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STUDY OF THE LOGISTICS CHARACTERISTICS OF SEA TRANSPORTATION FOR THE MOBILIZATION OF SOLAR POWER PLTS+BESS EQUIPMENT IN THE BAWEAN ISLANDS REGION

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ABSTRACT

The development of solar photovoltaic power plants (PLTS) integrated with Battery Energy Storage Systems (BESS) in archipelagic regions faces logistical challenges due to maritime transport dependence and limited port and inland road infrastructure. This study analyzes maritime transportation logistics for mobilizing and demobilizing equipment for a 3 MW and 6 MW PLTS+BESS project on Bawean Island, East Java. A descriptive-quantitative case study was conducted using primary data from road access surveys and vehicle maneuver simulations (swept path analysis), supported by secondary project assessment data. Results indicate two cargo categories: breakbulk cargo for heavy and oversized equipment, including battery systems, transformers, and mounting systems, and containerized cargo for solar modules, inverters, and cables. Two unloading alternatives were assessed: Bawean Port and a temporary jetty. Bawean Port provides lower estimated costs of IDR 61.1 billion, approximately 35% below the temporary jetty, while total mobilization requires approximately 73 working days. The findings support cost-effective and technically feasible logistics planning for renewable energy projects in remote archipelagic regions

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INTRODUCTION

Indonesia is the largest archipelagic country in the world with more than 17,000 islands, so inter-regional logistics connectivity is highly dependent on maritime transportation (Nasrullah, 2025). This geographical condition poses unique challenges in the development of energy infrastructure, including Solar Power Plants (PLTS) integrated with Battery Energy Storage Systems (BESS), especially in small and remote island areas that are not yet connected to the main mainland electricity grid. The development of PLTS + BESS in island areas is a relevant energy transition strategy, considering that the combination of the two technologies can provide a more stable electricity supply throughout the day despite the intermittent nature of solar energy production (Barai et al., 2017).

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However, the success of solar PLTS+BESS development in archipelagic regions is not only determined by the technical aspects of the electrical system design, but also greatly influenced by the logistical feasibility of mobilizing materials and equipment to the project site. The main components of solar PLTS+BESS, particularly the BESS units and transformers, are classified as heavy and oversized cargo, weighing up to tens of tons per unit, while port and land road infrastructure in many parts of the Indonesian archipelago still has limited capacity (Nasrullah, 2025; Widodo, Purwaditya, & Soemardjito, 2021). This imbalance between the need to handle heavy cargo and the limitations of existing infrastructure makes maritime transportation logistics planning a critical factor in the success of renewable energy projects in archipelagic regions (Chartron, 2019).

The case study in this research is the PLTS+BESS development project on Bawean Island, East Java Province, with two capacity configurations, namely 3 MW (±3.72 MWp) and 6 MW (±7.44 MWp), which are overall supported by an energy storage system (BESS) with a combined capacity of ±40,120 kWh. As an island with primary access via the Surabaya-Bawean sea route and port facilities that are still classified as small-medium scale regional/feeder ports, this project represents the typical logistical challenges of remote islands in Indonesia: the need for heavy cargo mobilization (BESS units 42-43 tons/unit, transformers 8-12 tons/unit) that must be aligned with the limitations of the pier length, the depth of the port basin, and the condition of the land road to the project location (M. O. A. González et al., 2024).

Studies on archipelagic transportation logistics in Indonesia have so far focused largely on the distribution of basic commodities and economic connectivity in remote areas, such as the evaluation of the Maritime Highway Program (Nasrullah, 2025) and the development of the House of Sustainable Logistics model in the Anambas Islands Regency (Widodo et al., 2021), as well as the concept of a Floating Logistics Supporting Facility for small islands (Gurning et al., 2022). On the other hand, international literature on the transportation logistics of large-scale renewable energy equipment has largely been developed in the context of offshore wind farm installations, highlighting port selection, vessel fleet, and component transportation strategies as logistical decisions that determine project cost efficiency (González et al., 2024; Vis & Ursavas, 2016). Specific studies on the characteristics of maritime transportation logistics for the mobilization of solar power plant equipment integrated with BESS in the Indonesian archipelago context, with an emphasis on the characteristics of heavy and oversized cargo such as battery units and transformers, are still relatively limited. This gap is the basis for the need for this research to be conducted (Gurning et al., 2022).

METHOD

This research uses a case study approach with a descriptive-quantitative method. The case study approach was chosen because this research aims to examine in-depth the logistics characteristics of a specific project (PLTS+BESS Bawean) that has a unique complexity and archipelagic context. While the quantitative approach is used to measure and compare technical parameters such as dimensions, weight, distance, time, and cost in a structured manner(Nasrullah, 2025).

The object of the research is the mobilization and demobilization process of PLTS+BESS project materials with two capacity configurations, namely 3 MW (±3.72 MWp) and 6 MW (±7.44 MWp), which are located at Alternative 5 (Alt-5) on Bawean Island, Gresik Regency, East Java Province, at coordinates -5.826775°, 112.726361°, with a project area of approximately 158,365 m². This area has topographic characteristics with mild to moderate local slopes (±3-15%) and main access via sea routes from the Port of Surabaya(Sikandar & Akram, 2025).

The research location is one of eight alternative solar power plant sites (Alt.1 to Alt.8) evaluated during the field survey phase, as shown in Figure 1 (Bawean Solar Power Plant Survey Team, 2026). Alternative 5 (Alt-5) is located on the eastern side of Bawean Island, while the existing power plants (PLTD, PLTMG, and PLTS Bawean) are concentrated on the southern side of the island, adjacent to Alt-3 and Alt-7. Bawean Port, as the main unloading point, is also located on the southern side (Sangkapura area), so cargo heading to Alt-5 must travel by land for approximately 10 km. This relative position forms the basis for the land route analysis in subsection 4.4.

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Figure 1. Map of Eight Alternative Locations for Solar Power Plants on Bawean Island (alt.1-alt.8) Along With Existing Generating Facilities
Source: Image Processed from the Bawean Solar Power Plant Survey Report, 2026

The variables analyzed in this study include: (1) cargo characteristics, namely the type, dimensions, and weight of the material; (2) infrastructure characteristics, namely the technical specifications of ports and land routes; (3) vehicle maneuvering parameters, namely the turning radius, clearance width, and number of critical points on the transportation route; and (4) logistics performance parameters, namely the estimated duration and costs of mobilization-demobilization.

Primary data was obtained through route and road access surveys which included measuring road width, bend radius, elevation, road slope, and identifying horizontal and vertical obstacles on two alternative routes (Bawean Port-site and temporary jetty-site). In addition, vehicle maneuver simulations were conducted using the swept path analysis method with the longest cargo configuration as a critical scenario (worst-case scenario), namely a unit with dimensions equivalent to ±6 meters long and ±3 meters wide, representing the dimensions of the BESS unit. Secondary data was obtained from the technical study document for mobilization and demobilization of Bawean PLTS+BESS equipment (Document No. TMI-2025-PLNE-PLTS BESS Bawean, Revision 1, April 17, 2026), which contains a list of materials (packing list), technical specifications of transportation equipment, field survey results, and estimates of mobilization-demobilization time and costs.

Primary data collection was conducted through a direct visit by the survey team to Bawean Island, as documented in Figure 2. Survey personnel were able to access the island by air using small-capacity pioneer aircraft, resulting in faster arrivals. However, this mode of transport is not suitable for transporting project materials weighing tens of tons, so all PLTS and BESS cargo remains dependent on sea transportation. The survey findings are recorded in the Bawean PLTS Survey Report (Bawean PLTS Survey Team, 2026).

Sosioedukasi
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Figure 2. Field Survey Team on the Airport Apron with a Pioneer Aircraft as a Means of Access for Personnel to Bawean Island
Source: Documentation of the Bawean PLTS Survey Team, 2026

The data were analyzed descriptively and quantitatively using a comparative approach, comparing two material unloading point scenarios (the existing Bawean Port and the temporary jetty) based on parameters such as travel distance, number and type of critical maneuver points, estimated time, and estimated cost. The comparison results were then interpreted by referring to the conceptual framework for logistics decisions for renewable energy installations (González et al., 2024) and the principles of sustainable island logistics (Widodo et al., 2021) to gain a more comprehensive understanding of the determinants of optimal logistics strategies(Vis & Ursavas, 2016).

The research was conducted through the following stages: (1) identification and classification of materials based on the project packing list; (2) survey of routes and road access at two alternative unloading points; (3) vehicle maneuver simulation (swept path analysis) to determine geometric critical points; (4) preparation of estimates of mobilization-demobilization time and costs for each alternative; (5) comparative analysis between alternatives; and (6) drawing conclusions and recommendations for logistics strategies(Widodo et al., 2021).

RESULT AND DISCUSSION

Material Characteristics and Cargo Classification

The total combined capacity of the Bawean PLTS+BESS project reaches ±11.16 MWp (3.72 MWp + 7.44 MWp), supported by an energy storage system (BESS) of up to ±40,120 kWh spread across 8 battery containers. Details of the main material requirements for each capacity are presented in Table 1.

Table 1. Recapitulation of the Main Material Requirements for the Bawean Plts+Bess Based on Capacity

Component	Capacity 3 MW (±3.72 MWp)	Capacity 6 MW (±7.44 MWp)
Solar modules	6,768 units	13,527 units
Inverter (350 kW/unit)	9 units	18 units
Battery system (BESS)	2 units (±10,030 kWh)	6 units (±30,090 kWh)
Transformer	2 units @2,500 kVA	2 units @5,000 kVA

Sosioedukasi
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Volume 15 No. 4 December 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Component	Capacity 3 MW (±3.72 MWp)	Capacity 6 MW (±7.44 MWp)
DC cable	±4,378 m	±11,848 m
AC cable	±6,783 m	±7,222 m
Mounting system	30 pallets	15 pallets

Source: Data Processed from the Project Technical Study Document, 2026

The dimensional and weight characteristics of each type of material form the basis for determining the appropriate mode of transportation, as presented in Table 2.

Table 2. Dimensional Characteristics, Weight, and Cargo Categories of Bawean PLTS+BESS Materials

Material Type	Dimensions (L x W x H)	Heavy	Cargo Category
Solar modules	±2.278 x 1.134 x 30 mm	±31.5 kg/unit	General cargo (container)
Inverter station	Compact	≤106 kg/unit	General cargo (container)
Water tank	Varies	Varies	General cargo (container)
DC/AC cable	Reel/drum	Varies (significant total)	General cargo (container)
Transformer	3,200 x 3,000 x 3,100 mm	8,000-12,000 kg/unit	Heavy cargo (SPMT)
Mounting system	5,900 x 1,100 x 1,000 mm	42,000-43,000 kg/shipment	Heavy cargo (SPMT)
Battery system (BESS)	±6,058 x 2,896 x 2,438 mm	42,000-43,000 kg/unit	Heavy & oversized cargo (SPMT)

Source: Processed Data from the Project Technical Study Document, 2026

Based on Table 2, project materials are classified into two main transportation categories. First, breakbulk/heavy cargo, which includes battery systems (BESS), transformers, and mounting systems, with a unit/shipment weight ranging from 8-43 tons and dimensions exceeding the capacity of standard transportation modes, thus requiring handling using Self-Propelled Modular Transporters (SPMT) on land routes and crane barges on sea routes. Second, general/small cargo, which includes solar modules, inverter stations, water tanks, and DC/AC cables, which can be shipped using a 20-foot container system via trucking and Roll-on/Roll-off (Ro-Ro) ships(Amin et al., 2021).

Interestingly, when referring to the definition of heavy lift in international transportation literature which generally requires a weight above 100 tons per indivisible unit, the BESS and transformer units in this project (42-43 tons and 8-12 tons respectively) individually do not meet this threshold. However, the combination of oversized dimensions (the length of the BESS unit reaches ±6 meters) and the limitations of local road and port infrastructure still make its handling equivalent to a heavy cargo project, in line with the emphasis of Sikandar and Akram (2025) that the complexity of SPMT transportation is not solely determined by absolute weight, but also by the interaction between cargo dimensions, bend radius, and the geometric conditions of the available route(Amin et al., 2024).

Modes and Mechanisms of Sea Transportation

The material mobilization mechanism is implemented through two parallel channels according to cargo category. For heavy/oversized cargo (breakbulk cargo), materials from the country of origin (a combination of Indonesian, Chinese, and German manufacturers) are sent to the Port of Surabaya using cargo ships, followed by a customs clearance process that includes verification of import documents, payment of import duties and taxes, and physical inspection(Díaz & Guedes Soares, 2023). The material is then loaded onto a crane barge at the Port of Surabaya and departed for Bawean Port or a temporary jetty with an estimated sailing time of ± 8-12 hours depending on weather conditions and sea waves. The crane barge is equipped with a 200-ton crawler crane for loading and unloading operations at sea (marine lifting) without relying

Sosioedukasi
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Volume 15 No. 4 December 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

on land port facilities. Upon arrival at the location, the material is transferred to a 6-axle SPMT for land transportation to the site, with the final unloading process using a 90-ton mobile crane according to the prepared lifting plan(Rahayu et al., 2024).

The general sequence of mobilization stages is summarized in Figure 3. Cargo is shipped from its origin to the Port of Surabaya, with the option of temporary storage in a warehouse or port area if a vessel schedule is not yet available. The cargo is then loaded onto a barge, sailed to Bawean, and unloaded at Bawean Port or a temporary jetty with the assistance of a mobile crane and lowbed (equivalent to the 6-axle SPMT discussed above). The cargo is then re-loaded onto the lowbed using a crawler crane for transport to the project site and unloaded by a mobile crane. Feedback arrows in the diagram indicate that the transport unit returns to the port or jetty to pick up the next load. This batching delivery pattern explains the heavy cargo duration of 6 days for the battery system and 15 days for the mounting system in subsection 4.5 (Bawean Solar Power PLTS+BESS Project Technical Study Team, 2026).

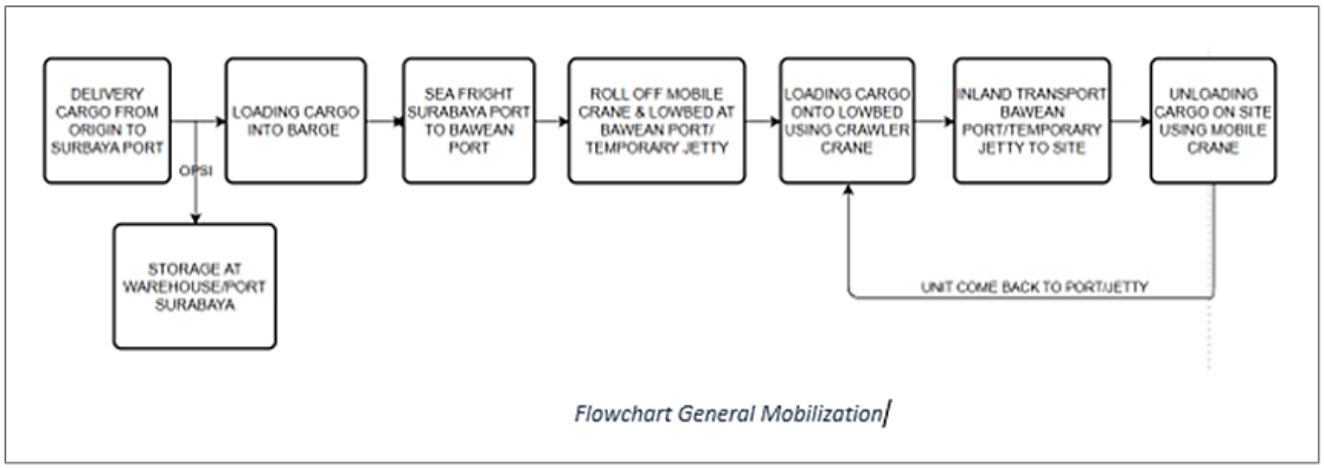


Figure 3. General Flow Diagram of Mobilization of PLTS+BESS Materials from the Port of Origin to the Project Location
Source: Image adapted from the Mobilization-Demobilization Technical Study Report, 2026

For general cargo (general/small cargo), materials are packed in containers and sent to the Port of Surabaya, then undergo a destuffing process using a forklift before being loaded onto a trucking unit (a 6-9 meter Fuso truck). The trucking unit and its cargo are then loaded onto a Roll-on/Roll-off (Ro-Ro) ship from Paciran Port to Bawean with a sailing frequency of twice per week (Monday and Wednesday), before finally being forwarded via land transportation to the project site(Sunitiyoso et al., 2022).

The departure point for Ro-Ro ships for general cargo is at Paciran Port, Lamongan Regency, on the north coast of East Java, as shown in Figure 4. Based on the image, Bawean Island (Tambak and Sangkapura) is located north of the port and can be reached directly by sea without passing through the Madura Strait. Paciran's role as a limited-frequency crossing node (Monday and Wednesday) is a determining factor in the delivery duration of 667 pallets of solar modules, which reaches approximately 22 days, because each voyage is limited by the vehicle's carrying capacity(Jiang, 2021).

The separation of these two transport routes reflects the principle of dual transport strategy also identified in the literature on offshore renewable energy installation logistics, where the use of a dedicated fleet for oversized components is separated from the regular fleet for standard-sized components to optimize costs and operating times (González et al., 2024).

Sosioedukasi
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Volume 15 No. 4 December 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index



Figure 4. Location of Paciran Port as the Departure Point for Ro-Ro Ships to Bawean Island
Source: Image Adapted from the Mobilization-Demobilization Technical Study Report, 2026

Characteristics of Port Infrastructure: Bawean Port vs Temporary Jetty

The existing Bawean Port is a regional/feeder port serving passenger ships and small-medium-scale cargo ships, with a pier length of ±80-120 meters, a pool depth of ±2-5 meters, and a limited yard area, under the management of PT Pelindo Bawean. As an alternative, the construction of a temporary jetty with dimensions of ±600 m x 20 m with a carrying capacity of 10-17 tons/m², which functions for barge berthing and Ro-Ro operations, is planned closer to the project area. A comparison of the characteristics of the two alternatives is presented in Table 3.

Table 3. Comparison of Characteristics of Bawean Port and Temporary Jetty

Aspect	Bawean Port (Existing)	Temporary Jetty
Distance from port of origin (China)	±2,661 nautical miles (NM)	±2,662 nautical miles (NM)
Distance from port to project location	±10 km	±1 km
Land transportation costs (estimate)	Rp61,107,801,520	Rp94,100,276,377
Land transportation duration (estimated)	±27-72 days	±17-72 days
Number of related licensing agencies	7 agencies	11 agencies
Public traffic interaction	High (via public road)	Low (limited access)
Operational risk level	Medium-high	Currently

Source: Data Processed from Project Technical Study Documents, 2026

The data in Table 3 demonstrates a clear trade-off pattern: the existing Bawean Port has a superior land transportation cost advantage, but it has a longer land travel distance and higher public traffic interaction due to its use on public roads. Conversely, the temporary jetty offers a much shorter land travel distance and minimal public interaction, but requires a more complex permitting process (11 agencies, including the Environmental Agency and the Ministry of Maritime Affairs and Fisheries) and investment in new infrastructure (Lin & Lu, 2023).

Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
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Volume 15 No. 4 December 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

The physical conditions of the two alternative unloading points are shown in Figures 5 and 6. The existing Bawean Port (Figure 5) is located in the Sangkapura area and field documentation appears to serve passenger ferries at a pier that juts out towards the sea. This condition is in line with the characteristics of a regional/feeder port with a pier dimension of ±80-120 meters and a pool depth of ±2-5 meters, so that loading and unloading operations of BESS units and transformers still require a crane barge that works independently from land facilities (Bawean Solar Power PLTS+BESS Project Technical Study Team, 2026).



Figure 5. The Existing Bawean Port in Sangkapura:
Location (Red Circle), Ferry at the Pier, and Aerial View of the Pier
Source: Image Documentation of the Bawean PLTS Survey Team, 2026

The second alternative, a temporary jetty (Figure 6), is measured in Google Earth imagery to be approximately 577 meters long, consistent with the planned dimensions of approximately 600 m x 20 m. The jetty juts out into the sea across shallow, light-colored waters near the coastline until it reaches deeper waters, while its base is adjacent to residential areas. These two points are relevant to the findings in Table 3, namely the need for permits from 11 agencies (including the Environmental Agency and the Ministry of Maritime Affairs and Fisheries) and low public traffic interaction due to limited access (Bawean Solar Power Plant Survey Team, 2026).

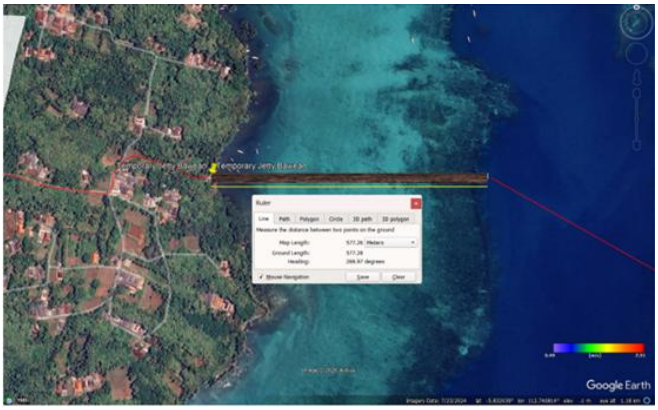


Figure 6. The Planned Location of the Bawean Temporary Jetty on Google Earth Imagery
(Imagery of July 23, 2024) with a Length Measurement of ±577 M
Source: Source: Image Processed from the Bawean PLTS Survey Report, 2026

Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
ISSN: 2086-6135 E-ISSN: 2541-612x
Volume 15 No. 4 December 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Simulation Results of Maneuvers and Critical Points of Land Routes

Maneuver simulations using the swept path analysis method were conducted with the longest cargo configuration (equivalent to the dimensions of a BESS unit, ±6 meters long and ±3 meters wide) as the critical scenario. Based on the simulation, the 6-axle SPMT requires an inner bend radius of 3.3 meters and an outer bend radius of 8.9 meters, with a required clearance area width of 5.2 meters(Yin et al., 2024).

On the route from Bawean Port to the project site, which is approximately 10 km long (10.4 km based on the route survey results), the existing road condition has an average width of approximately 5 meters with paving block pavement, except for the final access segment of approximately 1 km to the site, which is only approximately 2.5 meters wide and requires widening to approximately 4.5 meters. 6 critical points were identified on this route, as presented in Table 4.

Table 4. Critical Points of the Bawean Port Route to the Project Location

No.	Distance from starting point	Types of obstacles
1	20.33 m	Narrow turning radius
2	881.94 m	Narrow turning radius
3	1,344.6 m	Narrow turning radius
4	4,064.8 m	Steep gradient
5	7,298.9 m	Narrow turning radius
6	8,685.1 m	Narrow turning radius

Source: Processed from the Project Technical Study Document, 2026

On the alternative route from the temporary jetty to the project site, which is approximately 1 km long, the existing road has an average width of only approximately 2 meters with a combination of native soil and concrete pavement, so it still requires widening of up to approximately 4.5 meters. Two critical points were identified on this route, as presented in Table 5.

Table 5. Critical Points of the Temporary Jetty Route to the Project Location

No.	Distance from Starting Point	Types of Obstacles
1	160.23 m	Narrow turning radius
2	177.30 m	Narrow turning radius

Source: Data Processed from the Project Technical Study Document, 2026

A comparison of the density of critical points per unit distance reveals a noteworthy finding: the Bawean Port route has 6 critical points at a distance of 10 km (density of ±0.6 points/km), while the temporary jetty route has 2 critical points at a distance of 1 km (density of 2.0 points/km). This means that although in absolute terms the temporary jetty route has fewer critical points, the density of geometric obstacles per kilometer on this route is actually higher than that of the Bawean Port route. This finding strengthens the argument of Sikandar and Akram (2025) that the evaluation of the feasibility of SPMT transportation for oversized cargo cannot be based solely on the total distance, but also on local geometric characteristics along the route, especially the radius of curves and road gradients that directly impact the stability risk of transport vehicles(Sarichloo et al., 2026).

Estimated Mobilization Time and Costs

Estimated delivery times are based on cargo category. General stages include loading at the Port of Surabaya (2 days), sea freight to Bawean (1 day), and roll-off and inland transport to the site (1 day). For the heavy cargo category, namely battery systems (8 units), transformers (4 units), and mounting systems (30 units), delivery is carried out using a crane barge followed by SPMT in stages (batching), with an estimated duration of 6 days (battery system), 2 days (transformer), and 15 days (mounting system) respectively. For the general/small cargo category, namely water tanks, cables, and inverter stations, delivery is carried out using a Ro-Ro ship from Paciran Port with an estimated duration of 1 day for each type of material, while solar modules (667 pallets) require a longer time, namely around 22 days, because delivery is carried out in stages

Sosioedukasi
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Volume 15 No. 4 December 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

following the Ro-Ro shipping schedule (2 times per week) and vehicle carrying capacity. Overall, the total duration of material mobilization is estimated to last for ±73 working days, while the mobilization-demobilization permit process is estimated to require an additional time of ±3 to 6 weeks, some of which can be carried out in parallel with other stages(M. González et al., 2026).

In terms of costs, the estimated total mobilization-demobilization cost using the temporary jetty is recorded at Rp94,100,276,377, while using the existing Bawean Port is Rp61,107,801,520. This difference is equivalent to savings of approximately 35% if the project uses the existing port compared to building and operating the temporary jetty.

Discussion

The results of this study show that port selection is the most fundamental logistics decision in the Bawean PLTS+BESS project, consistent with González et al.'s (2024) conceptual framework, which places port decisions as the first and most influential decision on all subsequent logistics decisions in renewable energy installations. The 35% cost difference between the two alternative unloading points in this case study provides quantitative empirical evidence that strengthens the generalizability of the framework to a different context, namely island-based PLTS+BESS projects, which have previously been more verified in the context of offshore wind turbine installations.

The limitations of Bawean Port facilities, particularly the depth of the pool (±2-5 meters) and the length of the pier (±80-120 meters) which are classified as small to medium, are in line with the findings of Nasrullah (2025) who identified that only 58.7% of ports in the national Sea Toll network were assessed as having adequate facilities to support large-scale loading and unloading activities. This condition explains why the Bawean PLTS+BESS project still requires the support of a crane barge that operates independently from land port facilities, instead of fully relying on existing port infrastructure.

In the land transportation aspect, the use of 6-axle SPMT to move BESS units (42-43 tons, dimensions ±6 meters) and transformers (8-12 tons) is a solution that is in line with the practices and findings of Sikandar and Akram (2025) regarding the importance of SPMT stability control in challenging road geometric conditions. The identification of critical points with higher density on the temporary jetty route (2.0 points/km) compared to the Bawean Port route (0.6 points/km) shows that shorter travel distances do not necessarily mean lower maneuvering risks, so that the decision to select an unloading point needs to consider both cost aspects and operational technical risk aspects simultaneously, not just one factor alone.

From a battery transportation safety perspective, the technical study document that served as the data source for this research does not explicitly explain the state of charge (SoC) status or compliance with the International Maritime Dangerous Goods (IMDG) code during BESS unit shipments by sea. Referring to Barai et al. (2017), managing the SoC of lithium batteries during long-distance transportation plays a crucial role in reducing the risk of thermal runaway without compromising the long-term performance of the cells. Considering that the estimated delivery duration of the battery system in this case study reached 6 days and involved long sea and land transportation, the aspect of SoC management and compliance with dangerous goods regulations is an area that requires further attention in planning similar projects in the future, although it has not been a primary focus in the available technical study documents.

Overall, the findings of this study align with the principles of sustainable island logistics proposed by Widodo et al. (2021), who emphasize that infrastructure is one of the five key drivers of remote island logistics. In the case of Bawean, limited port and road infrastructure are the dominant factors determining the need for additional investment, both in the form of crane barge rentals and the construction of temporary jetties, to bridge the gap between the heavy cargo handling needs of renewable energy projects and the capacity of existing infrastructure.

This study is limited by its single-case study scope, meaning the cost and time figures presented are specific to the project, vendor, and technical review period (April 2026), and may not be directly generalizable to other island PLTS+BESS projects with different infrastructure characteristics. Further research using a multi-case approach on several island PLTS+BESS projects in Indonesia is recommended to gain a more comprehensive understanding of the generalizability of the determining factors of maritime transportation logistics strategies in this context.

Sosioedukasi
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CONCLUSION

This study examined maritime logistics for mobilizing and demobilizing equipment for the 3 MW and 6 MW solar photovoltaic power plant and battery energy storage system (PLTS+BESS) projects on Bawean Island, East Java. Findings identify cargo characteristics, port infrastructure, road geometry, costs, and schedules as key determinants of logistics feasibility. Materials comprise breakbulk/heavy cargo, including BESS units, transformers, and mounting systems, and containerized cargo, including solar modules, inverters, and cables. Each category requires transportation and handling arrangements.

The existing Bawean Port is more cost-effective, with estimated mobilization and demobilization costs of IDR 61.11 billion, approximately 35% below the IDR 94.10 billion estimated for the temporary jetty. However, it requires inland transport over approximately 10 km and interaction with public traffic. The temporary jetty shortens the route to approximately 1 km but has a higher density of critical maneuvering points and requires road improvements for oversized cargo. Mobilization is estimated at 73 working days, excluding three to six weeks for permitting. Thus, logistics decisions should consider cost, accessibility, maneuvering safety, permitting, and operational feasibility together.

This study is limited by its single-project scope, which may restrict generalizability to islands with different geographical and infrastructure conditions. It also relies partly on technical assessment documents and estimated costs and schedules rather than operational data. Furthermore, documentation provides insufficient detail on battery state-of-charge management and compliance with the International Maritime Dangerous Goods (IMDG) Code during transportation.

Future research should compare multiple PLTS+BESS projects across Indonesian islands to test these findings. Sensitivity and risk analyses could evaluate cost and schedule variations related to weather, vessel availability, fuel prices, and permitting delays. Studies should assess BESS transportation safety, including state-of-charge management, dangerous goods compliance, and emergency response procedures. Integrating these factors into a decision-making framework could support safer, efficient renewable energy development in remote archipelagic regions.

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