

Analysis of Delay Factors in Drinking Water Supply System Development Projects on Small Islands (Case study of the Drinking Water Supply System Project on Maratua Island)

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Abstract

To fulfill cost, quality, and schedule restrictions, construction projects must carefully plan, execute, and oversee project management. Construction delays frequently raise expenses and lower quality. An operational Water Supply System (SPAM) is essential in distant places like tiny islands. The Seawater Reverse Osmosis (RO) SPAM Project on Maratua Island deviated 6% from the contract timeline. This study analyzes and ranks delay factors in SPAM project development on Small Islands. This study collected primary data from 90 respondents (30 Consultants, 30 Executors/Contractors, and 30 Owners/Ministry of PUPERA) using non-experimental surveys. Validity and reliability testing, the Index of Importance for ranking, and Factor Analysis (PCA) to minimize and cluster the 23 original variables were performed. PCA divided the variables into three main categories that explained 61.808% of variation. Transportation, Geographical Location, Material, and Equipment were the biggest factor, accounting for 51.801% of variation. This component includes logistical challenges like distant site transportation and import delays. Second was Manpower, Scope Changes & Work Documents (5.404%), then Planning and Coordination (4.603%). Poor contractor job performance was the biggest delay issue. To reduce delays in small island SPAM projects, logistics planning and integrated multi-party project management must be urgently evaluated.

Keywords: *construction delay factors, small island spam, geographical constraints, logistics management, factor analysis PCA.*

INTRODUCTION

A successful construction project is characterized by adherence to the three main constraints (triple constraints): on cost/budget, on quality, and on time. Given the intricate and complex nature of construction projects, this success necessitates meticulous management functions, including detailed planning, precise execution activities, and stringent control measures. When planning and control are not executed properly, a project tends to experience delays. The recurring issue of project delays is significant, with some sources indicating that nearly 80% of projects experience delays.

Delays consistently result in detrimental consequences for both the owner and the contractor. The common impacts include an increase in overhead costs and the necessity for additional expenditures to accelerate work. Furthermore, delays often lead to conflicts and debates concerning the cause and responsibility, and they carry the risk of quality degradation if technical standards are violated in an attempt to recover lost time. Notably,

the indirect costs borne by the service provider (contractor) due to delays, such as overhead expenses related to the project or central office, are sometimes found to be greater than the direct costs.

The establishment of a functional Water Supply System (SPAM) is critical for public welfare, particularly for providing clean water to residents in remote areas such as small islands. Therefore, the timely success of SPAM construction projects directly translates into the quicker availability of clean water for the community. Due to the unique logistical and geographical challenges inherent in small island construction projects (such as the case study of the SPAM Project on Maratua Island), this research is focused on a deep analysis of the specific factors causing delays in this sensitive and vital sector.

Projects carried out on Small Islands face distinct obstacles, particularly those related to geographical access and logistics. The focus of this study is specifically directed toward addressing the problems encountered in the Construction Project for the Water Supply System on a Small Island (with a case study on the Maratua Island SPAM Project).

Extensive scholarly work has been conducted on construction project delays. Prior researchers have categorized delay causes into various groups. For instance, common major causes identified include poor management/supervision, unexpected ground conditions, slow decision-making processes, varying client requirements, and necessary work variations. These causes are often grouped into factors related to the client (e.g., project financing, interim payments), the design (e.g., complexity, document errors), the contractor (e.g., planning experience, cash flow), materials, labor, equipment, and external influences (e.g., environmental restrictions).

In the Indonesian context, studies have noted issues such as decreased labor productivity during religious holidays (e.g., the Pasar Kleco Project) and delays stemming from late material delivery and design changes (e.g., the UNS Project). However, the issue of delays frequently recurs because project actors often underestimate them and fail to use past experiences for future improvements. This research seeks to contribute to the existing body of knowledge by applying factor analysis techniques to the distinct context of SPAM projects on remote small islands, thereby identifying and ranking the most dominant factors specific to projects subject to significant geographic and logistical constraints.

Any research conducted must demonstrate utility in advancing general knowledge and resolving the investigated problem. This study is expected to provide significant benefits, particularly for service users, service providers, and all stakeholders directly involved in the management of construction projects. By detailing the constraints and potential causes of delays, the relevant parties can implement corrective and preventive measures. Ultimately, the outcome of this analysis is intended to serve as a guideline to ensure that the completion time of SPAM projects can be achieved according to the planned schedule and finished on time.

Based on the established focus and problem statement, the objectives to be achieved in this research are to analyze the factors causing delays in the construction project of the Water Supply System on a Small Island. To analyze the ranking of the factors causing delays in the construction project of the Water Supply System on a Small Island.

RESEARCH METHODS

The object of research is the scientific target established by the researcher to obtain objective, valid, and reliable data regarding a specific variable. In this study, the object is the factors influencing the delay of the Water Supply System (SPAM) Development Project on Small Islands. The subjects of research are the project managers and field managers involved in the SPAM Development Project on Small Islands, to whom the research questionnaire was administered.

The research method employed is the survey method. According to Sugiyono (2011:13), the survey method is used to obtain data from a specific, natural (non-contrived) location, but the researcher intervenes during data collection, for example, by circulating questionnaires or observation.

This research is categorized as a non-experimental study because no treatment is applied to the respondents. The purpose of this methodology is to seek factual and detailed information to describe the phenomenon of delays that occurred.

The general research procedure is illustrated in the flowchart below:

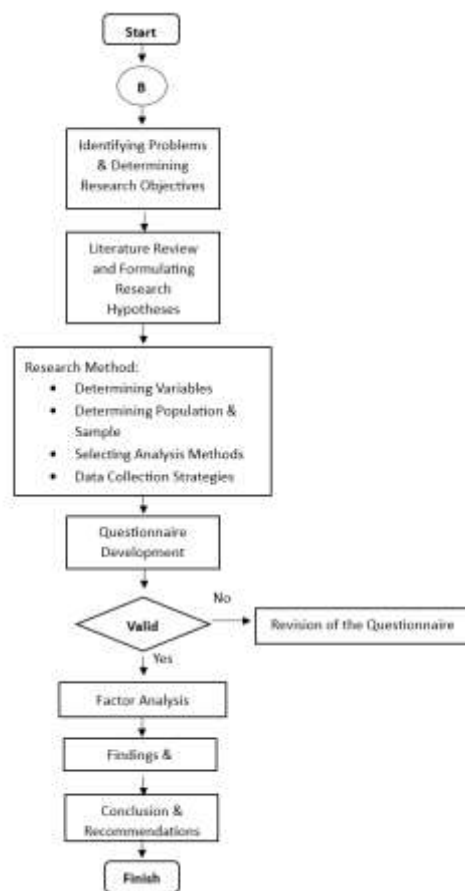


Figure 1. Research Flowchart

The operationalization of variables in this study details the dimensions and indicators that represent the factors causing project delays. These variables are measured using the Ordinal Scale.

Table 1. Operationalization of Variables

Variable	Project Delay Factor	Measurement Scale
Factors of Development Project Delays (X)	1. Poor execution of work stages by the contractor	Ordinal
	2. Unreliable suppliers/subcontractors	Ordinal
	3. Poor planning of the work schedule by the contractor	Ordinal
	4. Less than optimal productivity from the contractor	Ordinal
	5. Errors in planning and specifications	Ordinal
	6. Changes in Piping work	Ordinal
	7. Changes in work methods by the contractor	Ordinal
	8. Changes in the planning and specifications of processing components/equipment	Ordinal
	9. Errors in interpreting drawings or specifications by the Site Manager	Ordinal
	10. Poor Monitoring and Control	Ordinal
	11. Delay in ordering imported goods	Ordinal
	12. Difficulty of transportation facilities to the work location	Ordinal
	13. Limitation of expert labor at the project site	Ordinal
	14. Delayed payments by the <i>client owner</i>	Ordinal
	15. Non-availability of appropriate resources	Ordinal
	16. Heavy rain/waterlogged work location	Ordinal

	17. The process of obtaining permission to remove goods from the dock takes a long time	Ordinal
	18. Delayed approval of <i>shop drawings</i> by the consultant	Ordinal
	19. Lack of supporting project facilities (heavy equipment, material transport fleet)	Ordinal
	20. Soil conditions different from those planned	Ordinal
	21. Difficulty reaching the remote location/site of the project	Ordinal
	22. Changes in <i>scope</i> of work	Ordinal
	23. Inefficient Communication	Ordinal
	24. The class of the mooring dock at the port, which is only for passengers, complicates the process of loading and unloading goods	Ordinal
	25. Errors in material management by the contractor	Ordinal

Source: Operasionalisasi Variabel

The population of this study is the entire area of generalization consisting of objects/subjects with specific qualities and characteristics. The total population was set at 90 individuals, comprising 30 Consultants, 30 Executors/Contractors, and 30 Owners/Ministry of PU. The sample is a portion of the population. The sampling technique used is Saturated Sampling (Census), which means the entire population is used as the sample. Therefore, the sample size is 90 individuals (30 Consultants, 30 Executors/Contractors, and 30 Owners/Ministry of PU).

The data for this research were collected through two primary techniques, namely literature study and field study. The literature study was conducted by reviewing books, scientific articles, and other relevant documents to obtain secondary data that served as reference material for supporting the analysis. Meanwhile, the field study involved direct data collection from the research object through observation and questionnaires. Observation was carried out to obtain accurate information by directly examining the actual conditions in the field, while the questionnaire method was implemented by distributing structured written questions with predetermined answer options to respondents in order to gather quantitative data related to the research problem.

The research instruments used in this study were tested for validity and reliability prior to data analysis. The validity test measures whether a questionnaire is sound or valid. The correlation technique used is Product Moment correlation. The reliability test determines the degree of accuracy, stability, and consistency of the data collection tool. Reliability measurement uses Cronbach Alpha (α).

Data Analysis Methods

The analysis aims to simplify the data into a form that is easier to read and interpret. The analysis methods include:

1. Determining Scores for Questionnaire Statements

The measurement scale is ordinal data, which is converted into quantitative data as follows:

- Not influential is assigned a value of 0.
- Slightly influential is assigned a value of 1.
- Influential is assigned a value of 2.
- Very influential is assigned a value of 3.

2. Determining Ranking of Respondent Answers

The ranking of delay factors is analyzed using the Index of Importance (I) based on the average perception score of respondents.

$$I = \frac{\sum (X_i \cdot a_i)}{N} \text{ Where:}$$

- I = Index of Importance
- X_i = Frequency of response for each perception
- a_i = Value assigned to the perception (0, 1, 2, 3)
- N = Total number of data

Factor Analysis

The purpose of factor analysis is data reduction and finding the relationship between mutually independent variables, then clustering them into fewer groups (latent dimensions).

The steps involved in the factor analysis are:

a. Setting up the Correlation Matrix The procedure uses the Bartlett Test of Sphericity and the Kaiser Meyer Olkin (KMO) measure. Factor analysis is feasible if the KMO index ranges from 0.5 to 1. The Measure of Sampling Adequacy (MSA) value must also be greater than 0.5 (for individual variables).

b. Factor Extraction The method used to estimate the initial factors is the Principal Component Analysis (PCA). The criterion for retaining a factor is the Eigenvalue (eigen value). Only factors with $\text{Eigenvalue} \geq 1$ are retained in the factor analysis model, as this represents the variance explained.

c. Factor Loading The factor matrix shows the standardized coefficient for each factor, known as the Factor Loading (factor weight). A larger factor loading indicates a greater influence of the manifest variable on the latent variable.

d. Varimax Rotation Varimax rotation is performed to simplify the factor matrix and facilitate interpretation, especially if the manifest variables are spread across the extracted factors.

e. Factor Naming (Labelling) Once the factor groups are formed, the factors are named based on the researcher's judgment (judgement) and the variables comprising that group to ensure they are easily understood.

RESULTS AND DISCUSSION

This chapter presents the project location, execution conditions, and analysis of data collected from observations and questionnaires regarding the factors causing delays in the Water Supply System (SPAM) development project on a Small Island. The sample consisted of 90 respondents, specifically 30 Consultants, 30 Executors/Contractors, and 30 Owners/Ministry of PUPERA.

Execution of the Water Supply System Project on Maratua Island

The researched project is the Development of the Water Supply System on Maratua Island, utilizing seawater as the raw water source through Reverse Osmosis (RO) technology, with a processing capacity of 1 L/sec. The processing unit is located in Bohesilian. The resulting water is distributed to the communities in Bohe Silian and Payung-payung, while residents in Teluk Harapan and Bohe Bukut receive water via tank trucks.

Although the project was planned to run for 6 months, it encountered various problems and obstacles, resulting in delays in completion. Based on the execution S-Curve, the deviation of incomplete work at the end of the contract period reached approximately minus 6%.

The main components of the system include:

1. Raw Water Unit: Seawater intake uses an anti-rust duplex submersible pump, located approximately 60 meters from the production unit.
2. Transmission Pipe Unit: Uses 150 mm (6 inch) HDPE pipe over a length of 60 meters.
3. Raw Water Tank: Functions to hold water from the raw water pump, where mixing with KMnO_4 occurs.
4. Reverse Osmosis (RO) Membrane: The unit where the separation of salt particles and other elements from seawater occurs to produce product water.
5. Product Water Reservoir: A concrete tank with a capacity of 150 M^3 for storing treated water.
6. Distribution Unit: Water is sent from the main reservoir using a distribution pump to the Distribution Reservoir, located approximately 1,200 meters away, using 110 mm diameter pipe.
7. Supporting Equipment: Including Solar Panels and batteries, Control Panels, Gensets, and House Connections.

Results on Factors Causing Project Completion Delays

The ranking of delay factors was determined using the Index of Importance (I\$) based on the average perception score (Mean) of the respondents.

Table 2. Respondent Feedback on Research Questionnaire (Ranking Based on Mean)

No	Project Delay Factor	Mean	Ranking
1	Poor execution of work stages by the contractor (X1)	3.53	1
20	Soil conditions different from those planned (X20)	3.52	2
11	Delay in ordering imported goods (X11)	3.51	3
13	Limitation of expert labor at the project site (X13)	3.51	3
4	Less than optimal productivity from the contractor (X4)	3.47	4
24	Dock class only for passengers complicating loading/unloading (X24)	3.47	4
18	Delayed approval of <i>shop drawings</i> by the consultant (X18)	3.44	5
15	Non-availability of appropriate resources (X15)	3.43	6
9	Errors in interpreting drawings or specifications by the Site Manager (X9)	3.42	7
23	Inefficient Communication (X23)	3.42	7
21	Difficulty reaching the remote location/site of the project (X21)	3.41	8
...	<i>(Other factors)</i>		
10	Poor Monitoring and Control (X10)	3.18	17

Source: Data Processing Results Questionnaire, 2019.

Interpretation of Individual Rankings:

1. The most influential factor (Ranking 1) is the poor execution of work stages by the contractor (Mean 3.53).
2. Ranking 2 is soil conditions different from those planned (Mean 3.52).
3. Ranking 3 is tied between delay in ordering imported goods and limitation of expert labor at the project site (Mean 3.51).

4. The factor with the lowest mean (Ranking 17) is poor monitoring and control (Mean 3.18).

Classification of Response Categories

To classify the level of influence, an interval calculation was performed, yielding a class length of 0.8.

Table 3. Classification of Respondent Response Categories

Calculated Mean Value	Category
1.00 – 1.80	Highly non-influential
1.81 – 2.60	Non-influential
2.61 – 3.40	Quite Influential
3.41 – 4.20	Influential
4.21 – 5.00	Highly Influential

Source: Data Processing Results Questionnaire, 2019.

The distribution of the 25 factors based on this classification is:

Table 4. Frequency Distribution of Category Intervals

Value Interval	Meaning	Frequency	Percentage
2.61 – 3.40	Quite Influential	14	60%
3.41 – 4.20	Influential	11	40%
4.21 – 5.00	Highly Influential	0	0%
Total		25	100%

Source: Data Processing Results Questionnaire, 2019.

The results show that 11 factors (40%) were considered Influential (e.g., poor execution, different soil conditions, delayed imported goods, remote location). Meanwhile, 14 factors (60%) were rated as Quite Influential.

Factor Analysis

The objective of factor analysis is to reduce the initial 23 valid variables into a smaller number of underlying (latent) factors.

Feasibility Test for Factor Analysis (KMO and Bartlett's Test)

Table 5. KMO and Bartlett's Test Results (Initial)

	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.932
Bartlett's Test of Sphericity	Approx. Chi-Square	1444.914
	Sig.	0.000

Source: Data Processing Results Questionnaire with SPSS 23, 2019.

The KMO value of 0.932 (ranging between 0.5 and 1) and the significance value (Sig.) of 0.000 (less than 0.05) indicate that the variables and sample are suitable for factor analysis.

Variable Reduction

In the initial analysis of 25 variables (using Communalities), two variables (X4: Less than optimal productivity, and X9: Errors in interpreting drawings) had Communalities below 0.5 and were consequently removed. The analysis was repeated with the remaining 23 variables. The subsequent KMO test yielded a value of 0.928, confirming the continued suitability of the 23 variables for analysis, with all individual MSA values greater than 0.5.

Factor Extraction (PCA)

Factor extraction was performed using Principal Component Analysis (PCA), retaining only factors with an Eigenvalue ≥ 1 .

Table 6. Factor Extraction Results

Factor	Eigen Value	Total Variance (%)	Cumulative Variance (%)	Description
1	11.914	51.801	51.801	Used
2	1.243	5.404	57.205	Used
3	1.059	4.603	61.808	Used
4	0.888	3.860	65.668	Not Used

Source: Data Processing Results Questionnaire with SPSS 23, 2019.

The extraction resulted in 3 main factors being formed, which collectively explain 61.808% of the total variance of the research items.

Determination and Naming of Factors

Varimax rotation was applied to simplify the factor matrix. The variables were grouped based on their highest Factor Loading:

Table 7. Results of Project Delay Factor Loading (After Rotation)

Component	Variable Description
I	X11 Delay in ordering imported goods
	X16 Heavy rain/waterlogged work location
	X17 Dock clearance process taking too long
	X19 Lack of supporting project facilities (heavy equipment, transport fleet)
	X18 Delayed approval of shop drawings by consultant
	X14 Delayed payments by <i>client owner</i>
	X24 Dock class (passenger-only) complicating loading/unloading
	X12 Difficulty of transportation facilities to the work location
	X21 Difficulty reaching the remote location/site of the project
	X25 Errors in material management by the contractor
	X3 Poor planning of the work schedule by the contractor
II	X20 Soil conditions different from those planned
	X15 Non-availability of appropriate resources
	X8 Changes in planning/specifications of processing components/equipment
	X6 Changes in Piping work
	X13 Limitation of expert labor at the project site

	X7 Changes in work methods by the contractor
III	X22 Changes in scope of work
	X1 Poor execution of work stages by the contractor
	X23 Inefficient Communication
	X5 Errors in planning and specifications
	X10 Poor Monitoring and Control
	X2 Unreliable suppliers/subcontractors

Source: Data Processing Results Questionnaire with SPSS 23, 2019.

The three new factors formed and their respective names are:

1. Factor 1 (Most Dominant): Transportation, Geographical Location, Material, and Equipment.

- This factor explains 51.801% of the total variance.
- It is composed of variables strongly related to logistical challenges, such as the difficulty of transportation access, constraints imposed by the passenger-only dock class (X24), remote location (X21), delays in ordering imported goods (X11), and lack of supporting facilities (X19).

2. Factor 2: Manpower, Scope Changes & Work Documents.

- This factor explains 5.404% of the total variance.
- It includes limitations of expert labor (X13), non-availability of appropriate resources (X15), and changes related to processing equipment specifications (X8).

3. Factor 3: Planning and Coordination.

- This factor explains 4.603% of the total variance.
- Variables in this group include poor execution of work stages by the contractor (X1), inefficient communication (X23), changes in scope of work (X22), and poor monitoring and control (X10). (Note: Although X1 was ranked the highest individual delay factor (Mean 3.53), it contributes to Factor 3, which is the least dominant group factor).

CONCLUSION

Based on the analysis of data and discussion regarding the factors influencing delays in the Water Supply System (SPAM) development project on a Small Island, two main conclusions are derived, addressing the research objectives:

1. Factors Influencing Project Delays

Factor analysis successfully reduced the initial set of delay variables into three principal factor groups, which cumulatively explain 61.808% of the total variance among

the variables studied. These three factors are: a. Factor 1: Transportation, Geographical Location, Material, and Equipment. b. Factor 2: Manpower, Scope Changes & Work Documents. c. Factor 3: Planning and Coordination.

2. Ranking and Dominance of Delay Factors

The most dominant factor influencing the delays in the SPAM project on the Small Island is Factor 1: Transportation, Geographical Location, Material, and Equipment, which accounts for 51.8% of the total variance. This highlights that external and logistical constraints, such as the difficulty of transportation to the remote location, the inadequate class of the mooring dock (X24), and delays in ordering imported goods (X11), are the primary drivers of delays in this geographical context.

The subsequent factors in terms of dominance are Factor 2, explaining 5.4% of the variance, and Factor 3 (Planning and Coordination), explaining 4.6% of the variance. Furthermore, when analyzing individual items, the highest-ranked individual cause of delay (based on the highest Mean score) was the poor execution of work stages by the contractor (Mean 3.53).

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