Design of Lighter Aboard Ship (LASH) for distribution of goods in small islands: case study of Kangean archipelago

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Abstract. A ship is an important means of transportation for archipelagic countries such as in Indonesia. The development of ship technology in the world has shown a rapid progress, where various innovations have been made in the effort to ease and accelerate the sea transportation system. These are ranging from the design of ships, cargo and logistics handling systems, and enhancement of regulations related to ship safety. Lighter Aboard Ship (LASH) is an innovation of ship type that has the concept as a ship loading lighter barges. This ship is designed to reduce waiting times at the port and reduce the use of port docks, so that it is highly suitable to serve the small islands where adequate port facilities are typically not available. The aim of the study is to design a LASH that will be used as a means of transportation of goods in the Kangean Archipelago. This is a group of small islands located in the easternmost of Sumenep District, with a total population of 192,807 people forecasted by 2019. The LASH vessel size is determined by using the optimization with linear programing. The initial stages are the definition of owner requirements, which include primarily the cargo load capacity and ship speed. The design in turn provides the main dimensions of the LASH, namely the Length Over All (LOA) of 48.71 m, breadth moulded (Bmld) 10.43 m, and deck height moulded (Hmld) 4.09 m.

1. Introduction

The geographical condition of Indonesia as an archipelagic country with a vast number of islands, faces a challenge in the goods and logistic distribution system, especially through waterways. These challenges can be in the form of the process of shipping goods, which will have an impact on the amount of goods supplied to the small and remote islands, and subsequently governs the prices of goods in those small islands and the corresponding regions. The assurance in regularity of goods and logistic supply to remote and small islands will surely generate economic stability, social stability and enhancing security by minimizing the price gaps with the main islands [1]. Availability of reliable sea transportation in another stance means also providing easiness for people mobility from the small and remote islands to the main islands and vice versa. This in turn would certainly play an important role in boosting the human resource developments nationwide [2-4]. One area of interest in the current study is Kangean Archipelago.

Kangean Archipelago, as shown in Figure 1, is a small archipelago as a sub-district in the eastern most region of Sumenep District, East Java Province of Indonesia. Kangean Archipelago covers an area of approximately 487 km², consisting of some 60 small islands [5], located at 5°4’39”S 114°36’5”E. There are three large islands in the region, namely Kangean Island, Paliat Island, and Sepanjang Island,
each having a land area of 188 km$^2$, 36 km$^2$, and 67 km$^2$. Kangean Archipelago is considered as a significant natural gas resource since 1993 when the first fields were discovered by a US corporation ARCO. In this respect a 430 km underwater pipeline connects Kangean Archipelago and East Java to transport the natural gas product for use by the national electricity company and various other industries. Beside natural gas, Kangean Archipelago also produce certain agriculture and marine products [6]. On top of that the area is also famous with marine scenery and ecology, which are potential for marine tourism [5,7,8].

Figure 1. Location of Kangean Archipelago in conjunction with Java Island
Source: Google maps (edited)

The main hubs for supply and sea transportation to Kangean Archipelago are Kalianget Port in Sumenep and Tanjungwangi Port in Banyuwangi, where Sumenep and Banyuwangi are connected to the main industrial city of Surabaya, which is also the capital of East Java Province. The sea transportation which connects Kangean Archipelago with the two main hubs and some other regions is supported by vessels functioned to carry cargo, passenger, or combination of cargo-passenger. These are served by three sea transport providers, which are, firstly, the traditional shipping companies or widely known as pelayaran rakyat abbreviated as Pelra, secondly, the Sumenep District own shipping company, and, thirdly, the central government shipping company that operates pioneering ship or Perintis [9,10].

A special strategy is needed to create the appropriate sea transportation facilities to support the sea transportation network in small islands, considering that many aspects such as inadequate port facilities, so that the size of ships will be limited to be able to stop at the ports on these small islands. One of the ideas that became the aim of the current investigation is to conduct a design study of the use of the Lighter Aboard Ship (LASH). This type of ship is an innovation ship that was created for the first time in 1960 [11]. The ship is operated to load small barges designated as the lighter, which is basically containers for storing cargo. The lighters are floated in the seaside or even in the river for loading cargoes and then the lighters are transferred to the appropriate location to be loaded to the LASH. The loading of cargo in the lighter is aimed at reducing the waiting time, and reducing the use of docks at the port, so it is expected can be suitable for use as a transportation mode for shipping goods to small islands which mostly do not have adequate port facilities.

2. Methodology

2.1 Problem Identification
Conditions for shipping goods in Kangean have been going well, but there are some things that are not running efficiently. As with Pelra ships, the time needed to stay on the pier is around seven days or more, with components around approximately four (4) days for the time required for the process of unloading, and three (3) days or more for the process of loading goods or waiting for load availability. For Perintis ships, the time used to occupy the pier is around twelve (12) hours or half day for the loading and unloading process, with the illustration of the use of time in Figure 2.

Figure 2. The ships harbouring at the Port of Kangean: (a) Pelra vessels and (b) Perintis vessel

### 2.2 Data collection

The earliest data collection conducted in this study has been based on the data available for the year of 2016 to 2018 from the Central Statistics Agency of Sumenep District [12-14]. The first data collected is on the population as shown in Table 1. Population data is considered important as it is directly presenting to number of population to be served with goods and logistics as well as necessary mobility. Hence it reflects the market for sea transportation. The population is divided into three separate location according to the sub-districts, namely Arjasa, Kangayan, and Sapeken. As the data available from [11-13] covers only from 2016 to 2018, then the data for 2019 is forecasted from those available in previous years, where total population is approximately 192,807 people. From Table 1, it can be seen that the largest forecasted population is in Arjasa sub-district, followed by Sapeken and Kangayan sub-districts.

| Sub-district     | 2016  | 2017  | 2018  | 2019   |
|------------------|-------|-------|-------|--------|
| Sub-district Arjasa | 82,923| 84,700| 98,426| 109,164|
| Sub-district Kangayan | 24,768| 24,724| 26,779| 28,309 |
| Sub-district Sapeken | 50,327| 50,515| 53,242| 55,334 |
Figure 3. The Kangean Archipelago sea transportation network

The second data collected from [12-14] is the ports within the Kangean Archipelago transportation network, as illustrated in Figure 3. The hub ports are Kalianget Port in Sumenep and Tanjungwangi Port in Banyuwangi. While the ports in Kangean Archipelago are Batugolok Port in Arjasa, Kangayan Port, and Sapeken Port. The sizes and depths of those ports are listed in Table 2.

| No. | Location                          | Size     | Depth (m) |
|-----|----------------------------------|----------|-----------|
| 1   | Sumenep (Kalianget Port)         | 80.0 × 10.0 | 9.0       |
| 2   | Banyuwangi (Tanjungwangi Port)   | 543.0 × 15.0 | 12.5     |
| 3   | Arjasa (Kangean Batugolok Port)  | 45.0 × 10.0 | 9.0       |
| 4   | Kangayan Port                    | 35.0 × 2.0  | 1.8       |
| 5   | Sapeken Port                     | 130.0 × 12.0 | 9.0     |

2.3 The Pattern of Shipping Goods in Kangean Archipelago

From the field research, the pattern of cargo shipping by sea transportation in Kangean network can be identified. The majority of goods from industrial products are obtained by supplies from Kalianget Port of Sumenep and Tanjungwangi Port of Banyuwangi. For the case of time and capacity of loading and unloading for Pelra and Perintis vessels at Batugolok Port in Arjasa is as shown in Figure 4. It is obvious that the time required for Perintis vessels to loading and unloading is only about half day. Whereas for Pelra vessels take up to four days to unload and three days to load cargoes, hence totally takes about seven days. The total capacity of goods unloaded are larger than those loaded, for both the case of Perintis and Pelra vessels.
2.4 **Determination of the Concept of Utilization**

Of the several conditions in Kangean, the problem that occurs is the absence of activity on the ship, which means there are less optimum performances such as:

1) The engine idle is longer, and
2) Ships are not effectively operating because they are waiting for cargo.

The idea of the current study is to adopt the concept and utilizing LASH vessels where lighters or small barges as a storage container can be a temporary place at the port, to wait for the cargo to accumulate. This way makes it possible the ship continue to operate without waiting for the loading and unloading activities at the port. The concept that is conceived as exhibited in Figure 5 and explained in the scenario below:

a. The LASH vessel is anchored near the port area;
b. The LASH unload the lighter barges containing cargo to the port;
c. The already loaded lighter barges are pulled from the port and loaded to the LASH;
d. The LASH leave the port.

![Figure 4. Time and capacity chart of Pelra and Perintis ships at Batugulok-Arjasa Port](image-url)
3. Results and Discussions

3.1 Maximum Draft

To determine the maximum draft should consider the water depth at the port so that the ship as well as the lighter barge can be operated safely and free from obstruction. The approximate formula approach as follows [15]:

\[
\text{Maximum draft of Ship/Barge} = 1.1 < \frac{d}{T} < 1.5
\]  

(1)

\(d\) = water depth (m),  
\(T\) = draft of the ship or lighter barge.

Using equation (1), the maximum drafts of the LASH and lighter barge that can be accommodated at the ports within Kangean Archipelago network are listed in Table 3.

| No. | Location                      | Max Draft (m) |
|-----|-------------------------------|---------------|
| 1   | Sumenep (Kalianget Port)      | 7.5           |
| 2   | Banyuwangi (Tanjungwangi Port)| 12.50         |
| 3   | Arjasa (Kangean Batugolok Port)| 9.00         |
| 4   | Kangayan Port                 | 1.80          |
| 5   | Sapaken Port                  | 9.00          |

3.2 The Amount of Goods

The goods transported in the Kangean Archipelago network is divided into two groups. These comprise the goods supplied to the Kangean Archipelago, and the goods carried from the Kangean Archipelago.

a). The goods supplied to Kangean Archipelago, namely:

Type I is daily needs: sugar, cooking oil, flour, salt, LPG, etc, which can be approximated by the following calculation:

\[\text{Volume} = \text{Total Consumption per Capita} \times \text{Total Population} \times 365\]  

(2)
Type II is the need of materials to support building houses: plywood, cement, and steel. In the calculation of building materials the assumptions used are houses of type 36, and in one household will be accommodate four person. This can be approximated by:

\[ \text{Volume} = \text{Total Consumption per Capita} \times \text{(Number of Households} \times 365) \times \text{Population growth rate} \quad (3) \]

b). Goods carried from Kangean Archipelago are in the form of crops, namely rice, corn, coconut, and cassava. By considering all the available data of cargo supplied to and carried from Kangeab Islands, the matrix of cargo volume origin-destination per year is presented in Table 4.

**Table 4. Matrix of cargo origin-destination (ton / year)**

| No | Origin | Destination | Sumenep | Banyuwangi | Arjasa | Kangayan | Sapaken |
|----|--------|-------------|---------|------------|--------|----------|---------|
| 1  | Sumenep| -           | -       | 6,269      | 1,626  | 3,171    |         |
| 2  | Banyuwangi | -        | -       | 6,269      | 1,626  | 3,171    |         |
| 3  | Arjasa  | 4,373       | 4,373   | -          |        | 2,292    |         |
| 4  | Kangayan | 2,165      | 2,165   | -          |        | 1,572    |         |
| 5  | Sapaken| 127         | 127     | 2,112      | 1,572  | -        |         |

### 3.3 Lighter Barge Size

The optimum barge size is obtained by the minimizing the total cost of building a new lighter barge (Total Cost). The mathematical expression of the optimization is as follows:

- **Objective function**
  \[ \text{Min}(\text{Total Cost}) \]

  \[ \text{Total Cost} = \sum_{i=1}^{n} Wst \times Pst \quad (5) \]

  - \( Wst \) = steel weight
  - \( Pst \) = steel price
- **Constraint**
  1). Displacement = capacity equipment (40 ton);
  2). Size ratios: \( L/B = 1.97, B/T = 3.65, \) and \( B/H = 2.38 \).
- **Decision variable**
  Main lighter barge sizes: length \( L \) (m), breadth \( B \) (m), deck height \( H \) (m), and draft \( T \) (m).

  From the computation, finally the optimization yields the lighter barge sizes as presented in Table 5. The design of the optimized lighter barge is shown in Figure 6.

**Table 5. Results of the lighter barge size optimization**

| Item    | Size | Unit |
|---------|------|------|
| Length  | 7.55 | m    |
| Breadth | 3.84 | m    |
| High    | 1.62 | m    |
| Draft (T)| 1.35 | m    |
| Weight  | 8.18 | ton  |
| Payload | 31.82| ton  |
### Table 6. Results of the LASH vessel size optimization

| Item                        | Size  | Unit |
|-----------------------------|-------|------|
| Length Over All (LOA)       | 48.71 | m    |
| Breadth moulded (Bmld)      | 10.43 | m    |
| Deck height moulded (Hmld)  | 4.09  | m    |
| Draft (T)                   | 3.07  | m    |
| Payload                     | 960   | ton  |
| Deadweight (DWT)            | 1,056 | ton  |
| Item                              | Size   | Unit |
|----------------------------------|--------|------|
| Displacement (Δ)                 | 1,395  | ton  |
| Capacity (number of lighter barge)| 24     | unit |

3.5 LASH General Arrangement

Based on the results of the size calculation, the general arrangement design and the cargo handling concept for the LASH vessel that is proposed to serve the Kangean Archipelago sea transportation network are shown in Figure 7 and Figure 8.

Figure 7. The general arrangement design of the LASH vessel for Kangean Archipelago sea transportation network
3.6 Port Time Analysis of LASH Ship

Analysis has been conducted on the use of port time based on the operational pattern of LASH ship in Batugulok Port in Arjasa. This analysis involves the comparison of the current condition of ships serving shipping goods at the corresponding port, which further provides the following accounts:

1) Number of lighter barges sent = 10 units;
2) Number of lighter barges received = 10 units;
3) Capacity of 1 unit barge = 31.82 ton;
4) Estimated of lighter barge handling time = 15 minutes.

Results of the analysis of the port time of the LASH vessel are exhibited in Figure 9. These indicate that the time needed for the process of unloading cargo carried by 10 barges requires 2.5 hours, and for the loading process of 10 barges requires 2.5 hours also. Therefore, the total time for the unloading and followed by loading process of LASH vessels in the port of Batugulok in Arjasa is 5 hours.
4. Conclusions
A study has been conducted on the design of lighter aboard ship (LASH) for distribution of goods in Kangean Archipelago. Some findings from the study are summarized as follows:

- The LASH vessel dimensions are length over all $LOA = 48.71$ m, breadth moulded $Bmld = 10.43$ m, deck height moulded $Hmld = 4.09$ m, and draft $T = 3.07$ m. The LASH is designed to carry 24 lighter barge, each of which is sized length $L = 7.55$ m, breadth $B = 3.84$ m, height $H = 1.62$ m, and draft $T = 1.35$ m.

- Results of the computation on the port time with a particular case of one location in Batugulok Port in Arjasa indicate a single shipment by LASH vessel requires some 5 hours to process unloading and loading 10 barges with a capacity of 31.82 ton each.

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