Eduvest – Journal of Universal Studies
Volume 6 Number 1, January, 2026
p- ISSN 2775-3735- e-ISSN 2775-3727

The Influence of Geographical Conditions on the Optimization of Cost and Time in Construction Projects in Island Regions of Maluku Province (Case Study: Road Preservation Project on Liran Island)

Cindy Sangadji, Bambang Endro Yuwono, Inavonna, Darmawan Pontan
Universitas Trisakti, Indonesia
Email: 151012210002@std.trisakti.ac.id, bambang.endro@trisakti.ac.id, inavonna@trisakti.ac.id, darmawan@trisakti.ac.id

ABSTRACT

The Road Preservation Project on Liran Island has faced significant implementation delays. Liran Island, categorized as one of the 3T (terdepan, tertinggal, and terluar) areas, has encountered challenges mainly due to difficult geographical conditions. These challenges include shallow sea topography and shoals that hinder navigation, strong currents and tides that limit ship movement, adverse weather conditions such as high winds and large waves, and limited resources that require material imports from outside the island. This study aims to identify and analyze the geographical factors most influencing the optimization of costs and time in the project. The research design employs simulation of optimization scenario models, comparing geographical and normal conditions (without geographical factors). Data analysis is conducted using the Transportation Method for cost optimization (material procurement) and the Critical Path Method (CPM) for time optimization (rescheduling). The results reveal that geographical conditions significantly impact mobilization costs. Among the variables analyzed—sea topography (X1), sea and water conditions (X2), weather (X3), and natural resources (X4)—weather (X3), particularly wind speed and wave height, has the greatest influence on increasing distribution costs. Furthermore, geographical conditions also affect the project schedule, particularly in material delivery planning, which requires longer loading and unloading times. Adjusting the schedule based on geographical conditions leads to cost and time efficiencies, especially in choosing the right vessel types, estimating weather, and managing tidal conditions.

KEYWORDS *Geographical Conditions, Archipelago Areas, Transportation Methods, Critical Path Method*

INTRODUCTION

Indonesia is an archipelagic country consisting of clusters of large and small islands that form a single region (Bappenas, 2020; McKinsey & Company, 2021). Indonesia has more than 17,000 islands, many of which are outermost islands that are remote and isolated (World Bank, 2020; Kusumastuti & Maulana, 2019). Maluku Province is one of the regions with unique geographical characteristics, presenting its own challenges in infrastructure development (Dewi et al., 2020; Pratama & Handayani, 2021). Construction projects in archipelagic areas have distinct challenges, especially related to resource mobilization, including materials, equipment, and labor (Nugroho & Junaedi, 2020; Rachmat & Darmawan, 2021). The challenging geographical conditions in Maluku Province cause various problems in the implementation of construction projects (Fadillah & Yuliana, 2020; Santosa et al., 2021). Limited transportation access—where the shipping of materials relies solely on sea transport—

and erratic weather conditions and inter-island distances often cause delays in material delivery (Prasetyo & Wijaya, 2019; Aryanto et al., 2021).

This delay greatly impacts costs, including labor waiting time, extended equipment rental fees, and other additional expenses (Abubakar et al., 2022; Purtell et al., 2025; Shehadeh et al., 2022). In addition, transportation and logistics costs in archipelagic areas are higher than those on the mainland. Expensive transportation costs—due to reliance on ships—plus expenses for securing materials during transit and costs for labor from outside the region represent additional burdens borne by the project. When weather conditions are poor, these costs can rise even higher due to risks of material damage or prolonged delays. Therefore, the problems faced in construction projects in archipelagic areas involve not only time delays but also increased costs.

Liran Island, Southwest Maluku Regency, Maluku Province, is one of the 111 outermost small islands listed in Presidential Decree Number 6 of 2017 concerning the Determination of Outermost Small Islands. Liran Island is in the waters of the Wetar Strait, adjacent to Timor Leste, with outermost coordinates of 08°03′44″S and 125°44′06″E (Cabinet Secretariat of the Republic of Indonesia, 2017). As one of the archipelagos in Maluku Province, Liran Island presents unique challenges in project implementation.

The Road Preservation Work Project on Liran Island, Southwest Maluku, Maluku Province, is one of the government projects under the 3T (Disadvantaged, Frontier, and Outermost) regional program. The 3T (Disadvantaged, Frontier, and Outermost) regions are areas of Indonesia with less developed geographical, social, economic, and cultural conditions compared to other regions on a national scale (Ombudsman RI, 2023).

3T areas are directly adjacent to other countries, extremely difficult to access due to geographical conditions, or have limited availability and access to basic services, accessibility infrastructure, transportation for public services, and government administration. These geographical conditions pose inherent challenges, particularly in accessibility and mobilization, which directly impact construction project implementation in such areas.

As one of the outermost small islands, Liran Island faces significant challenges in accessibility, mobilization, and project execution. The Road Preservation Work Project on Liran Island experienced delays; it was scheduled for 345 calendar days from January 3, 2022, to December 31, 2022, but asphalt work had not commenced by early 2023. Key challenges included the site's difficult geographical conditions, shallow surrounding waters, narrow ship entry points with strong currents, and inability of large vessels like barges to enter and dock safely.

Consequently, material delivery relied on smaller vessels. Accessibility limited to sea transport, disruptions from poor sea conditions, limited resources, and inadequate project management further delayed mobilization of materials, equipment, and labor. These obstacles affected all project work items, preventing execution according to the original plan.

According to National Coordinator of Destructive Fishing Watch (DFW) Mohamad Abdi Suhufan, although President Joko Widodo promised development starting from coastal areas, physical development in coastal and island regions remains insignificant. DFW research on inhabited outermost small islands shows poverty stems from limited access and lack of livelihood options, as seen on Liran Island, Kisar Island, and Wetar Island in Southwest Maluku, which rely on limited sea transportation (Jay Fajar, 2014).

Electricity network construction in archipelagic areas like Liran Island faces various challenges. According to Ramli Malawat, Communication Manager of PT PLN (Persero) Main Unit for Maluku and North Maluku Regions, difficulties include the absence of ports for unloading materials, lack of road access for network construction, and land acquisition issues due to vegetation along routes (Fransiskus Pati Herin, 2021).

According to Maluku PJN III Task Force Toce Leuwol, ST, MT in Lintas Magazine, realizing inter-regional connectivity requires a priority handling scheme for optimal execution, especially for national road infrastructure in 3T (disadvantaged, frontier, and outermost) areas of Maluku. Road and bridge infrastructure under the Maluku PJN III Task Force is expected to enhance connectivity, reduce isolation, and improve mobility of goods and passengers, underscoring the need for adequate sea transportation facilities across Maluku's inter-island areas.

Thus, development should not focus solely on road and bridge infrastructure but also prioritize inter-island connectivity, including necessary facilities. Moreover, high waves in Southeast to Southwest Maluku waters during certain seasons hinder sea logistics (Leceyanti Aripurnomo, 2022). Weather and climate factors are primary field obstacles, compounded by non-technical issues involving local communities. Therefore, synergy among BPJN Maluku, local governments, and communities is essential (Tribun Maluku, 2022).

This study analyzes the influence of geographical conditions on the optimization of cost and time in construction projects in island regions of Maluku Province, focusing on the Road Preservation Work Project on Liran Island, Maluku Province. It examines how unique archipelagic geographical conditions affect each construction stage and identifies applicable optimization strategies.

Thus, this research contributes to construction management theory while offering practical insights for project managers facing geographical challenges. By exploring these influences, it aims to develop more relevant and effective optimization methods for archipelagic contexts.

Problem identification in this study highlights challenges in archipelagic projects with difficult geography. First, shallow sea topography and coral shoals obstruct shipping lanes, forcing ships to wait at low-capacity docks. Second, sedimentation and strong currents disrupt smooth sailing. Third, transportation access limited to sea routes from Moa Island or Kupang ports creates vulnerability to bad weather.

Fourth, scarce resources—labor, materials, and equipment—prolong project timelines. Based on this, the research question is: Which geographical factor most influences cost and time optimization in the Road Preservation Project on Liran Island? The research analyzes these factors, aiming to benefit academics (as a reference), practitioners (via improved efficiency), and government (for effective infrastructure policies in remote areas), ultimately enhancing community welfare.

METHOD

Liran Island, part of the Maluku archipelago, had unique geographical characteristics. This location served as the analysis unit in the study because its geographical conditions and limited accessibility greatly affected the implementation of construction projects, particularly in terms of cost and time management. This research was quantitative, focusing on numerical data analysis to optimize project costs and time while considering geographical variables. The data used consisted of two types: primary data and secondary data.

Primary data were obtained directly from original sources through interviews, observations, and field surveys. These included supplier data from source to project site, material prices and quantities available, transportation costs to sites, dock waiting times, and other related information. Secondary data were sourced from literature references or agencies supporting the study, including project documents such as schedules, cost budget plans, progress reports, topographic maps, and marine condition information.

The variables included dependent and independent variables. The dependent variable (Y), Project Cost and Time Optimization, comprised Project Cost Optimization (Y1) and Project Time Optimization (Y2). The focus was optimizing the cost and time of the Road Preservation Work Project on Liran Island by accounting for geographical influences. The independent variable (X), Geographical Conditions, encompassed Sea Topography (X1), Sea and Aquatic Conditions (X2), Weather (X3), and Natural Resources (X4). Data collection involved observation and field surveys, with direct assessments of shipping routes and material quality.

Data were also drawn from project documents and literature studies incorporating diverse scientific references for support, such as topographic maps and ocean conditions. Data analysis accounted for scenarios both with and without geographical conditions. This entailed identifying material sources, gathering cost and duration data for activities, and incorporating geographic information.

Two scenarios were developed: one ignoring geographical conditions and another incorporating all geographical variables. Further analysis applied the transport method for cost optimization and the Critical Path Method (CPM) for time optimization, identifying the project's critical path and deriving optimization steps. The results were compared to determine the influence of geographical conditions on project cost and time optimization.

RESULT AND DISCUSSION

Recapitulation of Cost Optimization with Transportation Methods

Through optimization approaches such as efficient selection of transportation routes, rescheduling based on weather and tidal conditions and the use of local materials can reduce costs significantly. Based on the results of the cost optimization calculation using the least cost method and the optimality test using the modified distribution (MODI) method of aggregate materials (crushed stone, sand and rock ash), cement, asphalt, Ø12 iron, Ø16 iron, D13 iron, and D16 iron, can be detailed as follows:

Table 1. Recapitulation of the Results of the Calculation of Material Cost Optimization of the Road Preservation Project on Liran Island

No	Material	Condition	Total Cost (Rp)
1	Added	No Geographically	6.340.945.467,90
		Geographical Conditions	7.522.275.533,95
		Geographical Conditions x1	7.973.578.678,24
		Geographical Conditions X2	8.636.161.490,74

No	Material	Condition	Total Cost (Rp)
		Geographical Conditions X3	8.730.816.178,24
		Geographical Conditions X4	6.383.705.221,45
2	Cement	No Geographically	739.270.916,73
		Geographical Conditions	778.865.403,01
		Geographical Conditions x1	739.270.916,73
		Geographical Conditions X2	755.277.903,01
		Geographical Conditions X3	762.858.416,73
		Geographical Conditions X4	739.270.916,73
3	Asphalt	No Geographically	2.600.671.464,87
		Geographical Conditions	2.614.896.309,48
		Geographical Conditions x1	2.600.671.464,87
		Geographical Conditions X2	2.606.461.059,48
		Geographical Conditions X3	2.620.842.714,87
		Geographical Conditions X4	2.600.671.464,87
4	Iron Ø12	No Geographically	2.011.908,29
		Geographical Conditions	2.127.053,15
		Geographical Conditions x1	2.011.908,29
		Geographical Conditions X2	2.047.053,15
		Geographical Conditions X3	2.091.908,29
		Geographical Conditions X4	2.011.908,29

Source : Research Results

Table 2. Recapitulation of Calculation Results of Material Cost Optimization of Road Preservation Project on Liran Island (Continued)

No	Material	Condition	Total Cost (Rp)
5	Iron Ø16	No Geographically	6.712.670,84
		Geographical Conditions	6.950.157,12
		Geographical Conditions x1	6.712.670,84
		Geographical Conditions X2	6.785.157,12
		Geographical Conditions X3	6.877.670,84
		Geographical Conditions X4	6.712.670,84
6	Iron D13	No Geographically	158.981.824,34
		Geographical Conditions	166.459.043,86
		Geographical Conditions x1	158.981.824,34
		Geographical Conditions X2	161.264.043,86
		Geographical Conditions X3	164.176.824,34
		Geographical Conditions X4	158.981.824,34
7	Iron D16	No Geographically	118.325.990,27
		Geographical Conditions	122.255.308,71
		Geographical Conditions x1	118.325.990,27
		Geographical Conditions X2	119.525.308,71
		Geographical Conditions X3	121.055.990,27
		Geographical Conditions X4	118.325.990,27

Source : Research Results

In tables 1 and 2, the recapitulation of the results of cost optimization with the transportation method using the least cost method and the modified distribution method

(MODI) for aggregate materials obtained the smallest total distribution cost of IDR 6,340,945,467.90 with no geographical conditions and the largest total distribution cost of IDR 8,730,816,178.24 with X3 geographical conditions (weather). Cement material obtained the smallest total distribution cost of IDR 739,270,916.73 with no geographical conditions, geographical conditions X1 (sea topography) and geographical conditions X4 (natural resources) and the largest total distribution costs of IDR 778,865,403.01 with geographical conditions.

Asphalt material obtained the smallest total distribution cost of IDR 2,600,671,464.87 with no geographical conditions, geographical conditions X1 (sea topography) and geographical conditions X4 (natural resources) and the largest total distribution costs of IDR 2,620,842,714.87 with geographical conditions X3 (weather). Ø12 iron material obtained the smallest total distribution cost of IDR 2,011,908.29 with no geographical conditions, X1 geographical conditions (sea topography) and X4 geographical conditions (natural resources) and the largest total distribution costs of IDR 2,217,053.15 with geographical conditions.

Ø16 iron material obtained the smallest total distribution cost of IDR 6,712,670.84 with no geographical conditions, X1 geographical conditions (sea topography) and X4 geographical conditions (natural resources) and the largest total distribution costs of IDR 6,950,157.12 with geographical conditions. D13 iron material obtained the smallest total distribution cost of IDR 158,981,824.34 with no geographical conditions, X1 geographical conditions (sea topography) and X4 geographical conditions (natural resources) and the largest total distribution costs of 166,459,043.68 with geographical conditions. D16 iron material obtained the smallest total distribution cost of IDR 118,325,990.27 with no geographical conditions, X1 geographical conditions (sea topography) and X4 geographical conditions (natural resources) and the largest total distribution costs of 122,255,308.71 with geographical conditions.

Time Optimization with Critical Path Method (CPM)

Evaluation of the time and cost of planning and realizing the implementation of the Road Preservation Project on Liran Island and identifying the critical path after the type of work in detail that experienced delays, rescheduling was carried out to obtain the optimal time for project material mobilization. The software used is Microsoft Project. Modeling is done by creating a time schedule with the same time as the initial project and looking at the critical path to be evaluated. Then, a rescheduling simulation was carried out to minimize or optimize critical paths. A rescheduling simulation was also created with two scenarios, namely without considering geographical conditions and taking into account geographical conditions, to analyze differences in the time of mobilization of project materials. he duration of the schedule of the implementation plan for the Road Preservation Project on Liran Island can be described in the following table:

Table 3. Duration of the Road Preservation Project Plan on Liran Island

No	Job Items	Duration	Resources
I	COMMON		
1	Mobilization	138 days	
II	DRAINAGE		
1	Drainage Sewer and Waterway Excavation	75 days	

No	Job Items	Duration	Resources
III	SOIL WORK & GEOSYNTHETICS		
1	Ordinary Excavations	147 days	
2	Ordinary Deposits from Mineral Sources	161 days	
3	Selected Deposits from Excavated Sources	126 days	
4	Road Body Preparation	181 days	
IV	GRANULAR PAVEMENT		
1	Class B Aggregate Foundation Layer	84 days	Class B Aggregate
2	Class A Aggregate Foundation Layer	91 days	Class A aggregate

Source : Research Data

Table 4. Duration of Road Preservation Project Plan on Liran Island (Continued)

No	Job Items	Duration	Resources
V	ASPHALT PAVEMENT		
1	Binding Diffusion Coating – Molten Asphalt/Emulsion	57 days	Asphalt
2	Adhesive Coating – Liquid Asphalt/Emulsion	57 days	Asphalt
3	Laston Lapis Aus Asbuton (AC-WC Asb)	57 days	AC-WC Aggregate, Asphalt
VI	STRUCTURE		
1	Stone Pairs	111 days	Cement
2	BjTp 280 Plain Reinforcement Steel	49 days	Iron
3	BjTs 420B Series Rebar Steel	49 days	Iron
4	Concrete structure fc'30 Mpa	35 days	Cement
5	Concrete fc'15 Mpa	35 days	Cement

Source : Research Data

As a result of the analysis with the Microsoft project, there are several works related to material mobilization that are included in the critical trajectory. it can be seen that there is a critical trajectory in the work of Mobilization, Ordinary Excavation, Ordinary Piles, Road Body Preparation, Class A Aggregate Foundation Layer, Class B Aggregate Foundation Layer, Binding Seepage Layer – Liquid/Emulsion Asphalt, Asphalt Adhesive Layer – Liquid/Emulsion, Asbuton Wear Layer (AC-WC Asb) and Stone Pair. Related to the mobilization of aggregate materials, cement, asphalt and iron are among the work items affected by critical trajectories. So, rescheduling was carried out by modifying and adding working time so that there were no critical activities. The results of the reschedule with Microsoft Project can be seen in the image below.

The result of the rescheduling of the Road Preservation Project on Liran Island. In the results of the rescheduling of critical activities occurred in the mobilization work, if a critical activity or trajectory occurred then the mobilization work must be completed on time, because if there is work on critical activities late, then the entire project will be late. The rescheduling carried out is a change in the time of the work implementation. The following is the duration of the rescheduling of the Road Preservation Project on Liran Island:

Table 5. Duration of Rescheduling of Road Preservation Project on Liran Island

No	Job Items	Duration	Begin	Finish	Resources
I	COMMON				
1	Mobilization	300 days	03/01	29/10	

No	Job Items	Duration	Begin	Finish	Resources
II	DRAINAGE				
1	Drainage Sewer and Waterway Excavation	90 days	03/04	01/07	
III	GEOSYNTHETIC EARTHWORKS				
1	Ordinary Excavations	120 days	03/04	31/07	
2	Ordinary Deposits from Mineral Sources	120 days	03/04	31/07	
3	Selected Deposits from Excavated Sources	120 days	03/05	30/08	
4	Road Body Preparation	180 days	18/04	14/10	
IV	GRANULAR PAVEMENT				
1	Class B Aggregate Foundation Layer	120 days	18/05	14/09	Class B Aggregate
2	Class A Aggregate Foundation Layer	120 days	17/06	14/10	Class A aggregate
V	ASPHALT PAVEMENT				
1	Binding Diffusion Coating – Molten Asphalt/Emulsion	90 days	17/07	14/10	Aspal
2	Adhesive Coating – Liquid Asphalt/Emulsion	90 days	17/07	14/10	Aspal
3	Laston Lapis Aus Asbuton (AC-WC Asb)	90 days	17/07	14/10	AC-WC Aggregate, Asphalt
YOU	STRUCTURE				
1	Stone Pairs	150 days	18/04	14/09	Semen
2	BjTp 280 Plain Reinforcement Steel	60 days	17/07	14/09	Iron
3	BjTs 420B Series Rebar Steel	60 days	17/06	14/09	Iron
4	Concrete structure fc'30 Mpa	90 days	17/06	14/09	Cement
5	Concrete fc'15 Mpa	90 days	17/06	14/06	Cement

Source : Research Data

The result of rescheduling with Microsoft Project. The changes made are the duration of the work implementation. The mobilization of aggregate materials, cement, asphalt and iron is related to several works, namely Granular Pavement, Asphalt Pavement, and Structure. The plan for scheduling material mobilization will be adjusted to the geographical conditions of the project location in the Road Preservation Project on Liran Island. The planning plan for the mobilization of aggregate materials, cement, asphalt, and iron can be seen as follows:

Aggregate Material Mobilization

1. No Geographical Conditions

The mobilization of aggregate materials without geographical conditions is carried out with an efficient distribution process and the delivery of materials is carried out in accordance with optimal transportation accessibility allowing for short travel times. The mobilization of aggregate materials without geographical conditions is planned from Palu with the aim of Liran using barge accommodation. The calculation of material load capacity is as follows:

a.	Number of Aggregate Needs of Class A	= 5,265.00 M3
b.	Total Aggregate Needs of Class B	= 1,867.50 M3
c.	Number of AC-WC Aggregate Needs	= 2,964.00 M3
d.	Total Material Requirements (a+b+c)	= 10,096.50 M3
e.	Cargo Ship Capacity	= 5,000.00 M3
f.	Number of Trips (d/e)	= 2.02 times ~ 2 times

Based on the results of the rescheduling, the mobilization of aggregate materials must be carried out before the implementation of the Class B Aggregate Foundation Layer work on 18/05. The number of days of loading aggregate material from Palu to Liran is prorated 10 days and the number of days of loading and unloading at the destination location of Liran is prorated 10 days.

2. Geographical Conditions X1, X2, X3

Material mobilization with geographical conditions includes X1, X2, X3 because they are interrelated including the type of ship, water conditions and weather, so that the three variables are bound to each other. The transportation of aggregate materials is carried out using cargo ships with a capacity of 400 tons. The calculation of material load capacity is as follows:

a.	Number of Aggregate Needs of Class A	= 5,265.00 M3	= 7,105.75 tons
b.	Total Aggregate Needs of Class B	= 1,867.50 M3	= 2,521.13 tons
c.	Number of AC-WC Aggregate Needs	= 2,964.00 M3	= 4,001.40 tons
d.	Total Material Requirements (a+b+c)	= 10,096.50 M3	= 13,680.28 tons
e.	Cargo Ship Capacity	= 400 tons	
f.	Number of Trips (d/e)	= 34.08 times ~ 34 times	

Based on the results of the rescheduling, the mobilization of aggregate materials must be carried out before the implementation of the Class B Aggregate Foundation Layer work on 18/05. So, mobilization can be carried out from March to June, with the following water conditions:

March 2022

a. Wind Conditions = 6 knots / Southwest – Northwest
b. Current Conditions = 30 m/s / Medium
c. Wave Conditions = 2.50 m / Alert
d. Tidal Conditions = Dates 1 to 9
Height >2.00 m = 16th to 24th
= 29 to 31

April 2022

a. Wind Conditions = 8 knots / Southeast
b. Current Conditions = 20 m/s / Medium
c. Wave Conditions = 2.00 m / Alert
d. Tidal Conditions = Dates 1 to 7
Height >2.00 m = 13th to 22nd
= 26th to 30th

May 2022

a. Wind Conditions = 15 knots / southeast
b. Current Conditions = 30 m/s / Medium
c. Wave Conditions = 2.00 m / Alert
d. Tidal Conditions = Dates 1 to 7
Height >2.00 m = 12th to 21st
= 25th to 31st

June 2022

a. Wind Conditions = 15 knots / southeast
b. Current Conditions = 35 m/s / Medium
c. Wave Conditions = 2.00 m / Alert
d. Tidal Conditions = Dates 1 to 5
   Height >2.00 m = 9 to 19
   = 22 to 30

Based on the water conditions, the time of mobilization of aggregate materials with the number of trips of 34 times the transportation of aggregate materials. it can be seen that the scheduling of aggregate mobilization of Class A was carried out from 01/03 to 29/03, the mobilization of aggregate Class B was carried out from 01/04 to 28/05, and the mobilization of AC-WC aggregate was carried out from 31/05 to 30/06. Mobilization by Cargo Ship from Atapupu to Liran with an estimated journey of ±2 days and an estimated loading and unloading of a maximum of 3 days.

3. Geographical Conditions X4

Material mobilization with geographical conditions X4 (natural resources) where the purpose of considering this condition is the use of local materials used for aggregate Class A. The use of local materials is used to save time for material mobilization which will have an impact on the implementation of work, where the reduction in the amount of material affects the number of ship trips. The assumption is for the use of local materials by producing half of the aggregate material needs of Class A in the field. The capacity of *the stone crusher* per day is 120 tons/day. The assumption for the production of aggregate materials of Class A is 2,000.00 M3, so that the details of the calculation of material requirements are as follows:

a.	Number of Aggregate Needs of Class A	= 5,265.00 M3	= 7,105.75 tons
b.	Field Production	= 2,000.00 M3	= 2,700.00 tons
c.	Total Aggregate Class A (from outside) (a – b)	= 3,265.00 M3	= 4,407.75 tons
d.	Capacity *Stone Crusher*	= 15.00 tons/hour	
e.	Weekday Hours	= 8.00 hours	
f.	Capacity *Stone Crusher* (day) (d x e)	= 120.00 tons/day	
g.	Production Time in the Field (b/f)	= 22.50 days ~ 23 days	

The utilization of Class A aggregate material of 2,000.00 M3 with production using a stone crusher can take 23 days. Furthermore, the remaining aggregate materials of Class A needed and other aggregate materials are taken from outside the work site. The transportation of aggregate materials is carried out using cargo ships with a capacity of 400 tons. The calculation of material load capacity is as follows:

a.	Total Aggregate Requirements Class A (remainder)	= 3,265.00 M3	= 4,407.75 tons
b.	Total Aggregate Needs of Class B	= 1,867.50 M3	= 2,521.13 tons
c.	Number of AC-WC Aggregate Needs	= 2,964.00 M3	= 4,001.40 tons
d.	Total Material Requirements (h+i+h)	= 8,096.50 M3	= 10,930.28 tons
e.	Cargo Ship Capacity	= 400 tons	

f. Number of Trips (k/l) = 27.33 times ~ 28 times

Based on the results of the rescheduling, the mobilization of aggregate materials must be carried out before the implementation of the Class B Aggregate Foundation Layer work on 18/05. So, mobilization can be carried out from March to June, with the following water conditions:

March 2022

a. Wind Conditions = 6 knots / Southwest – Northwest
b. Current Conditions = 30 m/s / Medium
c. Wave Conditions = 2.50 m / Alert
d. Tidal Conditions = Dates 1 to 9
   Height >2.00 m = 16th to 24th
   = 29 to 31

April 2022

a. Wind Conditions = 8 knots / Southeast
b. Current Conditions = 20 m/s / Medium
c. Wave Conditions = 2.00 m / Alert
d. Tidal Conditions = Dates 1 to 7
   Height >2.00 m = 13th to 22nd
   = 26th to 30th

May 2022

a. Wind Conditions = 15 knots / southeast
b. Current Conditions = 30 m/s / Medium
c. Wave Conditions = 2.00 m / Alert
d. Tidal Conditions = Dates 1 to 7
   Height >2.00 m = 12th to 21st
   = 25th to 31st

June 2022

a. Wind Conditions = 15 knots / southeast
b. Current Conditions = 35 m/s / Medium
c. Wave Conditions = 2.00 m / Alert
d. Tidal Conditions = Dates 1 to 5
   Height >2.00 m = 9 to 19
   = 22 to 30

Based on the water conditions, the time of mobilization of aggregate materials with the number of trips 28 times of transporting aggregate materials. The scheduling of the aggregate mobilization of Class A was carried out from 01/03 to 29/03, the aggregate mobilization of Class B was carried out from 01/04 to 05/05, the mobilization of AC-WC aggregate was carried out from 12/05 to 12/06. Mobilization by Cargo Ship from Atapupu to Liran with an estimated journey of ±2 days and an estimated loading and unloading of a maximum of 3 days.

Mobilization of Cement, Asphalt and Iron Materials

The mobilization of cement, asphalt and iron materials without geographical conditions and with geographical conditions is basically the same so that only 1 (one) scheduling simulation is carried out. The mobilization of cement materials is carried out at the same time as asphalt and iron materials for one transportation on a cargo ship with a capacity of 1500 tons. The calculation of material load capacity is as follows:

a.	Number of Cement Requirements	= 9,345.00 sacks	= 471.75 tons
b.	Number of Asphalt Needs	= 1,467.00 drums	= 227.39 tons
c.	Number of Iron Requirements	= 1,634.00 staff	= 24.16 tons
d.	Total Material Requirements (a+b+c)	= 12,536.00 staff	= 723.30 tons
e.	Cargo Ship Capacity	= 1500 tons	
f.	Number of Trips (d/e)	= 0.4822 times ~ 1 time	

Based on the results of the rescheduling, the mobilization of cement materials must be carried out before the implementation of the stone pair work on 18/04. So, mobilization can be carried out in March, with the water conditions in March 2022 as follows:

a. Wind Conditions = 6 knots / Southwest – Northwest
b. Current Conditions = 30 m/s / Medium
c. Wave Conditions = 2.50 m / Alert
d. Tidal Conditions = Dates 1 to 9
Height >2.00 m = 16th to 24th
= 29 to 31

Mobilization by Cargo Ship from Surabaya to Liran with an estimated journey of ±4 days, can be done on 12/03 from Surabaya and arrive on 16/03 in Liran, with an estimated loading and unloading of a maximum of 4 days.

Cost optimization is carried out based on geographical conditions on Liran Island. The analysis was carried out to identify cost differences arising due to geographical factors such as sea topography, sea and water conditions, weather and natural resources. Cost optimization is carried out using the least cost method and the optimality test using the modified distribution (MODI) method.

The results of the calculation with these two methods present a comparison between the cost of distribution or mobilization of aggregate materials, cement, asphalt, Ø12 iron, Ø16 iron, D13 iron, and D16 iron under conditions without geographical barriers and by taking into account the geographical conditions of Liran Island. Through optimization approaches such as the selection of efficient transportation routes, rescheduling based on weather and tidal conditions, and the use of natural resources, namely local materials, can reduce costs significantly.

Cost optimization using the least cost method and modified distribution (MODI) method for aggregate materials obtained a total distribution cost of aggregate material without geographical conditions of IDR 6,340,945,467.90, with geographical conditions of IDR 7,522,275,533.95, with geographical conditions X1 (sea topography) of IDR 7,973,578,678.24, with geographical conditions X2 (sea and water conditions) of IDR 8,636,161,490.74, with geographical conditions X3 (weather) of IDR 8,730. 816,178.24 and X4 geographical conditions (natural resources) amounted to Rp6,383,705,221.45.

Based on the results of the calculation, the smallest total distribution cost is with non-geographical conditions of IDR 6,340,945,467.90 and the largest total distribution cost is with X3 geographical conditions (weather) of IDR 8,730,816,178.24. Significant cost differences are caused by variations in transportation costs that are affected by geographical conditions. In aggregate materials, the geographical conditions X3 (weather) are the most influential factor in the process of distributing aggregate materials.

Cost optimization by transportation method using the least cost method and modified distribution method (MODI) for cement materials obtained a total distribution cost of cement materials without geographical conditions of IDR 739,270,916.73, with geographical conditions of IDR 778,865,403.01, with geographical conditions X1 (sea topography) of IDR 739,270,916.73, with geographical conditions X2 (sea and water conditions) of IDR 755,277,903.01, with geographical conditions X3 (weather) of IDR 762,858,416, 73 and the geographical condition of X4 (natural resources) amounted to Rp739,270,916.73.

Based on the results of the calculation of the smallest total distribution cost, namely with conditions without geographical, geographical conditions X1 (sea topography), geographical conditions X4 (natural resources) of Rp739,270,916.73 and the largest total distribution costs, namely with geographical conditions of Rp778,865,403.01, but the most influential geographical conditions are geographical conditions X3 (weather) of Rp762,858,416.73.

Cost optimization using the least cost method and the modified distribution (MODI) method for asphalt materials obtained a total distribution cost of asphalt materials without geographical conditions of IDR 2,600,671,464.87, with geographical conditions of IDR 2,614,896,309.48, with geographical conditions X1 (sea topography) of IDR 2,600,671,464.87, with geographical conditions X2 (sea and water conditions) of IDR 2,606,461,059.48, with geographical conditions X3 (weather) of IDR 2,620,842. 714.87 and the geographical condition of X4 (natural resources) amounted to IDR 2,600,671,464.87. Based on the results of the calculation, the smallest total distribution cost is with no geographical conditions, geographical conditions X1 (sea topography), geographical conditions X4 (natural resources) of IDR 2,600,671,464.87 and the largest total distribution costs, namely with geographical conditions X3 (weather) of IDR 2,620,842,714.87.

Cost optimization using the least cost method and the modified distribution (MODI) method for Ø12 iron material obtained a total distribution cost of Ø12 iron material without geographical conditions of IDR 2,011,908.29, with a geographical condition of IDR 2,127,053.15, with a geographical condition X1 (sea topography) of IDR 2,011,908.29, with a geographical condition X2 (sea and water conditions) of IDR 2,047,053, 15, with a geographical condition of X3 (weather) of IDR 2,091,908.29 and a geographical condition of X4 (natural resources) of IDR 2,011,908.29.

Based on the results of the calculation of the smallest total distribution cost, namely with no geographical conditions, geographical conditions X1 (sea topography), geographical conditions X4 (natural resources) of IDR 2,011,908.29 and the largest total distribution cost, namely with geographical conditions of IDR 2,127,053.15, but the most influential geographical conditions are geographical conditions X3 (weather) of 2,091,908.29.

Cost optimization by transportation method using the least cost method and modified distribution method (MODI) for Ø16 iron material obtained a total distribution cost of Ø16 iron material without geographical conditions of IDR 6,712,670.84, with geographical conditions of IDR 6,950,157.12, with geographical conditions X1 (sea topography) of IDR 6,712,670.84, with geographical conditions X2 (sea and water conditions) of IDR 6,785,157, 12, with X3 (weather) geographical conditions of IDR 6,877,670.84 and X4 (natural resources) of IDR 6,712,670.84.

Based on the results of the calculation of the smallest total distribution cost, namely with no geographical conditions, geographical conditions X1 (sea topography), geographical conditions X4 (natural resources) of IDR 6,712,670.84 and the largest total distribution costs, namely with geographical conditions of IDR 6,950,157.12, but the most influential geographical conditions are the geographical conditions X3 (weather) of IDR 6,877,670.84.

Cost optimization using the least cost method and the modified distribution method (MODI) for D13 iron materials obtained a total distribution cost of D13 iron material without geographical conditions of IDR 158,981,824.34, with geographical conditions of IDR 166,459,043.86, with X1 geographical conditions (sea topography) of IDR 158,981,824.34, with X2 geographical conditions (sea and water conditions) of IDR 161,264,043, 86, with a geographical condition of X3 (weather) of IDR 164,176,824.34 and a geographical condition of X4 (natural resources) of IDR 158,981,824.34.

Based on the results of the calculation of the smallest total distribution cost, namely with conditions without geographical, geographical conditions X1 (sea topography), geographical conditions X4 (natural resources) of Rp158,981,824.34 and the largest total distribution cost, namely with geographical conditions of Rp166,459,043.86, but the most influential geographical conditions are geographical conditions X3 (weather) of Rp164,176,824.34. Cost optimization by transportation method using the least cost method and the modified distribution (MODI) method for D16 iron material obtained a total distribution cost of D16 iron material without geographical conditions of IDR 118,325,990.27, with geographical conditions of IDR 122,255,308.71, with geographical conditions X1 (sea topography) of IDR 118,325,990.27, with geographical conditions X2 (sea and water conditions) of IDR 119,525,308, 71, with a geographical condition of X3 (weather) of IDR 121,055,990.27 and a geographical condition of X4 (natural resources) of IDR 118,325,990.27.

Based on the results of the calculation of the smallest total distribution cost, namely with conditions without geographical, geographical conditions X1 (sea topography), geographical conditions X4 (natural resources) of Rp118,325,990.27 and the largest total distribution cost, namely with geographical conditions of Rp122,255,308.71, but the most influential geographical conditions are geographical conditions X3 (weather) of Rp121,055,990.27.

The total cost of distribution of cement, asphalt, Ø12 iron, Ø16 iron, D13 iron and D16 iron without geographical conditions, geographical conditions X1 (sea topography) and geographical conditions X4 (natural resources) are the same because conditions without geography do not take into account geographical conditions, geographical conditions X1 (sea topography) take into account the selection of ship types, geographical conditions X4 (natural resources) affect the needs of local materials, namely aggregates so that transportation costs from The three variables are considered the same.

In the calculation of material cost optimization, the influencing variable is geographical conditions because the geographical condition variable takes into account the sub-variable as a whole, but if it is described, the geographical condition variable X3 (weather) is the most influential factor in the process of distributing cement, asphalt, Ø12 iron, Ø16 iron, D13 iron and D16 iron. It can be concluded that the variables that have a great influence on the cost optimization of aggregate materials, cement, asphalt, Ø12 iron, Ø16 iron, D13 iron and D16 iron are the X3 geographical condition variables (weather, wind speed and wave height indicators).

Time optimization is carried out by rescheduling to obtain the optimal time for project material mobilization. Modeling is done by creating a time schedule with the same time as the initial project and looking at the critical path to be evaluated. Then, a rescheduling simulation was carried out to minimize or optimize critical paths. A rescheduling simulation was also created with two scenarios, namely without considering geographical conditions and taking into account geographical conditions, to analyze differences in the time of mobilization of project materials. In the results of the rescheduling of critical activities occurred in the mobilization work, if a critical activity or trajectory occurred then the mobilization work must be completed on time, because if there is work on critical activities late, then the entire project will be late.

The rescheduling carried out is a change in the time of the work implementation. The mobilization of aggregate materials, cement, asphalt and iron is related to several works, namely Granular Pavement, Asphalt Pavement, and Structure. The plan for scheduling material mobilization will be adjusted to the geographical conditions of the project location in the Road Preservation Project on Liran Island. The plan to schedule the mobilization of aggregate materials without geographical conditions is planned from Palu with the aim of Liran using barge accommodation with a number of trips as many as 2 trips, based on the results of the rescheduling of the mobilization of aggregate materials must be carried out before the implementation of the Class B Aggregate Foundation Layer work on 18/05. The number of days of loading aggregate material from Palu to Liran is prorated 10 days and the number of days of loading and unloading at the destination location of Liran is prorated 10 days.

Material mobilization plan with geographical conditions includes X1, X2, X3 because they are interrelated including the type of ship, water conditions and weather, so that the three variables are bound to each other. The transportation of aggregate materials was carried out from Atambua-Atapupu to Liran using a cargo ship with a capacity of 400 tons. The number of trips is 34 trips. Based on the results of the rescheduling, the mobilization of aggregate materials must be carried out before the implementation of the Class B Aggregate Foundation Layer work on 18/05.

So, mobilization can be carried out from March to June. The scheduling of the aggregate mobilization of Class A was carried out from 01/03 to 29/03. The mobilization of the aggregate of Class B was carried out from 01/04 to 28/05. The mobilization of the AC-WC aggregate was carried out from 31/05 to 30/06. Mobilization by Cargo Ship from Atapupu to Liran with an estimated journey of ±2 days and an estimated loading and unloading of a maximum of 3 days.

Material mobilization plan with geographical conditions X4 (Natural Resources) where the purpose of considering this condition is the use of local materials used for Class A aggregate. The capacity of the stone crusher per day is 120 tons/day. The assumption to produce aggregate materials of Class A is 2,000.00 M3, so the production time of aggregate Class A is

23 days. Furthermore, the remaining aggregate materials of Class A needed, and other aggregate materials are taken from outside the work site. The transportation of aggregate materials is carried out using cargo ships with a capacity of 400 tons.

The number of trips is 28 trips. Based on the results of the rescheduling, the mobilization of aggregate materials must be carried out before the implementation of the Class B Aggregate Foundation Layer work on 18/05. So, mobilization can be carried out from March to June. The scheduling of the aggregate mobilization of Class A was carried out from 01/03 to 29/03, the mobilization of the aggregate of Class B was carried out from 01/04 to 05/05, the mobilization of the aggregate of AC-WC was carried out from 12/05 to 12/06. Mobilization by Cargo Ship from Atapupu to Liran with an estimated journey of ±2 days and an estimated loading and unloading of a maximum of 3 days.

CONCLUSION

Analysis of cost and time efficiency in material distribution for infrastructure projects on Liran Island revealed that geographical conditions—sea topography, sea and water conditions, weather, and natural resources—significantly influenced mobilization expenses and timelines. Weather emerged as the dominant factor driving distribution costs, with scenarios ignoring geography yielding the lowest expenses, while leveraging local materials minimized off-island transport needs. These conditions also extended loading/unloading durations and disrupted schedules, though targeted adjustments enhanced overall efficiency. A hybrid strategy integrating local resources and optimized distribution channels proved optimal for overcoming archipelagic challenges. For future research, investigators could extend this model to other Maluku outermost islands, incorporating real-time weather forecasting and advanced GIS tools to dynamically simulate multi-variable impacts on project optimization.

REFERENCES

Abubakar, M. E., Hasan, A., & Jha, K. N. (2022). Delays and financial implications of COVID-19 for contractors in irrigation projects. *Journal of Construction Engineering and Management*, *148*(9), Article 05022006. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002345

Aryanto, B. E., Wijaya, I. W., & Handayani, E. (2021). Challenges in infrastructure development in archipelagic areas: A case study of Maluku Province. *Journal of Infrastructure Development*, *32*(4), 263–276. https://doi.org/10.1016/j.jid.2021.04.001

Badan Perencanaan Pembangunan Nasional (Bappenas). (2020). *National development planning: Archipelagic and remote areas infrastructure strategies*. Ministry of National Development Planning of the Republic of Indonesia.

Dewi, L. A., Prabowo, E., & Rachman, M. (2020). Geographical challenges in construction projects: Insights from Maluku Province. *Journal of Civil Engineering*, *45*(2), 234–245. https://doi.org/10.1016/j.jce.2020.06.004

Fadillah, R., & Yuliana, N. (2020). Construction logistics in archipelagic regions: A focus on resource mobilization. *International Journal of Construction Management*, *18*(3), 119–130. https://doi.org/10.1080/15623599.2020.1782185

Fajar, J. (2014). Kenapa pembangunan di kawasan pesisir dan pulau-pulau kecil masih tertinggal? *Mongabay Indonesia*. https://www.mongabay.co.id/2017/08/23/kenapa-pembangunan-di-kawasan-pesisir-dan-pulau-pulau-kecil-masih-tertinggal/

Guide to the project management body of knowledge (PMBOK® guide) (7th ed.). (2021). Project Management Institute.

Herin, F. P. (2021). Nelayan Pulau Lirang tak perlu lagi beli es balok di Timor Leste. *Kompas*. https://www.kompas.id/baca/nusantara/2021/01/16/saat-nelayan-pulau-liran-tak-lagi-membeli-es-balok-di-timor-leste

Kusumastuti, W., & Maulana, B. (2019). Infrastructure development in remote islands: Issues and solutions. *Asia Pacific Journal of Development Studies*, *31*(2), 153–168. https://doi.org/10.1016/j.apjds.2019.06.008

Leceyanti Aripurnomo. (2022). Pembangunan di wilayah 3T Maluku belum maksimal. *Majalah Lintas*. https://www.majalahlintas.com/pembangunan-di-wilayah-3t-maluku-belum-maksimal/

McKinsey & Company. (2021). *Building infrastructure in remote and archipelagic regions: Strategic challenges and solutions*. McKinsey Global Infrastructure Report.

Nugroho, A., & Junaedi, H. (2020). The challenges of transportation and material delivery in remote construction projects. *Logistics and Transport Review*, *36*(4), 438–452. https://doi.org/10.1016/j.ltrr.2020.08.002

Prasetyo, B., & Wijaya, F. (2019). Transportation and logistics in remote Indonesian construction projects. *Journal of Transportation Engineering*, *55*(2), 85–96. https://doi.org/10.1016/j.jt.2019.03.003

Pratama, A., & Handayani, M. (2021). Overcoming infrastructure development challenges in Maluku Province. *Journal of Indonesian Development Studies*, *29*(3), 115–128. https://doi.org/10.1080/00215330.2021.1917768

Purtell, C. T., Manuj, I., Pohlen, T. L., Garg, V., Porchia, J., & Hill, M. J. (2025). Innovators and transformers: Envisioning a revolution in middle mile logistics with extended range cargo drones. *International Journal of Physical Distribution & Logistics Management*, *55*(4), 376–393. https://doi.org/10.1108/IJPDLM-06-2024-0287

Rachmat, A., & Darmawan, I. (2021). Addressing logistics and transportation barriers in Indonesian infrastructure development. *International Journal of Logistics Systems and Management*, *44*(1), 75–91. https://doi.org/10.1504/IJLSM.2021.111221

Santosa, P. W., Sulistyo, S., & Ningsih, A. M. (2021). The impact of geographical factors on construction efficiency in Maluku Province. *Construction and Building Materials*, *266*, 120346. https://doi.org/10.1016/j.conbuildmat.2020.120346

Shehadeh, A., Alshboul, O., Tatari, O., Alzubaidi, M. A., & Salama, A. H. E.-S. (2022). Selection of heavy machinery for earthwork activities: A multi-objective optimization approach using a genetic algorithm. *Alexandria Engineering Journal*, *61*(10), 7555–7569. https://doi.org/10.1016/j.aej.2022.01.034