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THE ESTABLISHMENT OF MINIMUM LUMINOUS RANGE FOR EXISTING LIGHTHOUSES IN THE AGE OF GLOBAL NAVIGATION SATELLITE SYSTEM BY LIMITING THE LUMINOUS RANGE WITHIN GEOGRAPHICAL RANGE

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ABSTRACT

Long range marine aids to navigation is not required by current marine navigational practice, therefore luminous range of lighthouses should be reduced. The objective of this study is to determine a minimum luminous range for major lighthouses. The minimum luminous ranges is determined by conducting two steps, namely by modifying the existing geographical range formula and determine a strong linear correlation between light intensity and luminous range with the lowest gradient as possible in a linear graph. The application of minimum luminous range would eliminate the loom of light beyond the lighthouse's geographical range, which is not necessary for current navigational practice. This method is applied to seven major lighthouses in Peninsular Malaysia, which resulted minimum luminous range that ranging from 12.2 nm to 14 nm. The existing luminous ranges of these lighthouses are ranging from 18 nm to 25 nm. These new minimum luminous ranges are sufficient for mariners who primarily rely on GNSS, reduce service provider operational cost and may sustain lighthouses operation in the future.

Keywords: lighthouse, luminous range, marine navigation.

INTRODUCTION

Lighthouse is a large conspicuous structure on land, close to shoreline or in water, which act as a day mark and provide a platform for a higher range marine AtoN[1] signal light [1]. Among the purpose of the lighthouse is to mark the landfall position, mark an obstruction, and provide a reference for mariners to take bearing or line of position [1].

Currently, the luminous range for lighthouse in Malaysia is assumed following the range that has been set since the 1960s, which positional fix for ships by using celestial navigation and landmarks at shore [2], [3]. During the time, lighthouses were manned and the lighting systems were powered by using engine generator. Starting from the 1990s, the obsolete lighting system has been changed to a more advance system, which is unmanned (automatic), more reliable and relatively low powered system that running on renewable energy such as solar energy. In the mid 2000s, the rotating lighting system for lighthouses are also phasing out from service in the United States in favour of LED flashing lighting system [4].

The GNSS[1] also was introduced widely to the marine commercial user in the 1990s. The GNSS has changed the mariners practice on navigation [5]. Currently, GNSS or widely known as GPS[1] has been integrated with radar, ECDIS[1], AIS[1] and autopilot. This luxury of having many inputs into a single screen has made life easier to mariner and the same time significantly reduced the dependency of the mariners to long range marine navigational aids and celestial bodies for positional fix. The current practice of navigation that rely heavily on GPS has turn long range marine aids to navigation such as lighthouses as a substitute for positional references. Radar also can be used to fix position in the event of GPS failure and further reduce dependency of mariners to lighthouses. Despite the introduction of GPS that changed the mariner practice on navigation, the luminous range of the lighthouse in Malaysia remained the same as before.

The 2010 A to N review in UK had resulted decommissioned six lighthouses by Trinity House UK, twelve lighthouses decommissioned by Northern Lighthouse Board, and two lighthouses decommissioned and another 14 lighthouses transferred to the local authorities by Commissioner of Irish Light [6]. Recent review conducted by the General Lighthouse Authority UK for 2010 to 2015 period, has resulted as follows: reduced luminous range for 41 lighthouses; discontinued of operation for six lighthouses; 14 lighthouses transferred to local authorities; one lighthouse replaced with PEL[2], one lighthouse light increased range; one lighthouse reduced fog signal range; established AIS for one lighthouse; and 76 lighthouses remain unchanged [7]. Majority of the 76 unchanged lighthouses lighting range are below 18 nm, which assumed had been reviewed in the 2005 to 2009 period. A result of these reviews showed that dependency of mariners to lighthouses is decreasing from time to time, which resulted in the reduction of lighthouse's luminous range and even discontinuation of lighthouse operation.

However, the report has not mentioned any specific method used to reduce the luminous range of existing lighthouses. Therefore, in order to address this

issue, this research proposes a new method to determine the minimum range for lighthouses, which is based on the height of existing structure and the linear correlation between light's intensity and luminous range achieved.

METHODOLOGY

The flowchart of the research activities is shown in Figure-1 below.

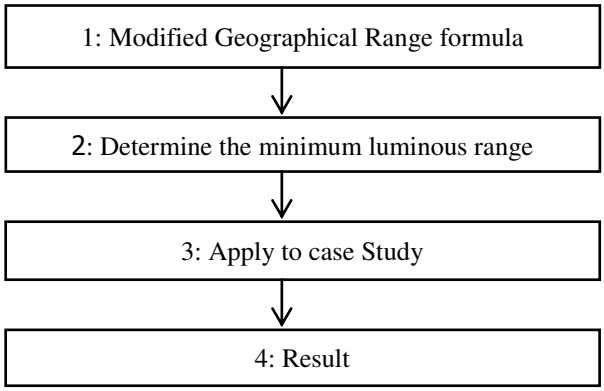

Figure-1. Flowchart of research activity.

The first step is to derive lighthouse geographical formula based on the existing geographical range formula [8]. The formula to calculate the geographical range is shown in Equation. (1). The objective of this study is to determine the geographical range of lighthouses according to its elevation above sea level and to eliminate the loom of light beyond the lighthouse geographical range. Therefore, Equation. (1) is modified by deleting the height of observer. As a result, Equation. (2) is derived and referred as lighthouse geographical range.

$$Range\ (nm) = 2.03 \times \sqrt{e + h} \quad (1)$$

Where:

e = elevation in meter of the object

h = height in meter of the observer's eye.

$$Range\ (nm) = 2.03 \times \sqrt{e} \quad (2)$$

The second step is to determine the lighthouse minimum luminous range. In order to do this, a graph of light intensity according to luminous range was developed by using IALA luminous range in nautical mile table from 7 nm to 28 nm. The luminous range of the table is according to transmissivity factor 0.74, which means that the remaining light from a source is 74% after passing through certain distance in atmosphere at sea level. The graph was plotted using Microsoft Excel software. Based on the trend line plotted in the graph, the exponential trend is the best fit and resulted in the highest correlation coefficient (R^2) close to one compared with other trends. The software also derived the exponential formula of the trend. The formula is then used to derive the data that perfectly match the exponential trend and eventually used to develop a new exponential graph. A range between 10 nm to 25 nm is selected in the graph to determine the best linear trend. Starting value 10 nm is selected because it is assumed as the lowest luminous range for major lighthouses [7]. The best linear trend is determined by using R^2 0.95 by testing different ranges starting from 10 nm until R^2 0.95 is achieved. When R^2 0.95 is achieved, the maximum value for the range is accepted as the minimum luminous range.

The third step is to apply the lighthouse geographical range and the minimum luminous range to major lighthouses in Peninsular Malaysia. The application to use either lighthouse geographical range or minimum luminous range is depended on the following rule. If the luminous range is more than the geographical range, then the luminous range is limited to matching the geographical range. If the geographical range is more than the minimum luminous range, then the minimum luminous range is applied.

RESULTS AND DISCUSSIONS

The geographical range of lighthouses was calculated using Equation. (2) to seven major lighthouses in Peninsular Malaysia. The results are shown in Table-1.

Table-1. Geographical range of selected lighthouses (Source: Marine Department Malaysia, 2012).

Lighthouse	**Elevation above MSL** (m)	**Existing luminous range** (nm)	**Lighthouse geographical range** (nm)
Muka Head	242	25	31.6
One Fathom Bank	43	23	13.3
Cape Rachado	118	23	22.1
Pulau Angsa	36	22	12.2
Pulau Rimau	39	22	12.7
Kuala Selangor	73	18	17.3
Tanjung Gelang	85	25	18.7

The lighthouse geographical range in Table-1 is calculated based on the elevation of each lighthouse structure above mean sea level (MSL). The lighthouse geographical range is used as the first limit for the

luminous range of lighthouse. This is to take advantage and utilize the height of the existing lighthouses. The purpose to limit the luminous range by using the lighthouse geographical range is to eliminate the loom of light beyond the lighthouse's geographical range, which is not required by current navigational practice.

The luminous is further limited by the minimum luminous range of lighthouse. The minimum luminous range for the lighthouse is a balance between the increment of light intensity and luminous range achieved. The breaking point of this balance is when the requirement of light intensity is drastically increased to gain the similar distance previously. In order to determine the minimum luminous range, graph in Figure-2 is developed based on IALA table for darkness luminous range in nautical miles. Based on the trend plotted by using Microsoft Excel, an exponential formula with R^2 close to one (1.0) was developed in Figure-2.

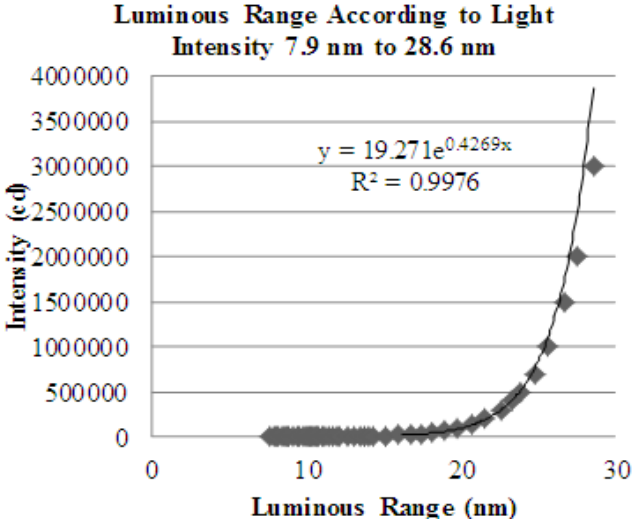

Figure-2. Luminous range of lighthouse according to light intensity for 10 nm to 25 nm (Source: IALA).

Based on the exponential formula developed in Figure-2, graph in Figure-3 is derived, which the data follows exactly the exponential line.

Selected data plotted based on the exponential formula in Figure-3 is used to develop a graph in Figure-4. The purpose to develop the graph in Figure-4 is to determine the breaking point from linear to exponential trend in the graph, which roughly shows in a graph of Figure-3. By testing different ranges from 10 nm to 25 nm in the graph, a range 10 nm to 14 nm yield a R^2 0.95 for the linear trend, which shows a high correlation factor for the linear trend. This shows that 14 nm is the breaking point before the graph changes into an exponential trend. This range (10 nm to 14 nm) also produced the least gradient compare to other ranges tested. The least gradient indicated the least increase of light intensity is required to increase luminous range between 10 nm to 25 nm.

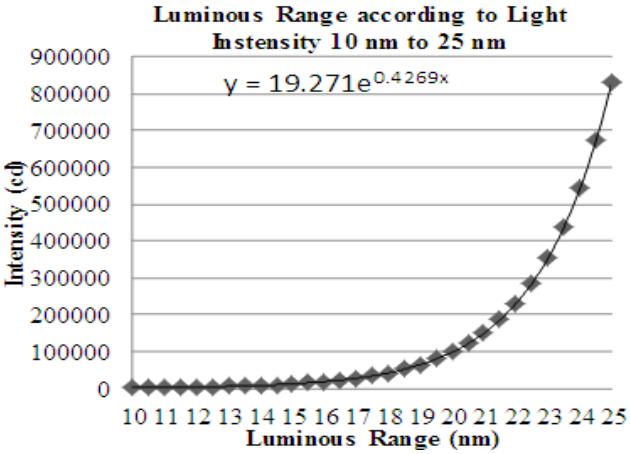

Figure-3. Luminous range of lighthouse according to light intensity 10 nm to 25 nm.

The least increase of light intensity is assumed using the least power required for the lighting system to increase the luminous range. The least power required to power the lighting system corresponds to fewer numbers of equipment needed to power the system such as solar panels and battery bank, especially at remote locations. This would reduce the cost for the procurement and maintenance of the lighting system.

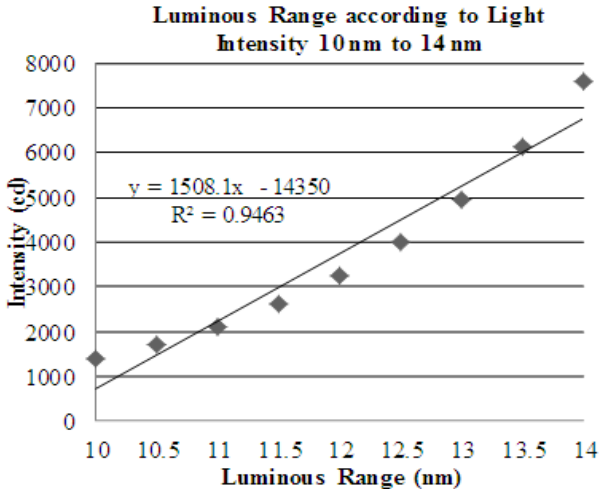

Figure-4. Range of lighthouse light according to light intensity 10 nm to 14 nm.

The lighthouse geographical range and minimum luminous range approach were applied to seven lighthouses in Peninsular Malaysia as shown in Table-2. The new luminous range for the lighthouses is ranging from 12 to 14 nm, which is lower than the existing range of 12.2 to 31.6 nm. These new luminous range would ensure the looms of light of each lighthouse would not go beyond its horizon, which is not necessary for current navigational practice.

Table-2. Proposed new luminous range of selected lighthouses.

Lighthouse	**Elevation above MSL** (m)	**Existing luminous range** (nm)	**Geographical range** (nm)	**Proposed min luminous range** (nm)
Muka Head	242	25	31.6	14
One Fathom Bank	43	23	13.3	13.5
Cape Rachado	118	23	22.1	14
Pulau Angsa	36	22	12.2	12.2
Pulau Rimau	39	22	12.7	12.7
Kuala Selangor	73	18	17.3	14
Tanjung Gelang	85	25	18.7	14

CONCLUSIONS

The luminous range of lighthouses should be reduced due to less reliance of mariner to lighthouse for positional fix. The minimum luminous range for lighthouse is determined by conducting two steps, namely by modifying the existing geographical range formula and determines a strong linear relationship between light intensity and luminous range. This approach would eliminate the loom of light beyond the lighthouse's structure geographical range and ensure the luminous range achieved is commensurate according to a linear correlation between light intensity and luminous range achieved. This new minimum luminous range is sufficient for mariner used and can significantly reduce the operational cost of the service provider. This new minimum luminous range may sustain lighthouse operation in the future.

REFERENCES

[1] IALA, "Aid to Navigation Manual," St Germain, 2014.

[2] J. F. D. van Hooff, Aids to Marine Navigation. Maritime Research Institute Netherlands, 1982.

[3] J. F. D. van Hooff and J. C. Sirks, "Lights for Landfall," J. Navig., vol. 28, pp. 168-192, 1979.

[4] B. Trapani, "Vega VRB-25 Last of the Lighthouse Rotating Beacons as We Know Them," Storm Heroes, 2012. [Online]. Available: http://www.stormheroes.com/aton/vrb25_200904.htm. [Accessed: 08-Jul-2012].

[5] A. Theiss, D. C. Yen, and C.-Y. Ku, "Global Positioning Systems: an analysis of applications, current development and future implementations," Comput. Stand. Interfaces, vol. 27, no. 2, pp. 89–100, Jan. 2005.

[6] ATKINS Ltd, "Assessment of the Provision of Marine Aids to Navigation around the United Kingdom & Ireland," London, 2010.

[7] Commissioners of Northern Lighthouses, Trinity House, and Commissioners of Irish Lights, "Aids to Navigation Review 2010 - 2015," 2010.

[8] Internatinal Hydrographic Bureau, "Standardization of List of Lights and Fog Signals," Monaco, S-12, 2004.

[9] Marine Department Malaysia, "Aids to Navigation Equipment," 2012. [Online].

[10] Available: http://www.marine.gov.my. [Accessed: 19-Jun-2012].