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SEAPORT DIMENSIONAL ANALYSIS TOWARDS ECONOMIC GROWTH IN ARCHIPELAGIC REGIONS

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ABSTRACT

The performance of a seaport is determined by the coherence between the optimal dimensions of the seaport and the economic potential of the area where the seaport is located. Otherwise, the economic potential of the region can drive how big the port should be developed. To study the behavior of seaport parameters on regional archipelagic economic zones, dynamics models are used, where the econometric model is applied to the completion of the Cobb-Douglas production equation. The results obtained by this analysis showed that the increased volume of loading/unloading cargo is correlated to local economic growth; and, the increase of loading/unloading of cargo can promote the growth of the region's Gross Domestic Product (GDP). Increased volume of loading-unloading cargo is correlated to the growth of vessel hold capacity/deadweight tonnage (DWT). GDP growth is correlated to the demand load capacity of the vessel (DWT); and the increase of GDP requires definition of a length of berth (Lb). Hence, it is concluded that there is a strong influence between the development of port dimensions and the economic growth of archipelagic regions.

Keywords: Archipelagic Region; Development; Dynamics models; Economy; Seaports

1. INTRODUCTION

Seaport infrastructure investment is believed to boost the economic growth of a region. Various analyses of the correlation between infrastructure development and economic growth in the long run concluded that there are positive effects of investment in transport and communication infrastructures towards economic growth (Canning & Pedroni, 1999), wherein transport has a strong positive influence on development and economic growth, on the contrary, the increased production of goods and services can be associated directly with the improvement of transportation infrastructure (Button, 1982). Transportation networks have a positive causal effect on per capita growth rate across all sectors such that infrastructure development should have a significant effect on the performance of the transport network and the change in the economic behavior (Banerjee et al., 2009). Likewise, Essoh, (2013) in his research concluded that the port activities resulted in an increase in fiscal revenue and accelerated economic growth, thus investing in the port can be considered as constituting capital for economic development. The achievement of certain economic levels is believed to encourage the development of the transportation system to be more effective and efficient (Pangihutan, 2008).

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The implementation process of sustainable development policies and infrastructure development is considered as an important dimension in strategic planning which will ensure the development of the region and socio-economic sustainability of a country (Grundey, 2008). Seaports are regional infrastructure wherein the focus of the supply chain is to find the most effective and efficient way in implementing value-added products, in order to obtain solutions of complex problems related to consumers' demand (Feame et al., 2001). The causal relationship between the port infrastructure investments and productivity towards the economic growth of the archipelagic regions is still to be proven (Baird, 1998). Concepts which bridge global prospectives calculate the effect of transportation investment on both the micro and macro level, where the economic model is developed to analyze the effect of transportation planning (Treyz, 1998). The above mentioned statement thus raises the question of how much port infrastructure investment is needed in order to achieve an economic growth rate at a particular level.

From an existing literature search, comprehensive research has yet to be found about the effect of the long berth, loading-unloading growth and the number of ship visits on local economic growth. Therefore, this study identifies model parameters of relationships between port dimensional infrastructure and economic growth of typical islands regions, by taking the seaport of Ambon Island as an example. It was presumed that there is a correlation between sea transportation described by deadweight tonnage (DWT), length of all ships (LOA), length of berth (Lb) and loading-unloading of cargo on the economic growth, described as the Gross Domestic Product (GDP). Low seaport performance affects the ships' queue length in a seaport, thus affecting the regional economic growth. Econometrics is the integration of economic theory, mathematics, and statistics in order to test the validity of economic theorems using empirical data (Setiawan & Kusrini, 2010). Theoretical approaches about the relationship of seaport development investment on the economic growth of the island regions can be attributed to modified neoclassical growth theory with the theory of endogenous development. Neoclassical growth theory which was pioneered by George H. Bort, (1960), in Sjafrizal, (2008) considers that the amount of output (goods and services) which is produced by an economic activity is determined by the availability and quantity of production factors used. In addition, Tukan (2013) found a positive correlation on the effects of marine transportation infrastructure to economic growth of archipelagic regions.

Therefore, this paper is aimed towards finding out how close the correlation is between seaport parameters and the economic growth of archipelagic regions.

2. METHODOLOGY

2.1. The Relationships between Seaport Variables and GDP

The growth of loading/unloading of cargo in seaports will promote the growth of Gross Domestic Product (GDP) of a region on a positive ratio. So, the increase of loading/unloading volume of goods can affect the performance of the seaport in a region (Tukan et al., 2012). Statistical data of the growth of loading/unloading of cargo and Gross Domestic Product (GDP) of a region showed a positive relationship between transport and economic parameters which can be analyzed by using econometric methods, where the overall length of the ship will affect the length of the berth (Lb) (Nasril, 2009). Then, by analyzing berth dimension, the potential of economic growth of an island region was calculated. And economic growth will occur if there is a growth of loading-unloading of cargo at the seaport, where the growth of cargo will impact the demand for ships' load capacity/deadweight tonnage (DWT) and the number of ship visits (Call). Load capacity also affects the length/length overall (LOA) of the ship.

2.2. Modeling of Seaport Variables and GDP

The above problems can be described as a causative relationship between the development of the seaport and economic growth, which can be modeled as shown in Figure 1 below. The coherence of the physical structure of transportation and the physical structure of economy is needed, and these parameters should be in synergy. If the economic growth of a region is not supported by the transportation infrastructure, the impact is low GDP in the region. The growth of GDP could be either positive or negative which depends on the loading-unloading volume of goods in the region or the opposite. The volume of loading-unloading of goods will determine the amount of vessel hold capacity (DWT) and the visiting frequency of ships (Call). The ships DWT affects the overall length of the ship (LOA), where the LOA affects the length of the berth (Lb).

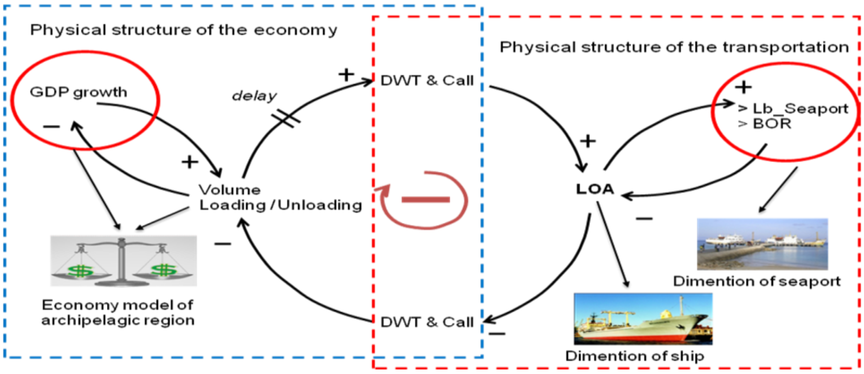

Figure 1 Dynamics model of seaport development

2.3. Formulation of the Problem

The increased volume of loading/unloading cargo would trigger the economic growth, and it can be modeled as:

$$GDP = f(\sum Loading,\ \sum Unloading, DWT, LOA, Lb) \tag{1}$$

Thus, for the maximum length of berth (Lb), what is the vessel length (LOA) and loading capacity (DWT), the number of ship visits (Call) and the loading/unloading of cargo that can be carried out and its impact on economic growth (GDP)? By using the optimization method it can be written as the following equation:

$$Maximum\ (Y) = X_1 + X_2 + X_3\ + \cdots\ X_n \tag{2}$$

where (Y) = GDP, as a function of a goal

Goals:

To find both the seaport parameters that are most influential and give a multiplier effect to economic growth in a region, with the question about whether the loading and unloading of cargo can boost growth of GDP?

Variables:

X_1 = loading, X_2 = unloading, X_3 = ship visits (Call), X_4 = carrying capacity of the ship (DWT), X5 = overall length of the ship (LOA), X6 = length of berth (Lb),

Constraint:
LOA ≤ Lb …. where: the overall length of the ships (*LOA*) is no longer than the berth or at least equal to the length of berth (*Lb*)

If the loading/unloading of cargo, ship visits, ship transport capacity, berth length, and GDP growth show a non-linear function of economic production, this has to be transformed to be a linear function by logarithmic transformation, so that the Cobb-Douglas function will be:

$$Ln(Y) = ln\beta_0 + ln\beta_1 X_1 + ln\beta_2 X_2 + \cdots ln\beta_n X_n + \mu \tag{3}$$

If ln(Y) = Y*, ln(β_0) = β_0*,lnx_1 = X_1* then the model will be:

$$Y^* = \beta_0^* + \beta_1 X_1^* + \beta_2 X_2^* + \cdots \beta_n X_n^* + \mu \tag{4}$$

While the regression coefficient is the elasticity value of production, i.e. the change in output percentage as a result of the change in input of one percent. β_0 and $\beta_{1,}$ $\beta_{2,}$ … β_v are referred to as the parameters. The β_0 intercept is when the value of X is equal to zero. $\beta_{1,}$ $\beta_{2,}$ …β_v also are also known as the slope. The slope explains how much are the changes of the parameters of loading (β_1), unloading (β_2), ship visits (β_3), carrying capacity of the ship (β_4), length of berth (β_5), if the GDP growth changes by one unit.

In economic mathematics, elasticity value can be obtained by the following equation:

$$E_{xi} = \frac{Y}{X_i} \tag{5}$$

AP_{xi} is the average product for the input of loading/unloading cargo which is obtained by the following equation:

$$AP_{xi} = \frac{MP_{xi}}{AP_{xi}} \tag{6}$$

Thus the elasticity equations of the loading and unloading parameters to the input (*Loading/Unloading*) is as follows:

$$E_{xi} = \frac{MP_{xi}}{AP_{xi}} = \frac{\beta_1 \beta_0 x_i^{\beta_1 - 1}}{y/x_i} = \frac{\beta_1 x_i^{-1} \beta_0 x_i^{\beta_1}}{y/x_i} = \frac{\beta_1 x_i^{-1} x y_1}{y} \beta \tag{7}$$

If in a loading and unloading process at the seaport where output (Y) = GDP is an area per unit time (IDR), and input (X_i) = the amount of goods that define the unloaded cargo per unit time (*ton*), then to be able to carry out a number of charges per unit time, it is required to have a ship with certain loading capacity also known as Dead Weight Tonnage (DWT).
Partially, all the variables significantly influence the economic growth. For each goods increment of loading/unloading of 1 percent, *ceteris paribus*, can boost economic growth (GDP), which can be modeled as:

$$Ln\ GDP = \beta_0 + \beta_1\ LnLoading/Unloading + \mu \tag{8}$$

where the GDP increase is strongly correlated to the increase in loading capacity of ships (DWT) which can be modeled as:

$$Ln\ GDP = \beta_0 + \beta_1\ LnDWT + \mu \tag{9}$$

The increased loading capacity of ship known as Dead Weight Tonnage (DWT) affects the growth of goods unloading /loading, which can be modeled as:

$$Ln\ DWT = \beta_0 + \beta_1\ LnLoading/Unloading + \mu \tag{10}$$

From Equation 10 where, *d*Loading/Unloading = f (*d*DWT) and a maximum capacity of the ship is correlated with the size of the overall length of the ship (LOA), it can be written *d*DWT = f (*d*LOA). Then when the equation on the left side is compared to the right side, there will be a new equation which describes the performance of the seaport or berth occupation ratio (BOR) and it can be written as:

$$\frac{dLOA}{dLd}\ X\ 100\% = dBOR \tag{11}$$

The increase of ship loading capacity (DWT) also affects the growth of GDP and the loading/unloading goods, which can be modeled as:

$$Ln\ DWT = \beta 0 + \beta 1 LnGDP + \beta 2 Ln\ Loading/Unloading\mu \tag{12}$$

Thus the relationship between the overall length of the ship (LOA) is correlated with the loading capacity of the ship (DWT), which can be modeled as:

$$Ln\ LOA = \beta_0 + \beta_1\ LnDWT + \mu \tag{13}$$

And to ensure the continuing operation of the ship in the berth, the overall length of ship (LOA) which will be mooring must be proportional to the length of berth (Lb), so it can be written as *d*LOA = f(*d*Lb), then for the overall length of the ship (LOA) can be accommodated on ideal length of berth (Lb) which can be modeled as:

$$Ln\ LOA = \beta_0 + \beta_1\ LnLb + \mu \tag{14}$$

Thus for extending of the length of berth (Lb) at specific time periods if estimates of desired economic growth (GDP) rate are x%, with the increase in the size of the overall length of ship (LOA) at x% , then the relationship (Lb) can be modeled as:

$$LnLb = \beta_0 + \beta_1 LnLOA + \beta_2 LnPDB\ + \mu \tag{15}$$

where the Cobb-Douglas production function can be used to obtain the global optimum in selecting the best model between port development and economic growth.

2.4. Model Analysis

Development of the seaport performance analysis model and of economic growth can be carried out through the following steps:

By using time series data of seaport performance and growth data, and then by performing a multi-linear regression, which is converted into the Cobb Douglas model that would become the input to find the optimal solution of the seaport development and its impact on economic growth.

The steps above can be seen in Figure 2 below:

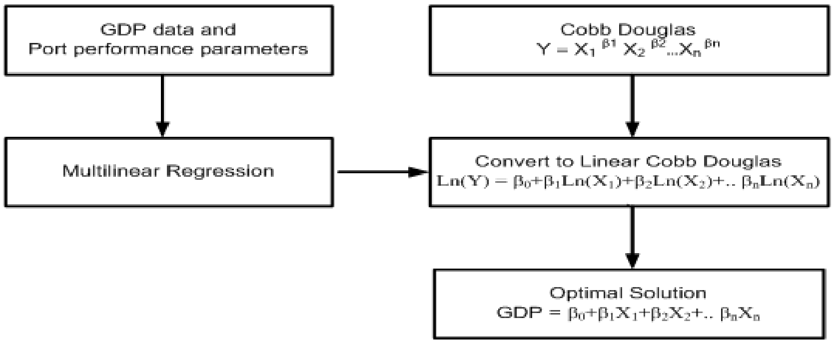

Figure 2 Phase diagram data analysis

2.5. The Data

This study used data of seaport performance (loading-unloading, DWT, LOA, and Lb), and economic data (GDP) of Ambon Island during the period from 2002-2012. Seaport performance and economic growth of Ambon are shown in Table 1.

Table 1 Data on seaport performance and economic growth of Ambon

Year	Loading	Unloading	DWT	LOA	Lb	GDP
2002	165518	119992	331036	91	180	1129738.50
2003	1123255	110945	1497673	91	180	1180831.23
2004	2164503	111531	2848030	96	180	1363790.20
2005	2187043	115769	3585316	96	220	1466715.48
2006	3218153	117966	4469621	115	220	1613730.64
2007	3267626	224274	4668037	115	220	1819984.16
2008	4301373	228366	5144819	118	220	2089100.34
2009	4311852	234580	5386420	122	220	2333813.38
2010	4331069	245864	5600113	133	300	2668234.55
2011	4864845	250151	5707231	138	300	3003452.44
2012	5019327	266267	6075828	138	300	3333832.21

Source: Seaport of Ambon and Ambon Statistics Office (2012), reanalyzed

3. RESULTS

Growth of traffic and ships of cargo increase each year. The quantitative approach analysis in answering the issue of congestion at the seaport is the trigger for the relatively high ship queue to harbor at the berth.

For the level of the number of ships using the side of berth, the Berth Occupancy Ratio (BORcondition) at the seaport of Ambon reached 117% in 2010. Productivity of loading-unloading at several seaports in the Eastern Indonesia Islands showed the need for figures to be further studied and analyzed. An overview of seaport performance in the Eastern part of Indonesia showed that loading-unloading productivity is below 40 tons/gang/hour, with an average BORcondition above 80%, while for the seaport of Ambon Island, the productivity had reached 60 tons/gang/hour, with a BORcondition that reached 117%. Ship visits (Call) for all seaports in the region exceeded 600 Calls annually resulted in an average of 2 (two) ships per day harbored at the seaport, except the seaports of Balikpapan, Sorong, Kendari and Ambon, which have reached an average of 4 (four) ships per day, while the loading/unloading/day at

Ambon Island seaport reached 12,540 tons. Analytical results of the relationship between the port parameters and the economy can be described in Table 2 shown below.

Table2. Recapitulation of equation model parameter relations between the Seaport and the Economy

Test Parameters	Equation Model	R^2	β_0
GDP vs B/M	GDP = β_0+0,413B/M	82.7	610272
GDP vs DWT	GDP = β_0+0,346DWT	73.5	576409
DWT vs B/M	DWT = β_0 +1,11B/M	96.6	393593
DWT vs GDP, B/M	DWT = -β_0 +0,485 GDP +0,435B/M	90.5	583844
LOA vs DWT	LOA_{daily} = β_0 +0,00709DWT	87.0	69.1
LOA vs Lb	LOA = β_0 + 0,350 Lb	84.0	332
Lb vs LOA, GDP	Lb = β_0 + 0,75LOA + 0,000042 GDP	87.3	62.4

Source: Results of analysis

where, R^2 is the correlation coefficient which expressed a strong correlation between parameters. β_0 is the intercept or constant coefficient. From Table 1, the trend of loading/unloading at Ambon Island can be explained as follows:

Relationship pattern of loading/unloading with GDP as shown in Figure 3 tends to be linear with a positive correlation, meaning that the growth of loading and unloading boosts GDP growth rate.
For the relationship of GDP versus the Loading/Unloading cargo variable, the values of both parameters are β_0 = 610272 and β_1 = 0.413, respectively which mean that GDP growth will be a negative or no growth factor, if there is no growth in the loading /unloading capacity in a region, whereas when unloading increases by 1%, then the change in GDP will occur at a rate of 0.413%.

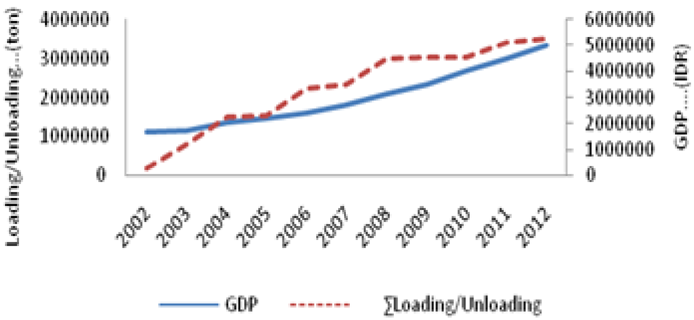

Figure 3 The growth trend for charges in Loading-unloading on GDP growth in Ambon Island

The relationship trend of ship loading capacity also known as Dead Weight Tonnage DWT versus GDP can be seen in Figure 4, where the correlation between both parameters tends to be linear or has a positive influence meaning that the growth of charges in loading-unloading at the seaport increased the GDP of Ambon Island.

For the relationship of DWT versus GDP, the known parameters β_0 = 576409 and β_1 = 0.346 means that GDP growth will be negative or no growth will occur if there is no growth of DWT, whereas when DWT occurs at 1%, the change of GDP will occur at a rate of 0.346%.

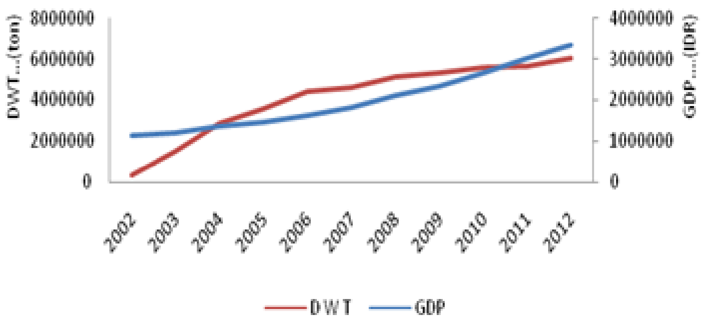

Figure 4 The growth trend of DWT on GDP in Ambon Island

For DWT versus Loading/Unloading cargo, the known parameters $\beta_0 = 3935933$ and $\beta_1 = 1.11$ indicate that an increase in load capacity of the ship will be followed by the growth of loading and unloading. If loading and unloading is increased by 1% then the growth in ship capacity will increase at a rate of 1.11%.

For DWT versus GDP and Loading-Unloading of cargo, the known parameters $\beta_0 = 610272$ and $\beta_1 = 0.413$ mean that GDP growth will be negative or no growth will occur in an island region. Whereas, if loading-unloading increases by 1% then the change of GDP will increase at a rate of 0.413%, where Loading-Unloading cargo is considered constant *ceteris paribus*. Likewise, if Loading-Unloading cargo grows by 1%, the increase of ship load capacity DWT will occur at a rate of 0.435%.

For the relationship of (Length Overall) LOA versus ship loading capacity DWT, the known parameters are $\beta_0 = 69$, 1and $\beta_1 = 0.00709$, which indicates that the growth of the DWT will be negative or no growth will happen if there is no growth in the ship length, whereas if DWT growth occurs at a rate of 1%, a change in the LOA will occur at a rate of 0.00709%.

For the relationship of the overall length of the ship LOA versus the length of the berth Lb, the known parameters are $\beta_0 = 332$ and $\beta_1 = 0.350$, respectively, which means the growth of Lb will be negative or no growth of ship length happens, whereas if Ld growth occurs at a rate of 1%, the change of LOA will occur at a rate of 0.350%.

The relationship between the trend of Lb and LOA versus GDP can be seen in Figure 5, where the three parameters can be said to be linear or positively correlated. This means that the increase of LOA must be followed by the increase of Lb; therefore, these could improve the performance of seaports leading to the growth of GDP of a region.

For the relationship of Lb versus LOA and GDP, the known parameters $\beta_0 = 62.4$ and $\beta_1 = 0.75$, respectively, means that the LOA growth would be negative or no growth would happen, if there is no growth of Lb in a region, whereas if LOA growth occurs by 1%, the change of Lb occurs at 0.75%, in which the GDP is considered constant *ceteris paribus*. On contrary, if the GDP grows by a rate of 1% , the increase of Lb will occur at a rate of 0.000042%.

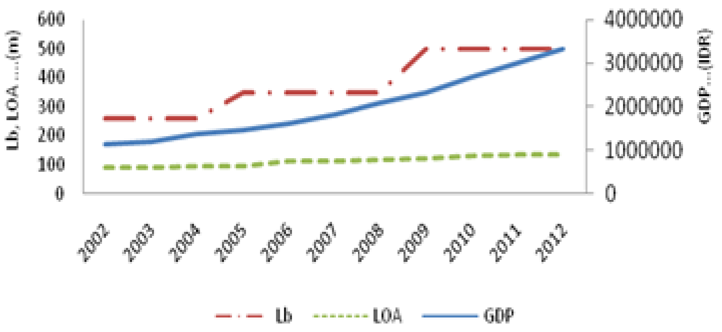

Figure 5 The growth trend of Lb and LOA on the GDP of Ambon Island

4. DISCUSSION

The development context and improvement of seaport performance in an archipelagic region, together with the efforts to promote economic growth through the extension of seaport length should be done for the purposes of: facilitating big-size ships, due to the increases in cargo volume, vessel hold capacity/deadweight tonnage (DWT) followed by an increase in ship length (LOA) and of ship visits (Call); and the shortening of the ship queue interval before mooring to berth. These factors could prevent congestion at the seaport which eventually would improve the continuity of ship operations - mooring and loading-unloading activities.

By using the data in Table1, the contribution of the length of berth (Lb) can affect economic growth, whereas the model of Ambon Island seaport development is as shown in Table 2. Geographically, this model has been applied at some seaports, such as at the seaports of Kendari (Southeast Sulawesi) with an increase in the Lb variable by 1% from which thus increased its GDP by 0.000030 (in trillions IDR). At the seaport of Manokwari (West Papua), with increase of Lb by 1%, which could result in an increase of its GDP by a figure of 0.000041(in trillions IDR), indicating that the result has a positive impact on economic growth.

The applications of this model could measure the economic growth of the islands regions through the determination of seaport infrastructure dimensions, which could be used universally and applied in a region having similar characteristics. The model application has been tested in two places, in Kendari representing the Central Indonesia Region and Manokwari for Eastern Indonesia.

5. CONCLUSION

From the test results, it is concluded that model parameters can be used to study the behaviorial dynamics of economic variables and the seaport region. For every increase in the productivity rate of Loading-Unloading cargo, the resultant boost in economic growth and an increase in the loading-unloading volume of cargo will also have an impact on the growth of DWT, thus increasing the vessel LOA. Therefore, an increase of LOA will have an impact on the length of the length of berth (Lb). And to determine the optimal length of a dock that can promote economic development in a region, it is proposed that this model can serve as an approach model to maritime infrastructure design in order to measure economic growth. Based on the proposition that the length of berth for each increase in an increment of GDP growth, an increase in the length of berth (Lb) is required so that this factor can shorten the queuing time of ships in port, ensure the smooth operation of loading and unloading activities, and lower the cost of seaport operations. Therefore, this increase in the length of berth (Lb) can enhance the competitiveness of the products of an islands region.

As a suggestion, in order to determine the relative dimension of seaport investment in the Indonesian Maritime Pivot Program (Poros Maritim) and to define the economic potential of the islands to achieve economic growth, an adequate amount of seaport infrastructure development must be considered and provided.

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