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Port's Land Optimization Using Linear Programming Method

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ABSTRACT

Port operational activities, in addition to loading and unloading activities, there are also other business activities, such as land rental business. Land port leased to service users to support loading and unloading activities at the dock. Therefore, the land leasing business is the supporting business that plays a vital role in the operation of the port. Land leased to customers based on zoning designation. There are major zoning to support the needs of dock activities and additional zoning to support other maritime businesses. A suitable zoning area will help operations and increase revenue from land leases. Efficient land use will also reduce the need for reclamation for port development since reclamation is now considered a move that harms the environment's ecosystem. The problem in zoning design for harbor land use is the mismatch of land zoning planning with the needs of land users. A lot of land is empty because it is not suited for the zoning that land users need, thus causing a financial loss for the company. An optimization model is needed to maximize the benefits of land use. This study uses profit as an objective function while regulating and projecting land demand is a constraint. This study has established the optimal land allocation using linear programming to optimize each land zoning to maximize revenue without ignoring existing regulations.

KEYWORDS: Optimization, Land Use, Port, Linear Programming

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1. INTRODUCTION

Land as the main capital in the port business is often a constraint in the smooth operation. PT. Pelindo III also gains substantial profits from leasing land to third parties. Land leasing is currently the second largest revenue contributor after revenues from ship and terminal services. The availability of good land for loading and unloading areas of goods with various types can clash with the needs of the land for the area of congestion. The current condition shows that a lot of land is unused or idle due to several causes. The main cause is the lack of land for a particular zonation when there is a large demand for the zonation.

Port performance data strongly influence port land use planning. Data from the development of ship arrivals becomes a benchmark for how much demand zoning requires to support the loading and unloading activities (PIANC, 2014). For example, from year to year, the flow of passengers decreased from 980,853 people/month in 2011 to only about 656,000 people/month in 2015, with an average decline of about 25% per year. So, the land requirement for the passenger terminal area and its supporting facilities can be reduced to be allocated to other zonation. The data will be useful to determine the minimum and maximum limit of land to support each of these activities.

The purpose of port land optimization is not only to gain internal benefits for the company but also to increase the value of Tanjung Perak Port in the international world. Good and efficient land management will minimize the need for land reclamation and help smooth the flow of loading and unloading goods (Anggraini et al., 2015). Good land use will help Pelindo III as the port operator to get green port certification(Sucofindo, 2017). In obtaining the green port certificate, the land becomes one of the inhibiting variables, as the increasing land demand clashes with limited land provision. It makes land problems a difficult factor to improve.

Pelindo III, as a port business unit, is now starting to pay attention to land as a business supporting main port activities, with the current conditions where zoning planning is not optimal because some land is too big and too small. So, it is not suitable for the needs of the land as a supporting port for loading and unloading. With optimization for the design of zonation, optimal land use criteria are expected to be fulfilled, among others, by increasing income from land rent. In addition, applying limits for the primary zoning requirement will reduce the chance of empty or idle land.

2. LITERATURE REVIEW

The government of Indonesia regulates the land use plan according to regulations set by the Directorate General of Sea Transportation. The port organizer has the right to design a layout to propose it as a port master plan, which is then determined to be a land use plan. Space requirements are calculated by considering port facility requirements following the hierarchy in the National Port Master Plan / National Port Arrangement and area availability(Ministry of Transport, 2017)

As a first-class port, the Port of Tanjung Perak has a complex land-use problem. In contrast, a logistical support port for Eastern Indonesia, Tanjung Perak, requires all zones to accommodate the needs of stakeholders. Tanjung Perak has a certified area of 5,230,456 m^2 divided into various zones. The most important thing to consider is the need for land to develop ports that should always anticipate the growth of port service demand.

Land Assets at The Port of Tanjung Perak

Pelindo III, as the port manager, has land with HPL status in several certificates. The certificate is a limitation in the management and development of the port area that Pelindo III manages. The land area will become the boundary in the developed mathematical model, where limited land will be arranged in some zoning to maximize revenue(Bazaraa et al., 2011).

The Port of Tanjung Perak has the characteristics of the land that forms a headland jutting into the north. PT PAL and East Fleet Indonesian Navy Commands border the land in the east and the south, while offices and residential border the west part area(Supriyono, 2010). Based on data from Pelindo III, several areas are suitable to serve as the main zoning of the port. The land access is also close to the dock and close to access out of the port; the land used as the main zoning will cause some pollution, so it should be kept away from residential areas and offices (PIANC, 2014).

TABLE 1. Tanjung Perak Land Assets

No.	HPL Certificate	Area [m^2]
1	No. 1/K GS 5726, 23 September 1988	1,857,445
2	No. 1/K GS 5727, 23 September 1988	3,245,645
3	No. 1/K GS 5727, 23 September 1988	37,550
4	No. 2 GS 5918, 26 May 1994	21,760
5	No. 3 GS 5919, 26 May 1994	14,000
	Total	5,176,400

Table 1 shows the total land area owned by Pelindo III to be managed. There are two certificates not listed in the table and not used in this study because the certificate is located separately from the mainland, located on Karang Jamuang island, which cannot be leased to a third party.

TABLE 2. Land for Main Zone

No	Location	Area (m^2)	Sales Tax / NJOP (Rp /m^2)
1	Jl. Jamrud Utara	76443	3,100,000
2	Jl. Jamrud Selatan	34600	3,100,000
3	Jl. Nilam Utara	165390	3,100,000
4	Jl. Nilam Timur	269078	3,100,000

No	Location	Area (m^2)	Sales Tax / NJOP (Rp /m^2)
5	Jl. Nilam Barat	275593	3,100,000
6	Jl. Prapat Kurung Selatan	74934	3,100,000
7	Jl. Prapat Kurung Utara	60343	3,100,000
8	Jl. Berlian	127080	3,100,000
9	Jl. Kalimas Baru	246253	3,100,000
10	Jl. Tanjung Tembaga	247582	3,100,000
11	Jl. Tanjung Mutiara	527	3,100,000
12	Jl. Tanjung Emas	831332	3,100,000
13	Jl. Laksda M Natsir/Tanjung Priok	503453	2,640,000
14	Jl. Tanjung Batu	178026	2,640,000
15	Jl. Kalianget	31359	2,352,000
16	Jl. Prapat Kurung Tegal	2304	1,032,000
17	Jl. Kalimas Baru I	246253	1,032,000
18	Jl. Prapat Kurung Pojok	2537	916,000
	TOTAL		**3,373,087 m^2**

Table 2 above shows the location of roads that match the land criteria required by the main port zoning. Each road also has a limited area. The total land area is 3.373.087 m^2, which is still sufficient for the projected land area of 3,191.005 m^2. Figure 1 below shows the designated area for the main zone.

FIGURE 1. The area designated for the main zone.

The land for supporting zoning will be allocated off-farm land for the main zonation of the port, where the land has an area of 1028453 m^2. The land for supporting zoning is placed outside the area adjacent to the dock because it is not directly related to the port activities.

TABLE 3. Land for Supporting Zone

No	Location	Area (m^2)	Sales Tax / NJOP (Rp/m^2)
1	Jl. Perak Barat	287441	5,095,000
2	Jl. Perak Timur	100961	5,095,000
3	Jl. Mirah	120681	5,095,000
4	Jl. Tanjung Sadari	63357	3,375,000
5	Jl. Sisingamangaraja XII/Jakarta	15663	3,100,000
6	Jl. Teluk Kumai Barat	44532	2,176,000
7	Jl. Teluk Kumai Timur	66768	2,176,000
8	Jl. Teluk Nibung	69523	1,722,000
9	Jl. Teluk Pang-pang	2042	1,722,000
10	Jl. Teluk Buli	7463	1,722,000
11	Jl. Teluk Betung	3854	1,722,000
12	Jl. Teluk Weda	7486	1,722,000
13	Jl. Teluk Aru	25912	1,722,000
14	Jl. Teluk Bone	18396	1,722,000
15	Jl. Teluk Sarera	6045	1,722,000
16	Jl. Teluk Amurang	12534	1,722,000
17	Jl. Teluk Langsa	302	1,722,000
18	Jl. Teluk Penanjung	1482	1,722,000
19	Jl. Teluk Sampit	3476	1,722,000
20	Jl. Teluk Bayur	25219	1,722,000
21	Jl. Teluk Tomini	5318	1,722,000
22	Jl. Tanjung Sadari Kolombo	18959	1,722,000
23	Jl. Tanjung Layar	5850	1,722,000
24	Jl. Tanjung Raja	1783	1,722,000
25	Jl. Tanjung Balai	8399	1,722,000
26	Jl. Tanjung Pinang	16112	1,722,000
27	Jl. Tanjung Pura	8346	1,722,000
28	Jl. Tanjung Karang	18633	1,722,000
29	Tanjung Torawitan	12670	1,722,000
30	Jl. Ikan Mungsing	5742	1,722,000
31	Jl. Ikan Lumba lumba	39355	1,722,000
32	Jl. Ikan Lumba lumba I	4149	1,722,000
	TOTAL		1,028,453 m^2

Growth of Land Demands

Once the maximum land area is known, it is necessary to calculate the maximum land boundary for each zonation. The data was obtained from the projected increase in existing dock activities. Each zoning provided will always follow the volume of dock activities when the dock activity increases. An increase will follow to support the needs of each type of activity. In contrast, if there is a decrease in the volume of activities, then there will be a decrease in land needs for a zonation. The data in Table 4 shows no decrease in the main port activities. There is a significant increase in activity for some sectors, such as container flows, that have increased above 50%.

TABLE 4. Port Activity Trend

			Forecast				
No	**Description**	**Unit**	**2015**	**2020**	**2025**	**2030**	**Trend**
A	Flow of Goods	ton	62,101,309	80,623,677	105,769,221	139,917,147	125
1	General cargo	ton	7,817,448	8,711,782	9,756,024	10,925,436	40
2	Dry Bulk	ton	11,851,713	13,593,278	15,590,759	17,881,763	51
3	Liquid Bulk	ton	2,160,334	2,453,773	2,858,431	3,329,822	54
	Subtotal 1 s/d 4	ton	21,829,495	24,758,833	28,205,214	32,137,021	47
B	Container Flow	TEUS	3,537,391	4,961,374	6,958,584	9,759,774	76
C	Cattle Flow	Head	23,500	23,500	23,500	23,500	-
D	Passenger Flow	People	1,133,478	1,219,875	1,312,858	1,412,928	25
E	Ship Visit	GRT	89,302,915	113,036,333	144,879,254	187,700,282	110

Since the tendency of port activity increases, the maximum land estimate required for each zonation can be calculated. The value of the trend will be combined with existing land data used for each zoning.

TABLE 5. Land Needs Based on Activity Growth

Land function	Present area A	Growth % B	Expansion A x (B/100)	Land needs A + B
Conventional Terminal	161500	40	64208	225708
Container Terminal	1,452,400	76	1103824	2556224
Dry Bulk Terminal	256800	51	130658	387458
Liquid Bulk Terminal	8,330	54	4498	12828
Passenger Terminal	7,030	25	1758	8788
TOTAL				3,191,005

Table 5 shows an increasing need for land for major zoning ports. Where projected up to 2030, the total land area required for primary zoning is 3,191.005 m2. The land area will be divided into several zones with different functions and areas.

The supporting land requirement is measured based on the Port's Masterplan zoning allocation and the existing land's condition. For land where the allocation of zonation is not met, the leased area determines the lower limit of zonation reduction. As for the land that has increased the lease area of the zoning provided, the leased land will be the minimum limit for the planned zoning allocation.

TABLE 6. Supporting Land Allocation

Zone	Present Occupied Land	Land Allocation Based On RIP
Office & Bussines Zone	75654	150000
Trade Center Zone	17885	200000
Industrial Zone	178000	150000
Public Facility Zone	80000	100000
Parking Area Zone	137890	120000
Distribution & Consolidation Zone	376150	300000
TOTAL	865579	1020000

3. METHODS

Linear Programming Model Formulation

The linear programming model is used to allocate optimally limited resources(Bernard W. Taylor, 1999). In this case, the limited resources to be optimally allocated are the land area for each zoning. The allocation of land needs to consider several aspects, namely gains in each road, boundary of land area, and land requirement for some zoning.

Objective Functions

In this research, the objective function to be achieved is to maximize the profit from zoning, which will be allocated to the port master plan by Pelindo III. The following equation expresses the objective function:

$$Maximize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\left(X_{ij}C_iD_i\right) \quad (1)$$

Where Z is the maximum profit, X_{ij} is the decision variable for the area of zoning I that will be allocated at location j, C_i is the land rental rate for each zoning, and D_j is NJOP for each road location.

Constraints

Some obstacles must be met for the existing problems in the field, followed by the desired model. The constraints are:

$$\sum_{i=1}^{n} X_{i,j} \leq b \quad (2)$$

$$a_i \leq \sum_{i=1}^{m} X_{i,j} \leq e_i \quad (3)$$

$$X_{i,j} \leq e_j \quad (4)$$

$$X_1 \geq 0;\ X_2 \geq 0;\ \ldots;\ X_m \geq 0; \quad (5)$$

Where b is the total land asset, a_i is the minimum area of zoning i, e_i is the maximum area for zoning i, and e_j is the maximum area for each road location.

4. RESULTS

Optimization is performed with the solver add-in available from Excel. The optimization uses land allocation for each zonation on different NJOPs as the variable. Optimization shows the amount of land allocated for each NJOP to maximize profits and accommodate the changing needs of each zoning. The optimization results indicate some changes to the placement and allocation of zoning from the current RIP to maximize the profitability of the land lease. The result of the optimization is shown in table 7 and table 8.

TABLE 7. Land Needs Based on Activity Growth

		Land Allocation For Land Rate Type (m²)					Income (Rp)
		3,100,000	916,000	1,032,000	2,352,000	2,640,000	
Terminals	Conventional			69,012	31,359	125,337	23,793,276,915
	Container	2,000,082				556,142	383,423,446,200
	Dry Bulk	387,458					60,055,934,062
	Liquid Bulk	12,828					1,988,371,000
	Passenger	8,788					1,362,062,500
	TOTAL	2,409,155	0	69,012	31,359	681,479	470,623,090,678

TABLE 8. Land Needs Based on Occupied Land Area

		Land allocation for land rate type (m²)					Income (Rp)
		5,095,000	3,375,000	3,100,000	2,176,000	1,722,000	
Zone	Office and Bussiness	33,416		15,663		26,575	13,228,598,500
	Trade Center					17,885	1,539,898,500
	Industrial				111,300	66,700	17,852,310,000
	Public Facilities					80,000	2,066,400,000
	Parking					137,890	1,187,232,900
	Consolidation and Distribution	475,667	63,357				131,867,662,000
	TOTAL	509,083	63,357	15,663	111,300	329,050	167,742,101,900

Tables 7 and 8 show that the maximum benefit obtained from the optimization result of zonation is Rp 470.623.090.678 for main zoning and Rp. 167.742.101.900 for supporting zoning. Maximum profit from the lease of land obtained is Rp 638,365,192,578, - per year 4. Maximum profit will be earned when using land allocation for leased zoning as big as shown in Table 9

TABLE 9. Land Allocation for Each Land Rate Type

Zoning [ha]	310	103.2	235.2	264	509.5	337.5	217.6	172.2
Conventional Terminal		69,012		125,337				
Container Terminal	2,000,082			556,142				
Dry Bulk Terminal	387,458							
Liquid Bulk Terminal	12,828							
Passenger Terminal	8,788							
Office & Business Zone	15,663				33,416			26,575
Trade Center Zone								17,885
Industrial Zone							111,300	66,700
Public Facility Zone								80,000
Parking Zone								137,890
Consolidation and Distribution					475,667	63,357		539,024

Optimum land use will minimize idle land. By minimizing idle land, land use will become more efficient. Idle land can accommodate land needs for major zoning that continues to increase as land needs increase. If land use can be optimal, it will reduce the need for land reclamation. The absence of a plan for land reclamation will allow port operators to obtain green port certification.

5. CONCLUSIONS

The results of this study are that land that can be used for major zoning planning is 3.373.087$m^{2,}$ and land for supporting zoning is 1,028,453m^2. Allocation of land to maximize profits from land rental for the main zoning is 225,708 m^2 for conventional terminals, 2,556,224 m^2 for container terminals, 387,458 m^2 for dry bulk terminals, 12,828 m^2 for liquid bulk terminals, and 8,788 m^2 for passenger terminals. Meanwhile, the supporting zoning is 75,654 m^2 for the office and business zone, 17885 m^2 for trade center zones, 178000 m^2 for the industrial zone, 80000 m^2 for the public facilities zone, 137890 m^2 for the parking zone, and 539024 m^2 for consolidation and distribution zones.

The maximum profit from land rental obtained is Rp 638,365,192,578. There is an increase in the income obtained from the actual zoning implementation to Rp 297,948,278,495 per year. Revenue from optimization consists of Rp 470,623,090,678 for the main zone and Rp 167,742,101,900 for the supporting zone.

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