

## A Study to Determine the Most Effective Daymark Shape for a Leading Line

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**ABSTRACT:** The use of daymark shapes for leading lines include its visual shape and symbol, to aid sailors who need to navigate safely through a marked narrow channel. The shapes which are currently used are rectangles, diamonds, and triangles. However, there is not much information on which shape is the most effective for navigational referencing. Therefore, the main objective of this research is to determine the most effective shape for a leading line daymark. The Kemaman Port was used as an area of interest to model the three-dimensional simulation. The size and height of the leading line daymark was calculated based on the dimensions of the navigational channel obtained from the Kemaman Port navigation chart. The simulation for different shapes of the leading mark in the same area was developed using a three-dimensional software. Experts were engaged to evaluate the effectiveness of each daymark shape across the maximum and minimum distances during the simulation run. Results showed that the diamond shape daymark was relatively better identified and used as reference, compared to other shapes in the same range due to its relatively larger surface area. Therefore, the study objective was achieved, and the results can be used to improve marine navigation safety.

### 1 INTRODUCTION

Navigation safety is essential to ensure the safety of life and assets at sea, and to protect the marine environment from any source of pollution. One way to ensure the navigational safety is to mark the area which has been identified as being safe for navigation using marine Aids to Navigation (AtoN). AtoN is a device, system, or service, which is external to the vessels, and is designed and operated to enhance the safe and efficient navigation of individual vessels and/or vessel traffic [1]. The usage of AtoN is regulated by the national maritime safety agency following the guidelines developed by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). AtoN is categorised into visual, audible, and electronic

categories. The typical AtoN used to mark navigation channels or fairways leading to a port are navigation buoys and leading line. Navigation buoys are used to mark the edge of either side of the navigation channel, while the leading line is used to mark the centre of the channel. The leading line is marked by leading marks during daytime and leading lights during night time. A combination of navigation buoys and leading line are used to mark the navigation channel. Leading marks and lights are categorized under visual AtoN. Leading marks are navigational marks used as components for a leading-line or range. Leading line is defined as "a straight line used for navigation produced by the alignment of marks (leading marks) or lights (leading lights) or by the use of radio transmitter" [1], [2] This study highlights the daymarks and different shapes of these daymarks to

mark the navigation channels, in order to maintain safety of navigational. There has not been much studies done on the effectiveness of the different shapes of daymark board. Therefore, in order to address this issue, the main objective of this study is to determine the most effective shape of leading mark board.

## 2 METHODOLOGY

To achieve the study objective, the research methodology has been developed. The overall research activities in shown by a flow chart in Figure 1. The detail explanation for each step is given in the following sentences.

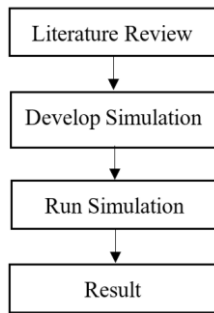


Figure 1. Overall research activities

Step 1 was to obtain information related to the shape of the daymark board of the leading mark through literature reviews and interviews. The information was obtained using the search engine in the IALA website <https://www.iala-aism.org/guidance-publications/search-in-publications/> [3]. The search engine was used for searching for the relevant information on the content of a repository based on the current IALA standards, recommendations, guidelines, model courses, and manuals, using the key words. In addition to literature reviews, online interviews were conducted with Marine Officer of the Marine Department of Malaysia in which oversees the operation and maintenance of the AtoN in East Coast Peninsular Malaysia. This was conducted using the WhatsApp application which enabled the sharing of documents and photos on leading marks or lights [4].

Step 2 was to develop simulations based on the shape of the leading mark board obtained in Step 1. The simulation was developed using the SketchUp Software [5]. The different types of daymark boards were developed, and the size of the board was determined using Eq. 1, Eq.2 and Eq.3 from the IALA.

$$H = \frac{D}{650} + h \quad (1)$$

$$R = \frac{KD(H-h)}{W} \quad (2)$$

$$K = \frac{RW}{D(H-h)} \quad (3)$$

where:

$H$ : Height of rear tower

$h$ : Height of Front Tower

$D$ : Distance we required/ Focus Distance

$W$ : Width of Channel

$R$ : Distance between two towers

$K$ : Index Sensitivity

Step 3 was to run the simulations and review it with experts. The experts were maritime lecturers in Universiti Malaysia Terengganu with a minimum unlimited class 3 certificates of competency. Based on the observations, the experts ranked the shapes.

## 3 RESULTS AND DISCUSSION

The first objective was obtained through literature reviews and interviews. Based on IALA (2001, 2014, 2016), there were four types of constructions for the daymark, namely flat, solid, lattice, and crossed plate constructions. Through the literature review, the flat construction was the most preferred design for the daymark for leading lights compare to solids, lattices and crossed constructions [6]. The reason was that the flat surface would project the same colour and brightness.

To achieve the second objective, the Kemaman Port was used as model for the study area. The reason for the selection of the Kemaman port was that it was equipped with leading lights and was much closer to the researcher's residence, which made the survey easier. Information on the leading light was obtained from the online electronic chart by Navionics which was sourced from the Malaysian charts, as shown in Figure 2. The first pair of leading lights that marked the fairway from the sea was the Tg. Berhala No. 8 and Tg. Berhala No.10. The second pair that marked the channel into the port's turning basin was the Tg. Berhala No. 7 and Tg. Berhala No. 9, and was used as a model for this study.



Figure 2. Kemaman Port Chart (Source: Navionics, 2022)

Tg. Berhala No. 7 is the front leading light and mark. The light's focal plane was 21 m with a quick-flashing green light. Approximately 18 m of a square skeletal tower carrying a triangular daymark painted in white with a red vertical stripe was seen as ideal [9]. Tg. Berhala No. 9 is a rear leading light and mark. The light's focal plane was 27 m with a green light,

which was on for 2 seconds and off for 2 seconds. Approximately 20 m of the square skeletal tower carrying a triangular daymark painted in white with a red vertical stripe was seen as ideal. The distance between the rear and front leading towers were 210 m [9].

Instead of using the real information as that used for the Kemaman Port to develop the area's simulation model, this study calculated the size and height of the daymark board based on the information obtained from the online chart, namely the width of the navigation channel and distance of the daymarks and lights. The chosen height of the observer's eye on the ship was 15 m. Therefore, the maximum height of the daymark at the front tower was set to 15 m. The calculation of both the leading line towers were done using Eq. 1, Eq. 2, and Eq. 3. Results of the calculation are shown in Table 1.

Table 1. Result of calculation

Item	Information
Height of rear tower	18.93 m
Height of front Tower	15 m
Distance we required/ Focus Distance	2560 m/ 1.4 nm
Width of channel	808 m
Distance between two towers	450 m
Index Sensitivity	1.7

IALA has derived the dimensions of the dayboard of the leading line which corresponds with the operational range as shown in Table 2. The distance of the channel mark was 1.4 nm. The operational range of 2 nm was chosen for the dayboard size of the front tower and 2.2nm was for the rear tower. The drawing of the towers and daymarks are shown in Figure 3.

Table 2. Dayboard size and range (Source: IALA (2016))

Dayboard Size L x W meter	Operational Range NM	Viewing angle for length L	Viewing angle for width W (L/2)
1.6 x 0.8	1	2.9'	1.5'
2.1 x 1.05	2	2.0'	1.0'
3.1 x 1.55	3	1.9'	1.0'
4.2 x 2.1	4	2.0'	1.0'

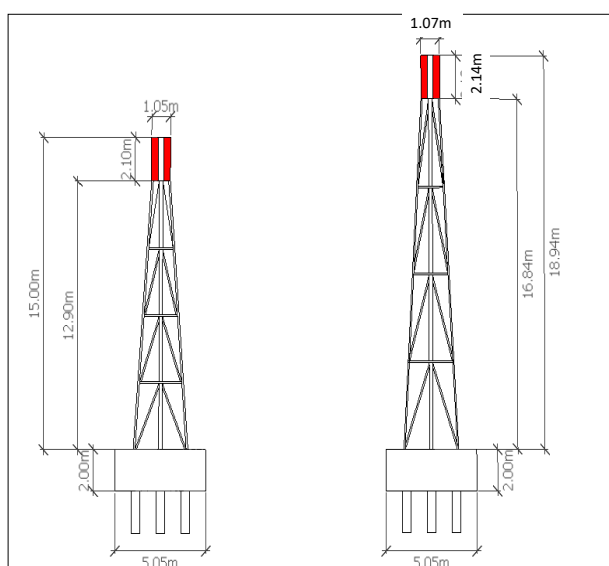


Figure 3. Leading light plan using rectangle daymark board front (left) and rear (right) tower

A three-dimensional design software was used to develop the three-dimension design of the tower and the simulation area. Figure 4 shows the rectangle, triangle, and diamond daymark, respectively. The design of the daymarks were according to the IALA guideline and fitted on the same size of the tower in the simulation [7].

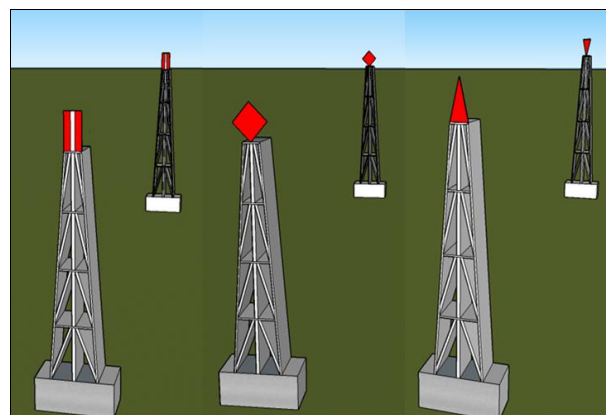


Figure 4. Rectangle (left), diamond (middle), and triangle (right) daymarks

To determine the most effective daymark shape among the three designs, the simulation videos were made using the SketchUp plugin features. The effectiveness was determined based on one criterion, namely the most easily spotted daymark from the maximum distance of 2560 m, which was the starting point of the leading line No. 7 and No. 9 from the leading line No. 8 and No. 10. The vessel then moved progressively towards the front tower. At least three simulation runs were conducted for three different daymark shapes for each expert. The three experts were nautical lecturers with unlimited competency certificates voyage deck officers. The simulation runs were displayed using a 17-inch monitor gaming laptop with a high-performance graphic card. The caption of the simulation run is shown in Figure 5. The three experts agreed that the diamond shaped daymark board (centre) was the most easily spotted from the maximum distance compared to the rectangle (left) and triangle (right) shape in Figure 5. Reason for the diamond shape daymark can be spotted easily compared to the triangle and rectangular shapes because it has a larger surface area. The surface area of the diamond shape front tower was 4.41 m<sup>2</sup> (2.1 m [L] x 2.1 m [W]) compared to the rectangle shape with an area of 2.205 m<sup>2</sup> (2.1 m [L] x 1.05 m [W]) and the triangle shape with an area of 1.10 m<sup>2</sup> (2.1 m [L] x 1.05 m [W] x 0.5). However, the diamond shape mark had the highest wind resistance. Therefore, the diamond shape was spotted first, followed by the rectangle and triangle, which corresponded to the surface areas. In addition, the diamond shaped mark was easy to identify because it had a distinctive shape compared to its background.

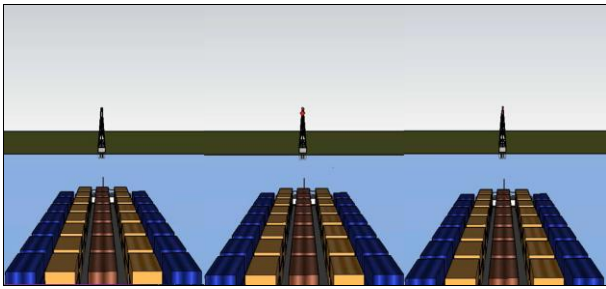


Figure 5. Caption of three videos moving towards the front tower stopped at the same time for rectangle (left), diamond (centre) and triangle (right) shape daymark.

As the vessel moved closer towards the front tower, the diamond shaped daymark was the first shape which lost its function when the daymark at the rear tower could not be. The second daymark shape which lost its function was the triangle, and finally the rectangle. The distance at which the daymark lost its effectiveness is referred to as the minimum distance and is shown in Table 3. This shows that the diamond shaped daymark board was relatively less effective when closer to the front tower. This is because the diamond shaped daymark had a relatively shorter pointer shape (1.05 m) between the front and the rear daymark compared to the rectangle and triangle board with 2.10 m. The vertical stripes red and white of the rectangle board could not be seen from a distance of 2560 m. Only the rectangle shape of the daymark could be identified.

Table 3. Minimum distance range according to shape of daymark

Shape	Minimum Distance (m)
Diamond	218
Triangle	198
Rectangle	158

#### 4 CONCLUSION

The leading light or mark is an AtoN used to mark the safe navigation channel to a port. The leading daymarks were used during daytime operations, while the leading light was used during the night. Currently, there are three daymarks which are widely used, namely rectangular, triangular and the diamond. The objective of this study was to determine the most effective shape for the leading mark. The results showed that the diamond shaped daymark

was the most effective shape for the leading mark and could be easily spotted from a certain distance due to its relatively larger surface area and distinct shape. This finding fulfilled the research objective. However, as the ship moved towards the front tower, the diamond shaped daymark was the first which became ineffective, followed by the rectangle and triangle shaped daymarks. Another downside of the diamond shaped daymark is its higher wind resistance compared to the rectangle and triangle shapes due to its relatively larger surface area. This research is expected to give much better technical information to the maritime safety authorities, such as the Marine Department of Malaysia, the Light Dues Board, and port authorities, in order to established leading lights or marks for port usage.

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