Integrated Coastal Zone Planning Based on Environment Carrying Capacity Analysis

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Abstract. Coastal zone is a crucial area in terms of planning development. It holds high economic value, which affect to increasing number of inhabitants living in the area. As a result, this condition influences environmental degradation. Thus, in every attempt towards coastal zone development, it is crucial to always refer to environment carrying capacity. Carrying capacity is the limit of a certain coastal zone capability to support all human created activities, in which all ecological performances are maintained at sustainable level. The failure to establish strong and clear method and regulation on carrying capacity analysis will lead to a very risky coastal zone development, which in turn would threat the area’s sustainability. This paper discusses method for analysing carrying capacity of coastal zone as important input for the area development plan. Two key parameters, i.e. land and clean water carrying capacities are discussed to form carrying capacity analytical method. Furthermore, an empirical data of Ambon Bay, Moluccas Province, is used to illustrate the operationalization of the method.

1. Introduction
As one of the largest archipelagic state, Indonesia owns 17.504 islands [1] and coastal line of 99.093 km² [2]. Territorially, Indonesia area includes around 65% of waters area and the rest of land areas (berjubel.net, 2015). Moreover, Indonesia is a habitat of a highly diverse marine life. As one of the proof, Indonesia has been included to the Coral Triangle Initiative (CTI), which is a multilateral partnership of six countries to address the urgent threats facing the coastal and marine resources of one of the most biologically diverse and ecologically rich regions on earth (CTI, 2007). With high potential on marine life it is no longer a question that Indonesia owns high economy value on its coastline. Therefore, around 60% of Indonesian lives along the coastline [3].

There are variety of definitions have been used to describe the area of coastal zone. Coastal zone is the interface where the land meets the ocean, encompassing shoreline environments as well as adjacent coastal waters [4]. Its components can include river deltas, coastal plains, wetlands, beaches and dunes, reefs, mangrove forests, lagoons, other coastal features. Moreover, another source defines coastal area as a junction between terrestrial ecosystems, marine ecosystems and ecosystems meet each other in a balance that is susceptible [5]. The transition between land and sea in the coastal region has formed a diverse ecosystem and is very productive; therefore, provide tremendous economic value to humans. In line with population growth and increased socio-economic development activities, the "value" of coastal areas continues to grow. With the unique potential and economic value was then
faced with the highly threatened of coastal areas, it should be handled specially the coastal areas so that these areas can be managed in a sustainable manner.

The notion of carrying capacity or sustainability yield has become a basic criterion of sustainability. The concept of carrying capacity is rooted in a notion of “limits to growth”. Ecosystems and populations have a limited capacity to cope with environmental stress; above a certain amount of stress there may be detrimental effects for the ecosystems [3]. Carrying capacity is defined as “the growth limits an area can accommodate without violating environmental capacity goals” [6]. In recognition of the diverse nature of carrying capacity as a concept, a variety of types of carrying capacity have been identified. Most of these fall into the following categories: physical, ecological, social, and economic. Among others, this paper focuses on physical carrying capacity. This is a measure of the spatial limitations of an area and is often expressed as the number of units that an area can physically accommodate, for example, the number of berths in a marina [7].

Ambon Bay, which is located in the eastern part of Indonesia, has a fairly rapid economic development. The increasing number of people who settled on the Ambon Bay as well as the number of tourists, both domestic and foreign, derive the increasing number activities that have an impact on the increasing need for land and natural resources, especially water resources to support the activities. In addition, land development also causes an increase in the pollution of Ambon Bay. This raise concerns on environmental degradation, particularly on Ambon Bay in which owns a variety of coral reefs, sea grass and mangrove areas, where these ecosystems need to be protected. Therefore, carrying capacity of the environment must be analyzed to prevent or decrease the environmental degradation, which caused by Ambon Bay development.

2. Methods
In order to do their activities human needs several aspects in their lives, including land, water, and supporting infrastructures, such as transportation infrastructure, waste management infrastructure, electrical infrastructures, and others. Human’s needs may increase or decrease time to time, depends on the number of population. In the case of developing country, normally the cities experience increasing number of population. Thus, the needs of resources also increase in line with the increasing number of population. Several aspects of the human’s needs may adjust according to the increasing number of demand. For example, due to the increasing number of population, number of waste generation is increasing. Thus, the waste management infrastructure needs to cope with this problem. It is possible that this infrastructure to be adjusted to meet people needs, the question may be only the technology improvement. This aspect of needs is called derived needs.

On the other hand, there are also several aspects of needs that are given. This means that, the supply of this type of human needs is nonadjustable to the increasing number of demand. Land and water are the example of the given needs. Even though up-scale development could be possible, in the end this type of development will find its maximum capacity. When there is no more land left to do any development, this means that land has meet its maximum carrying capacity. The same case also happens for clean water. Clean water is not adjustable to the people’s increasing demand. When there is no more clean water left from the sources, this means that clean water has meet its maximum carrying capacity.

Based on the discussion above, it can be concluded that the supply amount of land and clean water are classified as given, nonadjustable, or not able or hardly to be improved. While, land and clean water is the main needs of human to live and to do their activities. Thus, these two criteria are chosen to be the threshold of environment to cope with the increasing number of population or increasing development. The time when clean water or land is not able to deal with the number of population or activities, it is a sign that the environment carrying capacity has been reached. Thus, this criterion is crucial to be applied, as the basis for the prevention of the other ecological risks to rise.

Additionally, the analysis method also refers to the Regulation of Environment Ministry Number 17 Year 2009 on the guidelines on determining the environment carrying capacity in spatial planning. Knowing the capacity of the natural environment and resources to support human activities does the identification of environment carrying capacity. Environment carrying capacity is divided into two components, which are supportive capacity and assimilative capacity. In this guideline, the
environmental carrying capacity assessment is limited to the supplying capacity of the natural resources, particularly on the capability analysis of land and clean water. The capability analysis looks at how the supply meets the demand. As the natural resources capacity depends on the land and water capability, therefore the determination of environmental carrying capacity in this guideline is based on four approaches, namely:

- The capability of land to allocate people’s activities.
- The capability of the potential clean water supply to fulfill people activities.
- Comparison between the supply and demand of land.
- Comparison between the supply and demand of clean water.

In order to know the land availability, analysing the land capability is the first step to it. By overlaying the slope map, soil map, erosion potential area map, and other disaster potential area map, the land capability map can be produced. In this kind of map, the land characteristic is identified and then divided into several different classes. Thus, this land classes have their own role to address the growing development. In this research, the land needs that are calculated are the land for settlements and its supporting facilities (e.g. housing area, health facilities, education facilities, office and trade facilities, tourism facilities).

To calculate land area needs for housing area, a standard from SNI 03-1733-2004 on Procedures for Urban Housing Environment Planning is used. The assumption is that one family consist of five members (i.e. father, mother, and three children). Following calculation is using the previously mentioned standard.

\[
\begin{align*}
\text{The main floor area} & : (2 \times 9.6) + (3 \times 4.8) \text{ m}^2 = 33.6 \text{ m}^2 \\
\text{Floor area of service} & : 50\% \times 33.6 \text{ m}^2 = 16.8 \text{ m}^2 \\
\text{Total Floor Area} & : 50.4 \text{ m}^2
\end{align*}
\]

Assuming the Building Coverage Ratio (BCR) is 50%, then the minimum parcel of housing area for families with five members is 100.8 m². Moreover, other supporting facilities have different area standards.

The calculation of water supply is based on the current water source discharge located in Ambon Bay area. While as the water requirement is calculated based on the number of population and the standard of clean water needs per person. This formula is used in the calculation of water needs:

\[
D_A = N \times KHL_A
\]

\[
\begin{align*}
D_A & : \text{Total clean water needs (litre per day)} \\
N & : \text{Number of population (people)} \\
KHL_A & : \text{Standard of clean water needs (litre per people per day)}
\end{align*}
\]

In the Moluccas Province Spatial Plan 2013 – 2033, Ambon Bay is appointed as a Provincial Strategic Area from the aspect of environment support. It has a strong impact in the provincial scope in terms of its environment quality. Thus, Ambon Bay’s development should be prioritized, and requires an immediate support of spatial planning and management. Ambon Bay has natural resources that need to be protected, such as coral reefs, sea grass beds and mangrove forests. However, the pollution level in this area is at a point that is very alarming. Several issues cause the pollution, such as land use shift from green areas into settlement areas that may lead to a huge level sedimentation and hardly-decomposed waste that is disposed on the water surfaces (e.g. rivers, drainage channels), and then carried into the Ambon Bay which makes marine ecosystems are threatened.

In addition, based on Ambon City Master Plan Year 2011 – 2031, Ambon Bay is appointed to be a conservation area of coral reef ecosystems. In addition to its role as a provincial strategic area from the aspect of environment support, Ambon Bay also has a role as a provincial strategic area from the
aspect of economic support. Thus, it is also planned as a regional flagship fishery product and marine tourism. Those both roles might be contradictory, as economic activities usually lead to more development, while environment needs to be protected. Due to this condition, the coastal zone planning must facilitate the growing economic activities without harming the natural environment condition.

The area of coastal zone planning consists of 46 villages in five districts on the island of Ambon, which equals to 374.86 km$^2$ with a population of 52,354 people. The area consists of chosen sub-district that are adjacent to Ambon Bay or sub-district that are adjacent to a river that empties at the Ambon Bay.

3. Result and Discussion

3.1. The capability of land to allocate people’s activity

Comparison between the land needs and land availability is done to see the ability of land to accommodate the settlement and its activities in the future. Before comparing those two, firstly land capability must be analyzed. The land capability analysis is conducted to see the capacity of the land based on existing criteria such as slope, soil type, and other factors. Factors that are used to analyze land capability in Ambon Bay area is the data of slope and soil type. In addition, based on the Ambon City Master Plan and the Moluccas Province Master Plan, there are several areas, which are classified as protected zone. Thus, this zone is not available to be developed. These factors are then processed spatially in ArcGIS.

3.2. Land carrying capacity

Land needs is divided into two scales, which are land needs for sub-district (namely kelurahan in Indonesian term) and district (namely kecamatan in Indonesian term). The calculation of sub-district scale land adequacy is conducted to see the comparison between the land availability and the land needs in sub-district unit. The land needs include land area for settlements and the supporting facilities to support activities on the sub-district unit. The calculation of this land needs refers to SNI 03-1733-2004 on procedures for housing planning in urban area. The standard used in order to calculate the housing area requirement is that, each household, which consists of 5 people, requires 100 m$^2$ as land to be designated as their settlement. Moreover, supporting facilities which supposed to serve in a sub-district unit is included to the calculation, such as educational facilities, medical facilities, religious facilities, cultural and recreational facilities, open spaces, parks and athletic fields. As for the calculation of land needs for district unit is done to get the number of the land area, which are used to serve the district scale facilities and tourism facilities. The needs for district scale facilities refers to SNI 03-1733-2004 on procedures for housing planning in urban area, while for the needs for tourism facilities refers to DG of Tourism, Post and Telecommunications No. 22/U/VI/1978 dated June 12, 1978.
Table 1. Projection of Population Number and Population Density in 2027 and 2037

| No. | Sub-district   | Area (km²) | Population (people) | Population Density (people/km²) |
|-----|----------------|------------|---------------------|---------------------------------|
|     |                |            | 2027                | 2037                            |
|     |                |            |                     |                                 |
|     |                |            | 2027                | 2037                            |
| 1   | Teluk Ambon    | 93.68      | 81,188              | 125.916                         | 867 | 1.344 |
| 2   | T.A. Baguala   | 40.11      | 118.405             | 191.288                         | 2.952 | 4.769 |
| 3   | Sirimau        | 86.81      | 297.715             | 464.031                         | 3.429 | 5.345 |
| 4   | Nusaniwe       | 88.35      | 191.568             | 299.106                         | 2.168 | 3.385 |
| 5   | Leihitu Barat  | 65.91      | 13.387              | 14.027                          | 203  | 213   |
|     | Total          | 374.86     | 702.263             | 1.094.369                       | 9.620 | 15.057 |

Firstly, before we are able to calculate the land needs, calculating population projection is needed. Population projections up to 2037 carried out by the geometric projection model. The geometric projection model is chosen other than arithmetic and exponential projection model because it generates the smallest standard deviation value. Geometric projection model is performed by the following formula.

$$P_n = (1 + r)^n$$

- $P_n$ : number of tourists in year $n$
- $P_0$ : the number of tourists in the base year
- $r$ : growth rate of tourists
- $n$ : number of intervals

Land can be developed - Land needs (settlements and tourism) = Land availability

- Slope < 15%
- Not on the water catchment area
- Not in the water boundary area. Development is available after: for river: 30 meters of free area for coast: 100 meters after the coast line
- Settlement needs
  Housing: 100 m² / family
  Facilities: education, health, open space, office and trades, and others
- Tourism needs
  Hotel room: 48 m² / room
  Facilities: restaurants, bars, parking spaces, entertainment area, and others
- Surplus: Land that can be developed > Land needs
- Deficit: Land that can be developed < Land needs

Figure 1. Land Availability Calculation

Land area that can be developed minus the land area needed equals to land area availability. The land availability is divided into two categories, which are surplus and deficit. Surplus of land availability indicates that the sub-district still having an area to be further developed, while the deficit shows shortage of land area and it is impossible to carry out further development. Thus, from this analysis, it can be indicated that necessary anticipation in the increasing number of population in a sub-district with a future land deficit is needed. Moreover, future development can be done in the sub-district that is still having surplus of land in the future.
Figure 2. (a) Comparison Between Land Supply and Demand in 2027 (b) Comparison Between Land Supply and Demand in 2037

On the figure, it is shown that the unit of analysis is sub-district area. The figure above explains that the land availability is divided into two classifications, which are surplus (shown by the green color on the map) and deficit (shown by the red color on the map). If the land availability is surplus, it means that the available land is able to serve the land needs on the specific year. However, deficit of land availability means that the available land is no longer able to serve the land needs on the specific year. From the figure, it is shown that in 2027, there are number of sub-district which are having deficit land availability. Moreover, on the year 2037, more sub-districts are having the land availability status of deficit. Thus, it is concluded that the land carrying capacity in Ambon Bay, is decreasing time to time, which is shown by the increasing land deficit in the sub-district units.

3.3. Clean water carrying capacity
This analysis part shows the calculation of the water carrying capacity in the area, taking into account the supply and demand of water resources for the people who live in the area. Thus, it will be known whether the water resources in the area in a state of surplus or deficit.

Figure 3. Comparison Between Supply and Demand of Clean Water

Water supply is calculated based on the water discharge produced from the water sources. There are several water sources, such as:
• Surface water, is water on the surface of the earth, such as river, lake, and others.
• Groundwater is water present beneath the earth’s surface.
• Spring water, is water from a spring, which is a natural situation where water flows from aquifer to the earth’s surface.

Water demand is calculated based on number of population and the standard water requirement per person. Based on the water supply standards from Directorate General of Human Settlements on Year 2000, there are two types of water demand, which are:
• Domestic water, is household water demand
• Non-domestic water is non-household water demand, such as commercial and industrial area.

The domestic and non-domestic water demand differs for every type of cities, ranging from metropolitan, big scale city, medium scale city, small city, and village.

Other than domestic and non-domestic water needs, to include water needs of every activity is necessary. In Ambon Bay, water needs of tourist and livestock activity are included to the water demand calculation. For tourist, it is assumed that their water needs is used for bathing, washing, and toilet activities, which is *mandi, cuci, kakus* (*MCK*) in Indonesian term. The standard requirement refers to the SNI 03-2399-2002 on the supply specification for MCK. Standards clean water demand for MCK is 45 liter/person/day. Moreover, an addition of 2 liter/person/day is required for tourist for drinking water purpose. Thus, the total need for clean water for tourist is 47 litre/person/day. In addition, the calculation of livestock water needs refers to SNI 19-6728.1-2002 on balancing water resources. Different types of livestock have different water needs. As a case study, data on Ambon Bay clean water carrying capacity analysis is presented.

In the Ambon Island, PDAM (Regional Clean Water Company) and another private company distribute the clean water. Clean water sources used by both of them come from spring water and groundwater. In total, the current spring water discharge reaches up to 20,380,800 liter/day and the groundwater discharge is 9,288,000 liter/day (Ambon City Clean Water Master Plan, 2012). After the clean water demand and the clean water supply data are obtained, the difference between them can be counted. If the difference shows a negative value, then it means that Ambon Bay is on a water deficit condition. Vice versa, if the value is positive, then it means that Ambon Bay is having a water surplus. In Table 2, it is shown that Ambon Bay is having water deficit starting 2017. Thus, it is necessary for Ambon Bay to search for more water resources. Otherwise, the number population and activities must be restricted to a number which water resource could handle. From this finding, it is concluded the water carrying capacity is not sufficient to serve current Ambon Bay population and activities. In the end this condition may lead to environment degradation.

| Table 2. Comparison Between Supply and Demand of Clean Water in Ambon Bay |
|------------------|------------------|------------------|
| Year   | Demand (liter/day) | Supply (liter/day) | Difference Between Supply and Demand (liter/day) |
|--------|--------------------|--------------------|-------------------------------------------------|
| 2017   | 116,853,543,64     | 29,668,800,00     | -87,184,743,64                                  |
| 2022   | 144,603,896,85     | 29,668,800,00     | -114,935,096,85                                 |
| 2027   | 179,164,581,53     | 29,668,800,00     | -149,495,781,53                                 |
| 2032   | 222,268,647,82     | 29,668,800,00     | -192,599,847,82                                 |
| 2037   | 276,094,020,51     | 29,668,800,00     | -246,425,220,51                                 |
4. Conclusion

Environmental carrying capacity is a method of analysis, which is necessary to be done in order to see how the environment is able to cope with the area development. Since coastal zone owns high economical value, then it is vulnerable to uncontrolled development. Clean water and land area are the two main environment factors that are also the main needs for living. Thus, without the adequate number of clean water and land area, it is impossible for people to live and to do their activities. Moreover, if development is still going with adequate number of clean water and land, environmental degradation will be the case. This study analyses the land and clean water carrying capacity in Ambon Bay. From the land carrying capacity, it is shown that number of areas which are unable to meet the needs increase time to time. As for the clean water carrying capacity, it is shown that since the year of 2017 Ambon Bay is having a water deficit problem. From these two reasons, it can be said that the development in Ambon Bay must be adjusted in order to meet the balance between the environment carrying capacity and the development itself, particularly to anticipate possible problems due to the great scale of marine tourism development in this area.

From the case of Ambon Bay, it can be seen that the land utilization has not been spread out. Only several sub-districts that are experiencing land deficit up until 2037. As a solution, the land in other sub-district, which is still having a surplus quantity of land, could be more utilized. This can be done by equally distributing the number of population. As for clean water, the solution is to look for other clean water potential sources. Ambon Bay is a home of several wide rivers. It can be the case that not all rivers have been utilized. Thus, searching for more clean water potential might be the answer. However, in the end, after every population or development adjustment are done, but the environment carrying capacity has not been met, that is the time when number of population or development needs to be restricted. Otherwise, environment degradation will be the case. The goal of ICZM is to find the resolution of land use conflicts for the development and conservation of coastal and marine environment. Thus, by being aware of the environment carrying capacity and also to include the solutions into the ICZM, will contribute into the conservation of coastal and marine environment.

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