



RISK FACTORS IN LIFE CYCLE PHASES OF INDONESIA GEOTHERMAL POWER PLANTS PROJECT

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Abstract

The project life cycle must be managed by carrying out a series of project management activities, which are generally known as the project management process. Each project management process generally produces one or more outputs, including the implementation of the Geothermal Power Plant Project in Indonesia. It can be seen that, as of now, the development of several Geothermal projects in the country is at risk of delay or loss. This is most likely caused by several risk issues that arise throughout the project life cycle. Therefore, this study aims to identify various obstacles that contribute to the risks that interfere with the success of the project. This study is a descriptive study where the research method is intended to overcome existing risks, which still happen today, with a description of Geothermal Project Development activities. The Statistical Package for the Social Sciences (SPSS), a statistical method, was used to analyse various risk factors. The results of processing the discussion data from 17 risk factors revealed the 5 greatest risk factors in sequence, namely X2 (Exploration), X3 (Drilling Test), X4 (Feasibility Study), X11 (Actual Volume Estimation), and X17 (Risk Management).

Keywords: Project Life Cycle, Construction, Geothermal, Power Plant Project

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INTRODUCTION

Indonesia is currently implementing the 20-year development plan, starting from 2005 to 2025. One of the programs is carried out with the intention of expanding the electricity plants to meet the demand for electricity, which increases by 10% every year (Kashem, 2021). In essence, electricity consumption will encourage economic growth in a country (Mohammed, 2023). One of the significant components of energy consumption is electrical energy. In fact, the importance of electricity for economic growth has been recognised by economists, engineers, and various government agencies.

Based on the energy sector, Indonesia has the largest capability to advance geothermal energy as it has the largest geothermal resources in the world. In other words, Indonesia is endowed with 35% – 40% of the world's geothermal resource potential (Fan & Nam, 2018). One of the biggest advantages of geothermal energy is that geothermal power is a very predictable and reliable energy source, especially compared to other renewable energies (Energy Sage, 2021).

Fan and Nam (2018) found that significant social change requires systematic development of Indonesia's geoscience sector through improvements in economic, social, environmental, legal, and regulatory contexts. GeothermEx (2010) reports that the high project risks in geothermal development create the main hurdle preventing the expansion of such projects since developers must accept substantially greater risks when compared to other investments (Castlerock, 2010; International Finance Corporation, 2013; Nur et al., 2023). According to JICA (2009), the main resource-related challenges and the initial investment burden are the key obstacles to geothermal development in Indonesia (Nur et. al., 2023).

LITERATURE REVIEW

GEOTHERMAL

Geothermal can be defined as hot steam that originates from beneath the earth's surface, which can be utilised as one of the potential sources of renewable energy. Basically, geothermal energy originating directly from the earth's crust comprises an estimated 20% of the new formation of the core of the earth and 80% of the materials under the crust and radioactive disintegration (Kashem et al., 2021). Although magma is a mixture of liquid or semi-liquid rock located beneath the earth's crust, it is also active. Magma generates heat through the continuous radioactive decay of naturally occurring radioactive substances like uranium as well as potassium.

Besides, Kashem et al. (2021) list some practical applications of geothermal energy in one's daily life. In winter, it is necessary to wash using hot water. Hot water from a geothermal pump can heat the whole bathroom when, for instance, someone is taking a bath. In order to receive hot water instantly from

below the surface of the earth, several countries construct geothermal water reservoirs. Some of the reservoirs are employed for industrial and commercial uses as well as residential use.

GEOTHERMAL ENERGY

In modern usage, hot water is obtained from geothermal reservoirs. Hot water is often required for many processes that need heating. In this case, a well is made to the geothermal reservoir in order to draw hot fluids from the earth's interior through a pipeline in a closed-loop geothermal heat pump. In general, its mechanical system includes a piping system, a heat exchanger, and some controllers. Besides transferring the water through the well mechanism, this type of mechanical system can be applied as a direct heat distribution system for other purposes. To minimise the flow rate of cold water from the system, a discharge system is incorporated to return the cold water to the ground or discharge it to the surface of the earth (Kashem et al., 2021).

On the other hand, in some countries, geothermal energy potential is utilised for greenhouse and aquaculture purposes. These two are the primary ways that geothermal energy potential sources are utilised within agribusiness. This is so because geothermal resources can substitute the use of traditional energy sources by 80%. This is very important because, in the past, the use of conventional energy resources like fuel energy could have polluted the environment in many ways, and it was also cheaper to use geothermal energy than to use some of these conventional sources of energy. Geothermal energy in remote geographical regions can mean clean air and water, fewer disease incidences, and opportunities for stable employment for those living in such regions (Kashem et. al., 2021).

GEOTHERMAL POWER PLANT PROJECT

A power plant is an installation that generates electrical power from some form of primary energy. The majority of power plants rely on one or more generators that turn mechanical energy into electrical energy, so that they pull power from the electrical grid needed by the community. The only exception is the solar power plants that source this electricity with the help of photovoltaic cells, not turbines (Atkins & Escudier, 2013).

During the implementation of the geothermal project development, there are several risks and obstacles that occur in several stages, which must be managed properly. Cost overruns occur when actual project expenditures exceed initial cost estimates, thereby causing financial stress, delays in completion, and stakeholder dissatisfaction (Sondakh & Palsson, 2021). In general, the average magnitude of cost overruns in the construction industry depends on various project characteristics, including project location, project type, industry, and construction time (Habibi et al., 2019).

Several contingencies in a few activities of the Geothermal Project development phase in Sarulla have led to the prolongation of time and cost. While drilling, the drill pipe becomes lost in the borehole; hence, formation irregularities or the drill pipe could not maintain the right mud pressure, which leads to a blowout (Schlumberger, 1999). On the other hand, in the construction phase, the developer relies on the contractor, asserting that the factory will be constructed by the contractor and its subcontractors in accordance with the design and timeline within which the project is developed, and that the key components of the technology will operate as anticipated (Rakhmadi & Sutiyono, 2015).

PROJECT LIFE CYCLE

The project life cycle is controlled through the performance of project management activities referred to as Project Management Processes. Each of the project management processes results in an output or multiple outputs from one or more inputs by employing project management tools and techniques. It can be a deliverable or an output. Outcomes are a terminal condition, as they are the culmination of something. Project management processes are used universally across organisations (PMI, 2017). Project management processes are sequentially integrated because of their deliverables.

The Project Management Process Group is a collection of processes that apply to a certain project purpose. Process groups do not correlate with project phases. There are five major Project Management Process groups that categorise project management processes. The EPC project problems and challenges are segregated for each phase of the project for better understanding (Akhtar, 2020).

Based on interviews with experts, some reasons attributable to EPC project cost overruns include inadequate resource commitment to actual activities, a limited budget, inapplicable resources, and resource procurement problems that do not meet project goals or objectives. Thus, safety, time, quality, and cost are the four key PSs for evaluating the success of project performance of all the projects being managed by the project management regardless of the type of project and the different phases of the project from initiation to project completion in accordance with the contractual terms (Mairizal et. al., 2020; Roshdi et. al., 2023).

The composition of development costs for geothermal power plant projects varies greatly in each project's life cycle. The probability of success rate is very low in the initial stages of development, particularly in the exploratory stage, wherein there is still a high degree of risk. The upstream initiation stage, especially the test drilling stage, is generally considered the most risky in the development of a geothermal power project (Gehringer & Loksha, 2012). The risk is relatively lower after test drilling, but the cost is equally high since SAGS and power plant construction costs can amount to 60% or more of the total project cost (Sondakh & Palsson, 2021).

Initiating Process Group

Procedures executed to establish what a given project entails or a given phase of a project following the acquisition of approval to commence the project or phase (PMI, 2017).

1. Front End Engineering Design (FEED) Readiness & Endorsement
2. Inherited Bidding Inaccuracies and Estimation Mistakes
3. Aggressive Un-realistic Schedule

Planning Process Group

The specific activities are those that are needed to define what the project will encompass, what is to be accomplished within the processes, and the action plan for achieving the goals for which the project was done (PMI, 2017).

1. Changes in Rely Upon Data/Information
2. Engineering & Design Deliverables Late Submission & Approval
3. Weak or Poor Project Planning
4. Non-receipt of NOC Or Permits from statutory authorities after the due date
5. Delay in Developing Project Management Team & Relevant Inadequacies
6. Team Competency Gaps
7. No Consideration of the Previous Project's Lesson Learn

Executing Process Group

As per those processes that are carried out to deliver the work that has been specified in the project management plan to meet the requirements of the specific project (PMI, 2017).

1. Engineering Query and Resolution: The following complicated the process by delaying response time.
2. Engineering/Design Issues and Changes
3. This has led to ineffective leadership and poor decision-making: This has made leaders ineffective and caused them to make poor decisions.
4. Lack of project workforce, tools, and other equipment
5. Delay in Materials Ordering, especially LLI's
6. Delay in Manufacturing and Delivery of Materials (incl. LLIs)
7. Poor Cash Flow
8. Serious HSE Violations and Accidents
9. Construction Implementation Failures
10. Delay in Permit to Work (PTW) issuance and compliance

Control & Monitoring Process Group

Those processes needed for monitoring, controlling, and documenting the project's progress and performance; determining which aspects of the plan require modification; and implementing such modifications (PMI, 2017).

1. Lack of proper supervision and legislative measures during the implementation process of a project.
2. As mentioned above, poor Interface Management also includes poor communication in project management.
3. Lack of Risk Identification, Analysis, and Assessment for Project Risks

Closing Process Group

Adaptive: Those processes performed to formally complete or close the project, phase, or contract (PMI, 2017).

1. There was an inadequate inclusion of provisions for feedstock for commissioning and start-up.
2. This is due to either a delay in the finishing of the item. Project As-built activities are taking longer to complete.
3. Around the prevention of early demobilisation of the project management team
4. Delay in punch list clearance
5. Incomplete, inadequate, or untidy close-out report
6. Delay in punch list clearance
7. Delay in provisional acceptance certificate issuance

RISK FACTORS

Power plant construction encompasses elaborate and sophisticated mechanical, electrical, and civil works together with highly related technical, environmental, social, and political factors (Islam et al., 2023). This makes projects a bit risky, especially where the cost overruns are frequent and sometimes highly charged. For instance, in their review of 401 power infrastructure projects across the globe, they discovered an average cost overrun of 66%. However, according to another study, this figure was as high as 200% for power plant projects in Europe and North America, as ascertained by HIS in 2014. Hence, the advice to lessen overruns is often to assess the possible risks implicated and their consequences carefully (Islam et al., 2023).

A major problem in doing this for complex projects is that there is little information concerning project uncertainties and incomplete knowledge of the project, implying that project complexity in general raises the level of information uncertainty. Lack of understanding of the interactions between risks during risk assessment is also one of the key reasons for producing an incorrect risk

assessment in projects of various kinds of complex nature. However, it is always difficult to get the full picture of prospects of large and complicated projects in terms of objectives, resources, environment, and project risk, owing to their specificity. Regarding interdependencies between power plant project risks, it has to be remembered that they are high and the practitioners must keep this in mind when deciding on the cost of the project and its risks (Islam et. al., 2023). Below are several risk factors during the project life cycle of a geothermal development project, as outlined in some literature (Table 1).

Table 1: Risk Factors during Project Life Cycle from literature.

	Initiating	Planning	Executing	Control & Monitoring	Closing
Oishi (2000) Setiawan (2014) IAEA (2015) Zhu et. al.(2015) Rera et.al. (2021) Aziziah et. al. (2023)	Pre-survey	Pre-survey			
Oishi (2000) Setiawan (2014) Zhu et.al. (2015) Rera et.al (2021) Aziziah et. al. (2023)	Exploration	Exploration			
Oishi (2000) Setiawan (2014) Zhu et.al. (2015) Rera et.al (2021) Igwe (2021)	Test Drilling	Test Drilling			
Oishi (2000) Setiawan (2014) IAEA (2015) Zhu et.al. (2015) Rera et.al (2021) Aziziah et. al. (2023)	Feasibility Study	Feasibility Study			
Oishi (2000) Setiawan (2014) Zhu et. al. (2015) Rera et. al (2021) Igwe (2021)	Drilling	Drilling			
Setiawan (2014) Zhu et. al. (2015) Igwe (2021) Negara et. al. (2022) Putri & Sulhan (2023)		Construct-ability	Construct-ability	Construct-ability	Construct-ability
Setiawan (2014) Sahdarani et. al. (2020) Negara et. al. (2022) Aziziah et. al. (2023) Negrin (2024)					Start-up
Sovacool et. al.(2014a) Valipour et. al. (2015) PMI (2017)		Working Items Complexity	Working Items Complexity	Working Items Complexity	Working Items Complexity

	Initiating	Planning	Executing	Control & Monitoring	Closing
Eash-Gates et. al. (2020)					
Islam et. al. (2023)					
Oishi (2000)		Working Detail	Working Detail	Working Detail	Working Detail
PMI (2017)		Understand	Understand	Understand	Understand
Wahyudi et.al. (2019)					
Sarbini et.al. (2021)					
Yudha et.al (2022)					
Zhu et. al. (2015)			Design Change	Design Change	Design Change
Yudha et. al (2022)					
Negara et. al. (2022)					
Negrin (2024)					
Zarrouk & Simiyu (2013)			Actual Volume	Actual Volume	Actual Volume
Bilqist et. al. (2018)			Estimation	Estimation	Estimation
Dewi et. al. (2022)					
Negrin (2024)					
Pambudi & Ulfa (2024)					
Zarrouk & Simiyu (2013)		Complexity of	Complexity of	Complexity of	Complexity of
Bilqist et. al. (2018)		Work Method	Work Method	Work Method	Work Method
van Wees et. al. (2020)					
Sarbini et. al. (2021)					
Dewi et. al. (2022)					
Mairizal (2021)		Inspection Test	Inspection	Inspection Test	
Sarbini et. al. (2021)		Plan	Test Plan	Plan	
Kashem et. al. (2021)					
Karytsas et. al. (2022)					
Dachyar et. al. (2023)					
Setiawan (2014)	Site	Site			
Zhu et. al. (2015)	Investigation	Investigation			
Rera et. al (2021)					
Mairizal (2021)					
Aziziah et. al. (2023)					
Zarrouk & Simiyu (2013)		Resources	Resources		
PMI (2019)		Availability	Availability		
Mairizal (2021)					
Dewi et. al. (2022)					
Larasati et. al. (2024)					
PMI (2019)					
Mairizal (2021)		Contractor			
Yudha et. al. (2022)		Planning			
Aziziah et. al. (2023)					
Larasati et. al. (2024)					
PMI (2019)	Risk	Risk	Risk	Risk	Risk
Mairizal (2021)	Management	Management	Management	Management	Management
Karytsas et. al. (2022)					
Yudha et. al. (2022)					
Aziziah et al. (2023)					
Total frequency	7	14	9	8	8

RESEARCH METHODOLOGY

This study is descriptive research, and its purpose is to address existing risks associated with the Geothermal Project Development activities. The author used the Statistical Package for the Social Sciences (SPSS) statistical method to analyse various risk factors that cause cost overruns in the construction of the Geothermal project. The following explains the methodological steps used and the risk factors that caused excess costs, as shown in Figure 1 and Table 2.

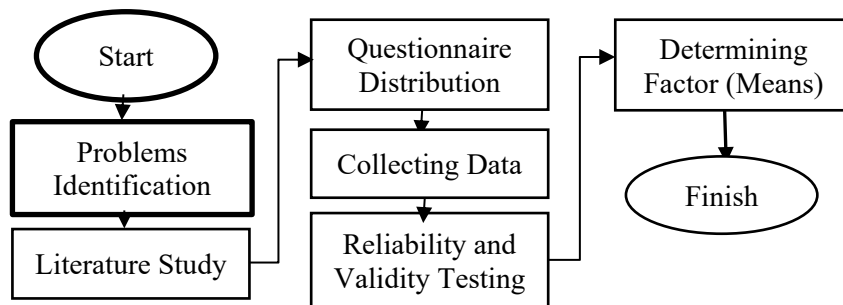


Figure 1: Research Methodology

This study produced 17 risk factors in 5 project cycle phases and tested them on 18 respondents (n+1) taken from investor companies and EPC contractors using the purposive sampling method. Based on the description of the 17 risk factors in Table 1, data processing was carried out using SPSS to evaluate the reliability and validity outcomes. The results of the data processing are sorted from the highest to the lowest mean value.

In this study, data collection was conducted on 18 geothermal development companies in Indonesia. Data were collected using questionnaires from those who are very influential in the development of geothermal projects and who have more than 20 years of experience.

They were given a questionnaire related to 17 factors that determine the sustainability of geothermal development in Indonesia. In its implementation, all of them responded based on their experience in developing geothermal-based power plants in Indonesia.

Table 2: Risk Factors During Project Life Cycle (summary)

	Initiatin g	Plannin g	Executing	Control & Monitoring	Closing
Pre-Survey (X1)	/	/	-	- -	-
Exploration (X2)	/	/	-	-	-
Test Drilling (X3)	/	/	-	-	-
Feasibility Study (X4)	/	/	-	-	-
Drilling (X5)	/	/	-	-	-
Construct Ability (X6)	-	/	/	/	/
Start-up (X7)	-	-	-	-	/
Working Items Complexity (X8)	-	/	/	/	/
Working Detail Understand (X9)	-	/	/	/	/
Design Change (X10)	-	-	/	/	/
Actual Volume Estimation (X11)	-	-	/	/	/
Complexity of Work Method (X12)	-	/	/	/	/
Inspection Test Plan (X13)	-	/	/	/	-
Site Investigation (X14)	/	/	-	-	-
Resources Availability (X15)	-	/	/	-	-
Contractor Planning (X16)	-	/	-	-	-
Risk Management (X17)	/	/	/	/	/
Total Schemes	7	14	9	8	8

ANALYSIS AND DISCUSSION

The study starts its analysis section by validating reliability scores with alpha values > 0.70 and validity standards that exceed r-table values. Pearson coefficient characteristics show $r\text{-table} = 0.4000$ according to Pearson's Product-Moment r-table with a significance level of 0.05. Next, the study establishes its research beginning with the analysis section by validating reliability scores that exceed 0.70 values and demonstrating validity standards higher than r-table benchmarks.

The results of data processing carried out using the statistical program of social sciences version 24.0, recommending $r\text{-table} = 0.4000$ ($r\text{-table}$ for Pearson's Product Moment significant level = 0.05). Data was analysed by SPSS, whereby the minimum r-count result was 0.404 (X3) for the test drilling factor. Meanwhile, for the reliability test, the Cronbach's Alpha value ranged from 0.938 to 0.951 (Table 2). In addition, the highest mean calculation result was 4.0556 (X2 or exploration), and the lowest mean was 3.3333 (X15 or resource availability).

Table 3: Item Statistics

	Mean	Std. Deviation	N	Corrected Item- Total Correlation	Cronbach's Alpha if Item Deleted
X1	3.7222	.82644	18	.729	.941
X2	4.0556	.72536	18	.529	.945
X3	3.8333	1.04319	18	.404	.951
X4	3.8333	.70711	18	.479	.946
X5	3.7222	.82644	18	.807	.940
X6	3.5556	.85559	18	.858	.938
X7	3.3333	.68599	18	.894	.938
X8	3.6667	.68599	18	.718	.942
X9	3.3889	.91644	18	.852	.938
X10	3.6667	.59409	18	.805	.941
X11	3.7778	.64676	18	.702	.942
X12	3.3889	.91644	18	.617	.944
X13	3.6111	.69780	18	.583	.944
X14	3.6111	.60768	18	.747	.941
X15	3.3333	.68599	18	.761	.941
X16	3.4444	.78382	18	.775	.940
X17	3.7778	.64676	18	.734	.942

As can be seen from the factor analysis highlighted in Table 3 above, the seventeen risk factors can be ranked as determining risk factors that have an impact during the project life phase, as shown in Table 4 below.

Table 4: Determinant Risk Factors during Project Life Cycle

	Mean	Std. Deviation	N	Corrected Item- Total Correlation	Cronbach's Alpha if Item Deleted
X2	4.0556	.72536	18	.529	.945
X3	3.8333	1.04319	18	.404	.951
X4	3.8333	.70711	18	.479	.946
X11	3.7778	.64676	18	.702	.942
X17	3.7778	.64676	18	.734	.942
X1	3.7222	.82644	18	.729	.941
X5	3.7222	.82644	18	.807	.940
X8	3.6667	.68599	18	.718	.942
X10	3.6667	.59409	18	.805	.941
X13	3.6111	.69780	18	.583	.944

	Mean	Std. Deviation	N	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
X14	3.6111	.60768	18	.747	.941
X6	3.5556	.85559	18	.858	.938
X16	3.4444	.78382	18	.775	.940
X12	3.3889	.91644	18	.617	.944
X9	3.3889	.91644	18	.852	.938
X7	3.3333	.68599	18	.894	.938
X15	3.3333	.68599	18	.761	.941

When looking at the results of the ranking of the determining factors in Table 4 above, it can be seen that the Exploration factor is ranked at the top. This is in accordance with research by Pálsson (2017), which states that the composition of geothermal power plant project development costs varies greatly in each project life cycle. The exploration stage is the one that still has a very low success rate in development.

The second rank is Test Drilling, which is also in accordance with research by Gehringer & Loksha (2012), which states that the upstream initiation stage, especially the test drilling stage, is usually seen as the riskiest part of geothermal power project development.

Meanwhile, the third rank, namely the Feasibility Study, is also a determining factor according to Kashem et al. (2021). There are several challenges in the development of geothermal energy in Indonesia that need a highly detailed analysis of the feasibility study. The obstacle is the high operational costs. As for the risk distribution level, the highest percentage is observed at the exploration stage. As a result, more funding is required from the owner for the advancement of geothermal energy.

CONCLUSION

Referring to the results of the previous discussion, X2 (Exploration), X3 (Test Drilling), X4 (Feasibility Study), X11 (Actual Volume Estimation), and X17 (Risk Management) were the most significant factors that contributed to the highest risk. Due to the limitations in terms of opportunities and writing space, this research was developed in a broader direction with more detailed data processing steps.

Geothermal investment development requires multiple years for implementation, along with substantial financial costs. This initiative presents both dangerous conditions and five crucial alerting results according to the study findings. Results from the investigated cases established that exploration

processes take excessive durations, while drilling tests require substantial financial investments. Consistent geological research conducted repeatedly escalates drilling expenses and results in operational unpredictability. Initial investments in geothermal development need precise underground event prediction data at project initiation; thus, this study serves as an essential tool for new geothermal ventures. Nevertheless, the research constraints require strict research expansion among all participating programs.

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