B28	858	3.7%	54.4%	11
12	The difficulty of finding workers with the skills needed	B14	789	3.4%	57.8%	12
13	Design changes in the middle of work without coordination, or a lack of understanding of design specifications	B29	748	3.3%	61.1%	13
14	The scheduling process becomes longer and prone to errors.	B13	724	3.2%	64.2%	14
15	Negligence in document preparation or unclear requirements	B9	694	3.0%	67.3%	15
16	Inadequate quality of work	B21	682	3.0%	70.2%	16
17	Miscalculation of budget, increase in material price, need for additional work, and mistakes in reading design drawings	B26	666	2.9%	73.1%	17
18	Low-skilled workers	B20	650	2.8%	76.0%	18
19	Failure to comply with technical or administrative requirements	B8	644	2.8%	78.8%	19

Proposed Preventive Action

Table 12. Proposed Preventive Action

Preventive Action (PAn)	Code
Create training and certification programs for competent experts	PA1
Use of project management software to monitor and control progress	PA2
Improve coordination between stakeholders to prevent communication barriers.	PA3
Preparation of a realistic project schedule, taking into account potential risks	PA4
Periodically evaluate project progress and take necessary corrective actions.	PA5
Conducting recruitment of competent experts in their fields	PA6
Involving geotechnical consultants in construction planning	PA7
Use of BIM technology (building information modeling) to detect design errors early on	PA8
Preparation of flexible budget estimates, taking into account price fluctuations	PA9
Strict supervision with checklists and standard operating procedures	PA10
Conduct training sessions on correct installation methods according to specifications.	PA11
Collaborate with educational institutions or professional training institutions.	PA12
Implementation of a strict approval process before design changes are made	PA13
Use of project management software	PA14

Conducting a checklist of administrative requirements before the project starts	PA15
Conduct periodic audits to ensure compliance with project standards	PA16
Provide team training to properly understand design drawings and prevent misinterpretation.	PA17
Preparation of workforce competency standards based on project needs	PA18

Table 12. is the result of preventive proposals action at home of risk 2. Preventive action is an important step to identify potential causes of risk, so that negative impacts can be avoided. There are 19 proposed preventive actions that are coded PA1 to PA19 to facilitate analysis. PA1 is to create a training and certification program for competent experts because construction workers can have an impact on the quality of work done. Thus, the company does not lack incompetent experts in the process of conducting feasibility studies and market analysis. PA2 is the use of project management software to monitor and control progress used so that there are no delays in the preparation of the project work plan, the aim is to complete the work according to plan.

D8. Development of House Of Risk Matrix 2

Table 11. explains the results of risk 2, based on the risk agent and the preventive action that has been analyzed in the previous sub-chapter. Then, it is developed in the house matrix of the risk, with the risk event on the vertical axis and preventive action on the horizontal axis. The aggregate risk potential (ARPj) shows the potential risk. Degree of difficulty (DK) is the level of ease in implementing preventive measures. Determination of difficulty focuses on the aspects of time, cost, and resources. Meanwhile, Effectiveness to Difficulty (ETD) measures how effective a preventive measure is compared to the difficulty in implementing it. The difficulty assessment is adjusted to 4, regarding the development of difficulty analysis on time, cost, and resources.

Table 11. Development of House Of Risk Matrix 2

Risk Agent (Aj)	**Preventive Action**					**ARPj**
	PA1	**PA2**	**PA3**	**PA4**	**PA5**	
B7	9	3	3	1	3	1770
B10	3	9	9	9	9	1266
B15	0	9	3	9	9	1212
B6	0	9	3	9	9	1212
B12	0	3	3	9	9	1140
Total effectiveness of the action (Tech)	50829	67455	55350	55686	97794	
Degree of Difficulty (Dk)	27	8	12	12	27	
Effectiveness to Difficulty (ETD)	1883	8432	4613	4641	3622	
Rank of Priority	12	1	6	5	9	
Total effectiveness of the action (Tech)	PA1	PA2	PA3	PA4	PA5	

Determining the Priority of Preventive Action

Table 12. Preventive Action Priority

	Preventive action (PAk)								
Pack	PA2	PA14	PA10	PA17	PA4	PA3	PA11	PA15	PA5
ETD	8432	8159	7089	5281	4641	4613	3969	3809	3622
Presentation	13.22%	12.79%	11.11%	8.28%	7.27%	7.23%	6.22%	5.97%	5.68%
Accumulation	13.22%	26.01%	37.12%	45.40%	52.67%	59.90%	66.12%	72.09%	77.77%

Table 12. preventive priorities, actions that have been calculated in the previous sub-chapter, there are as many as 19 preventive actions. Effectiveness value to The difficulty (ETD) is calculated and the largest value will be selected in the risk priority based on the Pareto diagram principle. The ETD value indicates the effectiveness of the difficulty or assesses how effective the solution provided is against the existing risk.

Preto House Of Risk Digram 2

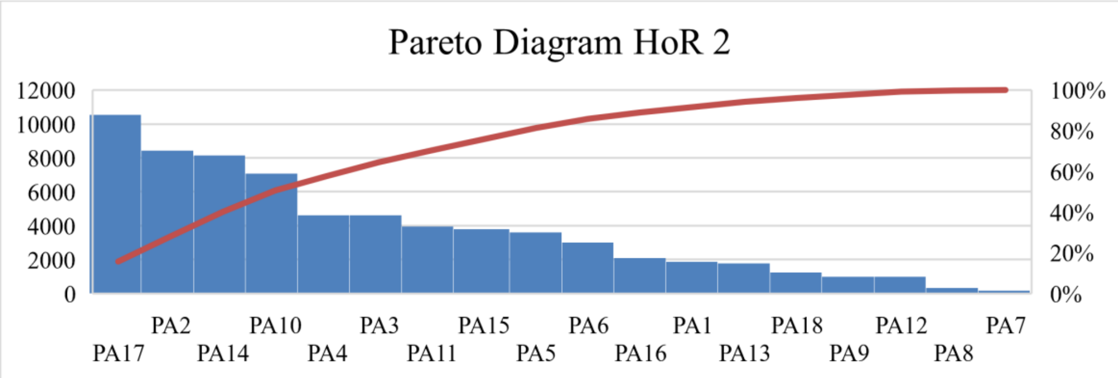

Figure 2. Pareto HoR 2 diagram

Preventive priority results in action. The most important thing to mitigate is using the Pareto concept, namely 80/20, which states that 80% of preventive measures can overcome 20% of the total potential risks. Based on the Pareto, it can be seen that the most important risk, namely PA17, is considered to be the easiest solution, namely providing team training to understand design drawings properly and preventing misinterpretation, because the over budget experienced was caused by workers misreading engineering drawings.

The selection of PA17 in the form of team training to improve understanding of design drawings is considered a priority solution because it is in line with the actual conditions in the Indonesian construction industry. One of the fundamental problems that often occurs is the lack of competence of workers in reading and interpreting technical drawings, which leads to errors in the implementation stage, resulting in material waste, work delays, and even rework. Other mitigation alternatives, such as increasing field supervision or implementing design management software, are indeed relevant, but both have limitations. Increased supervision requires additional human resources and higher operational costs, while the use of modern software such as BIM (Building Information Modeling) requires high-tech investment and digital infrastructure readiness, which remains a challenge for many medium-sized contractors in Indonesia.

CONCLUSION

Identification of risks that arise in the housing construction project process, there are risk agents and risk events with the total of both being 33 risks. Identifying these risks certainly begins with identifying each process in the housing construction project using the project management life cycle. This process goes through the initial phase, planning phase, execution phase, monitoring phase and project closing phase. One of the risk-arising processes is that housing construction has a risk event with code A22, namely delays in completing project work and work accidents in the project environment.

The causes of risk that are prioritized for mitigation in the housing construction project process are 19 risk agents. This is taken through house of risk calculations based on the results of the Pareto diagram. Based on the results of the Pareto diagram, the risk cause that has a major impact on B7 is the lack of competent experts, because it will have an impact on the overall project activities. Competent experts are very important to ensure construction quality. The cause of risk B10 is the delay of the entire project which has an impact on the construction of housing so that the risk causes corrective action to ensure the project is completed on time and on budget. Risk agent B29 is a design change in the middle of work without coordination or lack of understanding of the design specifications causing a discrepancy with the initial design so that it is necessary to coordinate with all parties involved such as architects, contractors and craftsmen so that there is no misunderstanding. Then, if there is a lack of understanding of the design, it can cause the final result to be inconsistent with the initial plan.

The mitigation plans are carried out in order to avoid risks that arise in the housing construction project process. The proposal is based on the results of preventive action in the house of risk. Based on the Pareto, it can be seen that the most important risk, namely PA17, is considered the easiest solution, namely providing team training to understand design drawings properly and prevent misinterpretation, because the over budget experienced was caused by workers misreading engineering drawings, so training is needed. PA2, namely the use of project management software to monitor and control progress, is used to avoid delays in project work so that it does not disrupt the entire project work timeline.

This study not only contributes academically through modifications to the difficulty analysis in the HoR method, but also provides practical solutions that can be applied in the field. However, this study has limitations because it only uses one case study on a housing project with limited data from 2024–2025, so the results cannot be generalized to other construction projects of different scales. Therefore, further research is recommended to involve more case studies on infrastructure or high-rise building projects, as well as integrating the latest technologies such as Building Information Modeling (BIM) or artificial intelligence-based analysis to improve the accuracy of risk identification and mitigation.

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