Search and rescue station location selection and conceptual design: a case study of western region of Indonesia

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Abstract. The existence of marine Search and Rescue Units (SRU) to support the search and rescue operations currently are not supported by sufficient infrastructures and facilities. The infrastructures and facilities operated by the National Search and Rescue Agency (NSARA) have not been able to cover all working areas. One example is the location of NSARA dock facilities which is in remote area and has a narrow access channel causes duration to get to the area of accident is quite long. In that condition, the coordination among the SAR vessels and crew cannot perform efficiently and effectively. On the other hand, the National SAR Agency regulation No. 14, the year 2015, describes the necessary infrastructures and facilities that must be provided to support the implementation of marine SAR operations. This paper uses Western Region of Indonesia as a case study aiming to determine the optimum location and conceptual design of SAR station. Set Covering Problem method used to determine SAR station location and SAR vessels required, whereas conceptual design of the infrastructures is established based on data of routes and location selected. From the set covering model, we found 10 locations of SAR station, namely Aceh, South Kalimantan, Bengkulu, South Sumatra Bangka Belitung, Riau, West Kalimantan, Central Java, Riau Islands, and Yogyakarta. There is a total of 20 units of ships deploy with the total operation cost of IDR 263 billion/year (USD 18.5 million/year). The minimum dimensions of the berth have a length of 15 m and a width 5 m, while the gangway has a length of 163 m and a width of 5 m. The total cost of SAR station is IDR 8 billion/year (USD 562,390/year).

1. Introduction

Indonesia is an archipelagic country, where marine transportation is the primary means not only for the mobility of goods, people, or passengers, as well as livestock but also for national defences and security purposes. Marine transportation has more advantages in comparison to other modes, namely the capability of reaching remote and small islands that cannot be reached by other modes. This causes the demand for marine transportation to increase, causing an escalation of heavy shipping traffic in Indonesian waters, which in turn increasing the risk relating to maritime safety and security. Although several international regulations related to maritime safety and security already exist, the issue of maritime safety and security is still a significant concern of the shipping industry [1]. In addition to this, poor weather and relatively severe sea conditions in certain months and seasons lead to the high potential of sea transportation accidents [2,3].

Referring to the study conducted by the Japan International Cooperation Agency (JICA) and Directorate General of Sea Communication (DGSC) in 2002, in the period between 1982 up to 2000...
there were some 3,826 ship accidents have been recorded in Indonesia [4]. This means averagely 204 ship accidents per year, or one accident occurs in every two days. The most notorious ship accidents so documented are, firstly, KM Tampomas II on January 27, 1981 while in a voyage from Surabaya to Makassar. A fire was originating from the car deck and spreading over the ship when sailing at Masalembo. Due to heavy seas, SAR operation was not effective, and 594 fatality took place in conjunction with the total ship loss [5]. Secondly is KMP Gurita, which suffered an accident on January 19, 1996, when sailing between Aceh Besar and Sabang within a distance of only 19 seamless. The vessel was hit by severe waves, and strong winds led to capsize and to sink, brought a total of 338 casualties [6]. Thirdly, at the turn of 2006 to 2007 a passenger ship, KM Senopati Nusantara, on its voyage from Kumai, Central Kalimantan, on December 28, 2006, to Tanjung Mas Port, Semarang, had sunk in the Java Sea on December 29, 2006, in the area around 40km from Mandalika Island, Jepara Regency. The sinking of KM Senopati Nusantara is reported to have taken about 404 human victims. From various perspectives, these three national sea accidents are significant [7].

Ship accidents that occur will be tackled by the National Search and Rescue Agency (NSARA), i.e. the agency which has the responsibility to conduct searches, assistance, and evacuations to victims of accidents, especially at sea. Currently, NSARA faces several obstacles in performing operations of evacuating ships or sea accidents [8]. One of the obstacles of NSARA is the lack of infrastructure to berth the SAR ships. In the time being, there are only three (3) berths owned by NSARA for the western Indonesia region, while the total number of the SAR ships that should be accommodated are 34 units. These vessels have not been able to berth inappropriate places due to the lack of facilities owned by the NSARA. The presence of a fast-responsive Search and Rescue Unit (SRU) is needed to minimize the number of victims from the accidents at sea. Moreover, the current berths owned by NSARA do not have appropriate supporting facilities for the SRU crew to rest, so they mostly rest inside the SAR ships. Therefore, to support the activity of SAR operations proficiently, the facilities urgently needed is a place for the crew to rest and subsequently to coordinate [9].

Therefore, with the problems associated with the availability of ship berths and the existence of SRU, it is necessary to do an analysis of SAR center conceptual design and planning. This study aims to plan the design of the SAR center according to the essential need to support the activities of SAR operations. The shipping routes are planned close to open sea waters.

2. Methodology

2.1 Determination of SAR Station Locations

Before determining the candidate station and regional points, it is necessary to know the destination area. The determination of the area to be used in this research is based on the division of SAR Work Areas that have been set on the regulation. No. 20 of 2014 concerning the Organization and Work Procedures of Search and Rescue Offices. To obtain a division for the Western Working Area there are 16 regional points with the easternmost boundary: Semarang and South Kalimantan. The area's destination point is the point that must be reached by ship, which is the midpoint of the area’s territorial waters. The determination of the destination point of the region can be seen in Figure 1.
In determining the location of this station, the factors that determine the candidates chosen to be a SAR station are:

1) The distance from the SAR work area to the candidate location is the closest determinant
2) The distance from station to station with the maximum distance
3) The number of victims that can be transported
4) Coverage Area that can be reached
5) SAR Ship Cruising Capability

The following is a mathematical model of the objective function for determining the location of the station [10]:

\[ Z_{\text{min}} = \sum_{a=1}^{4} \sum_{i=1}^{16} \sum_{j=1}^{16} B_{aij} \cdot X_{aij} + \sum_{j=1}^{16} BP_{j} \cdot Y_{j} \]  \hspace{1cm} (1)

Where:
\[ B_{aij} = \text{SAR Operation Costs for each class of Ship (a) from station (j) to the region (i)} \]
\[ BP_{j} = \text{Station construction investment (j)} \]

The decision variable is in the form of a binary decision (0, 1), in which the decision needed is the location of the selected station with which ships are assigned to 16 SAR work areas. There are two decision variables in this optimization model, which are as follows:

a. Selected station candidates
\[ Y_{j} = \begin{cases} 1, & \text{if base (j) is selected} \\ 0, & \text{if base (j) is not selected} \end{cases} : j = 1, 2, 3, ..., 16 \]

b. Ships assigned at the station to reach several areas
\[ X_{aij} = \begin{cases} 1, & \text{if ship (a) is assigned from station (j) to region (i)} \\ 0, & \text{if ship (a) is not assigned from station (j) to region (i)} \end{cases} : a = 1, 2, 3, 4 \quad ; i = 1, 2, 3, ..., 16 \]

2.2 Conceptual Design

The current study is evaluation research, in which the design and evaluation procedure in collecting and analysing data is conducted systematically to design the berth of the SAR vessel and the required supporting facilities. The data were collected through documentation studies, surveys, interviews with the NSARA as well as exploring some relevant references. Data analysis starts from (1) specifications and the number of SAR vessels, (2) reference on the berth or dock design, and (3) dock design process and supporting facilities for the SAR station. In this plan, the number of mooring is four units, which is designed to accommodate four types of SAR ship classes.
According to Wang [11] the evolution of maritime SAR has matured as a comprehensive system, which is made up of following functional components, including:

1) Communications network throughout the SAR region (SRR) and collecting with external SAR services;
2) A rescue coordination center (RCC) for the coordination of SAR services, and one or more rescue sub-centers (RSCs) to support an RCC within its SRR, if necessary;
3) SAR facilities, including SAR units (SRUs) with specialized equipment and trained personnel, as well as other resources which can be used to conduct SAR operations;
4) On-scene coordinators (OSCs) assigned, as necessary, for coordinating the on-scene activities of all participating facilities; and
5) Support facilities that provide services in support of SAR operations.

Among these components, the RCC and/or RSC is the hub to get other components working together to realize the SAR system's objective, i.e., to rescue the crew and persons from a ship in distress, and/or to find and rescue shipwrecked persons in a short time as possible. The RCC and/or RSC also takes the overall responsibilities of establishing, maintaining, and managing a state's SAR system.

3. Results and Discussions

3.1 SAR Station Location
Based on existing regulations, for marine facilities owned by NSARA, there are six (6) types of SAR ships should be made available [12]. In the future, the type of SAR vessel may be expanded to cover advanced configurations [13,14]. However, for the time being, only two (2) types of SAR ships are considered; namely, rescue ship and rescue boat wherefrom those kinds of ships, there are four (4) types ship classes are derived. The detailed specification of the SAR ship classes can be seen in Table 1 below.

| No | Description | Value | Unit |
|----|-------------|-------|------|
|    | Class 1 | Class 2 | Class 3 | Class 4 |
| 1  | LOA      | 59.8  | 30.0 – 40.0 | 20.0 – 30.0 | < 20.0 | meter |
| 2  | B        | 16.0  | 7.5 | 5.4 | < 5.0 | meter |
| 3  | H        | 4.5 | 3.65 | 1.1 | 1.0 | meter |
| 4  | Vmax     | 28.0 | 29.0 | 20.0 | - | knot |
| 5  | Vexplore | 23.0 | 12.0 | 10.0 | 15.0 | knot |
| 6  | Crew     | 23 | 19 | 12 | 6 | persons |
| 7  | Capacity of Fuel Oil | 60 | 25-40 | 5-10 | 25-40 | tons |

The SAR fleet planning is needed to optimize SAR operation coverage area. In determining the number of ships, there are some factors related: (a) number of victims who can be transported in each SAR work area, and (b) The length of time the SAR operation is seven days, is a limit to get the number of ships that suit your needs. Based on the results there are 10 locations of SAR base in the western part of Indonesia, namely Aceh, South Kalimantan, Bengkulu, South Sumatra Bangka Belitung, Riau, West Kalimantan, Central Java, Riau Islands, and Yogyakarta. There is a total of 20 units of ships deploy (Table 2).

| No | Base            | Region      | Class I | Class II | Class III | Class IV |
|----|-----------------|-------------|---------|----------|-----------|----------|
| 1  | Aceh            | Aceh        | 1       | 0        | 0         | 0        |
| 2  | Kalimantan Selatan | Kalimantan Selatan | 1 | 0 | 0 | 0 |
| 3  | Kalimantan Selatan | Kalimantan Barat | 1 | 0 | 0 | 0 |
3.2 Planning of SAR Ship Berth
In this sub-section, planning a conceptual SAR station design is based on a basic review of the theory or review of the literature. The results of this review will be used to describe the conceptual design of the SAR station suitable for berthing the SAR vessels. In this plan, one of the berths owned by NSARA has taken the greatest number of ships to accommodate all types of SAR ships, and the selected one is the berth in the Jakarta area. Therefore, the SAR station to be designed in this study is the one in the Jakarta area.

Before doing the design and calculations, the specification data is required for vessels assigned in the western Indonesian region. As the Base for the construction of the dock to berthing SAR vessel, the size of the largest vessels will be used in the calculation process. This is eventually the SAR ship class 1, as listed in Table 1.

3.3 Planning Facilities of SAR Station
The facilities evaluated in this study are berths in the Jakarta area. The chosen berth is the closest one from the coast and shipping route. The calculation of waterside facilities and landside facilities for SAR station is as follows [15].

3.3.1 Sea facilities
The sea facilities are designed by considering several factors, namely the permitted draft, channel of entry, length of the entry, the width of entry, turning basin diameter, basin depth, basin length, and basin width [15,16]. Survey and data collection for SAR center in the Jakarta area gives the values of those factors as put forward in Table 3.

| No | Base            | Region            | Class I | Class II | Class III | Class IV |
|----|-----------------|-------------------|---------|----------|-----------|----------|
| 4  | Bengkulu        | Bengkulu          | 1       | 0        | 0         | 0        |
| 5  | Bengkulu        | Sumatera Barat    | 1       | 0        | 0         | 0        |
| 6  | Jakarta         | Jakarta           | 0       | 1        | 0         | 0        |
| 7  | Jakarta         | Lampung           | 1       | 0        | 0         | 0        |
| 8  | Jambi           | Jambi             | 0       | 0        | 0         | 1        |
| 9  | Sumatera Selatan| Sumatera Selatan  | 0       | 4        | 0         | 0        |
| 10 | Sumatera Selatan| Bangka Belitung   | 1       | 0        | 0         | 0        |
| 11 | Riau            | Sumatera Utara    | 1       | 0        | 0         | 0        |
| 12 | Riau            | Riau              | 0       | 0        | 1         | 0        |
| 13 | Jawa Tengah     | Jawa Barat        | 1       | 0        | 0         | 0        |
| 14 | Jawa Tengah     | Jawa Tengah       | 0       | 2        | 0         | 0        |
| 15 | Kepulauan Riau  | Kepulauan Riau    | 1       | 0        | 0         | 0        |
| 16 | D.I. Yogyakarta | D.I. Yogyakarta   | 1       | 0        | 0         | 0        |

Table 3. Sea facility factors and values

| No | Description     | Value | Unit   | Information |
|----|-----------------|-------|--------|-------------|
| 1  | Permitted Draft | 1.1   | meter  |             |
| 2  | The Channel of Entry | 1.8 | meter ; open sea |
| 3  | The Length of Entry | 300.0 | meter  |             |
| 4  | The Width of Entry | 76.8 | meter  |             |
| 5  | Turning Basin Diameter | 120.0 | meter  |             |
| 6  | Basin Depth     | 1.65  | meter  |             |
| 7  | Basin Length    | 90.0  | meter  |             |
3.3.2 Land facilities
The planning of land facilities for the SAR center is directed towards establishing the useful building as a support facility that will support the implementation of SAR operations, especially in accommodating the SAR vessels. Based on the existing regulations, it is explained that the required SAR center's infrastructures should comprise at least 11 components: berth, office, mess, equipment storage, health center, medical devices storage, helipad, post guard, bollard, and fender.

3.4 Investment and Operational Cost of Building the SAR Station
In this sub-section, the calculation of investment cost for SAR station construction will be explained. In this calculation, it is assumed that the number of people who are at the station consists of class I - IV type crew members and the construction of a berth for each type of SAR ship. The detailed account for the calculation is as given in the following sub-sections [17].

3.4.1 Investment
In Table 4, the investment cost for the development of the SAR station amounted to IDR 55 billion, this, is the cost allocated to build a berth for 4 types of SAR vessel classes. From the total cost incurred for the development of SAR station, it is then evaluated for a 50-year economic age of the SAR station to get the costs incurred by the institution per year. The total investment for SAR station with to comply with the regulation is IDR 8 billion/year, at an exchange rate of USD 1.0 equivalents to IDR 14,225.

3.4.2 Operational cost
The operational costs are presented in the present value (P.V.) to find out how much budget should be spent to be able to accommodate the needs for operations. The cost component is assumed to consist of crew salary, clean water costs, electricity costs, as well as maintenance costs for the building and supporting infrastructures. This also includes the weighted average cost of capital (WACC) for the next 50-year activities. Table 4 displays the detailed calculation to come up with the operational cost should be budgeted per year by the NSARA.

| No | Description                | Unit     | Year 1 | Year 2 | ... | Year 49 | Year 50 |
|----|----------------------------|----------|--------|--------|-----|---------|---------|
| 1  | Operational costs          | IDR/year | 2,102,498,740 | 2,144,548,715 | ... | 5,439,312,226 | 5,548,098,470 |
| 2  | P.V                        | IDR/year | 1,885,649,094 | 1,724,988,409 | ... | 26,246,747 | 24,010,477 |
| 3  | WACC                       | 11.50%   | assumption |         |      |         |         |
| 4  | SUM PV                     | IDR/year | 21,873,768,982 |         |      |         |         |
| 5  | Annual Value (A)           | IDR/year | 2,526,416,995 |         |      |         |         |

| Description                          | Unit     | Year 50 |
|--------------------------------------|----------|---------|
| Investment Costs of SAR Station      | IDR 6,311,778,526 | /year   |
| Operational Costs of SAR Station     | IDR 2,526,416,995 | /year   |
| Total Cost of SAR Station            | IDR 8,838,195,521 | /year   |

3.5 Layout Design of SAR Station
After doing the calculations, then the conceptual design process for the next step is conducted. Results of the SAR station design comprise the layout of the seaside facilities and landside facilities as shown. Figures 2-4 are the drawings of the SAR Station Facilities.
4. Conclusions
A study on the conceptual design of SAR center for Western Region of Indonesia located in Jakarta area has been conducted with the following primary results:
Based on the optimization results for the number of ships assigned to the selected station numbered 20 units, with the following description: Class I Ship (11 unit), Class II Ship (7 unit), Class III Ship (1 unit), Class IV Ship (1 unit). Optimal total costs for SAR operations are 263 Billion Rupiah, with 10 SAR station locations and 16 regional coverage.

Based on the physical design and economic evaluation, the investment cost to build the SAR station will be IDR 6.3 billion/year while the operational costs reach IDR 2.5 billion/year. Thus, the total cost for the construction of SAR station will reach IDR 8 billion/year.

The seaside facilities would consist of the berth, trestle, fender, the channel of entrance and basin. In contrast, the landside facilities would cover office, gathering point, parking, guardhouse, health place, medical devices, emergency tent, and helipad.

The dimension of the berth has a length of 15 m and width of 5 m, while the dimension of the gangway has a length of 163 m and width of 5 m.

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