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Assessing the Sustainable Development of Coastal Reclamation Area Using AHP and GIS Application: A Case of Jakarta

Andi Yurnita[#], Slamet Trisutomo[*] and Mukti Ali[*]

[#]Post Graduate Student, Department of Architecture, Hasanuddin University, Makassar 90245, Indonesia.

** Department of Architecture, Hasanuddin University, Makassar 90245, Indonesia.*

** Department of Architecture, Hasanuddin University, Makassar 90245, Indonesia.*

[#]Orcid: 0000-0002-4137-6608

Abstract

The assessment of sustainable development of reclamation area using Reclamation Sustainability Index (RSI) with Geographic Information System (GIS) analysis is a challenging task. The prime objective of the paper is to provide a novel approach for assessing the sustainability of reclamation environments while the second objective is to provide a decision support tool for coastal resource managers in the assessment of environmental impacts of development in reclamation areas. In this paper, as a case study, a coastal city of Jakarta Indonesian was assessed for sustainable development in reclamation area. Assessment will be done by Reclamation Sustainability Index (RSI) and analysis by GIS as the tools. RSI was built from previous research that has simplified from many researches and analysed by Analytic Hierarchy Process (AHP) and expert choice. RSI uses 9 indices from three indicators of environment factor which are coastal resources, building and infrastructure. The assessment results indicated that reclamation in Jakarta was almost in the potentially unsustainable development or intermediate sustainable development.

Keywords: Assessment, reclamation area, GIS, Reclamation Sustainability Index (RSI).

INTRODUCTION

The great urban development taking place in the last decades of the 20th century, urged the search for new approaches to urban problems. Population concentration in coastal areas is an additional source of urban problems; over 360 million people live in these areas, vulnerable to weather phenomena, natural disasters and the sea level rise [1]. Reclamation becomes one of the solutions to provide land for housing. Coastal reclamation is a practice that creates land or water areas by filling in or enclosing shallow coastal space [2].

As a result of the rapid development of industrialization and urbanization, the coastal zone in many part of the word showed a rapid change during the past few decades. In particular, the issues about coastal ecology and environment had brought about a serious challenge for coastal zone sustainable development [3] including Jakarta as the capital Indonesia.

Sustainable development is concerned to be a kind of ideal development model, and one of the main problems which mankind will face in the 21th century [4]. According to the definition of sustainable development, the sustainable development of coastal zone does not only meet the increasing demand, but also protects ecology and environment, without prejudice to future generation's access to adequate food security. In order to provide a scientific basis for decision-makers, therefore, it is very necessary to comprehensively assess the status of regional development with regard to economy, resources and environment [3]. Urban ecosystem sustainability assessment plays an important role in the decision-making and urban planning processes at the national, regional or local levels.

From previous work, the paper has simplified index from many kind indices of sustainable development research. The papers consist of many indices then the works simplify the indices into only nine indices using Analytic Hierarchy Process (AHP), it called Reclamation Sustainability Index. Reclamation Sustainability Index (hereinafter referred to as "RSI") was developed using expert choice analysis to classify and simplify the indices,. There were three types of experts who served as respondents whose opinions are considered and included in the matrix. They were from professional fields, government staffs and academics. They chose the most important indicators by pair wise system, using expert choice [5].

The summarized criteria obtained from experts' opinion from 72 criteria disclosed 26 applicable indicators, and from AHP, it listed 9 indicators which were most important according to the experts' choice. The experts assessed whether an indicator has more important influence than other indicators with a range of assessment 1 – 9, then ranked and graded [5].

The RSI is a tool of assessing the process of coastal reclamation areas in terms of their sustainability development. RSI can assist in assessing coastal reclamation development to sustainable environment and help to shape (or reshape) coastal development plans to create a well laid-out coastal environment. The planners need the process of appraising and grouping specific coastal areas in terms of their sustainability for defined uses [6].

The process is using geographic information system (GIS) as a tool for data input, storage, retrieval, manipulation, analysis and output of the spatial data [7]. Studies of present land distribution to residents, recreation, agriculture, industry and other human activities in Jakarta reclamation area can give information about their dynamism which is useful for policy planners and can indicate key areas for effective future regional sustainable development [8].

However, because of the different research purposes, time and condition, no further study related to assessment of sustainability of the reclamation project on the coastal environment using RSI has been carried out yet. This paper aims to assess the sustainability or coastal reclamation area in Jakarta city using RSI and is analysed by GIS.

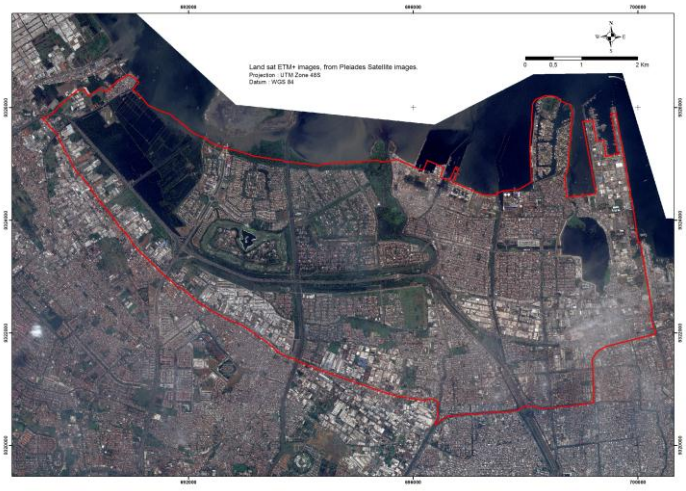

Figure 1: Satellite Image Coastal Reclamation Area of North Jakarta

(Source: Pleiades satellite images (2013) UTM Zone 485, Datum WGS 84.)

State of the Art

Theory on Urban Sprawl Northam (1975) : Urban sprawl in the urban centre is an extension beyond what they have created. Urban sprawl involves conversion of peripheral land into urban centres that were previously not for urban development of the population however [9]. Reclamation is extension of the land out of the land, as the urban sprawl does.

According to the researches, when the impervious surface coverage (i.e. the percentage or ratio of cement surface or rigid surface in the entire land area) reaches 10%, environmental degradation will generally occur. Reclamation often leads to high ratio of impervious surface coverage (>10%) [10].

Land use change reflects largely the integrated influences of human activities and ecological conditions, so land use change influences the ecosystem services from many complex aspects, and even a kind of change of land use can lead to many kinds of changes of ecosystem services. In the mean while, the ecosystem services are changed in the sequence of land use activity, such as changing habitat, structure, material and energy circling [10].

Relying on the theory of ecosystem services and the impacts brought by land use change [10], this paper analyzes the development sustainability of the reclamation area by RSI and diagnoses the condition by GIS analysis. This paper chooses indicators of many sustainable development papers that have been simplified by AHP and expert choice analysis.

McHarg's theory of ecological land use planning developed a model called the layer-cake, which overlays suitability maps of different land use patterns in order to identify ecologically sensitive places and provide strategies based on the analysis [11, 12]. This model also provides a theoretical basis for the geographic information systems (GIS) [13].

From all theories mentioned earlier, this paper concludes that assessing the sustainable development of the reclamation area based on the urban sprawl theory consider that reclamation making a new urban area for coastal activity that need more space. The analysis uses sustainability index based on the ecological theory ecosystem services which impacts brought land use change and McHarg's theory of ecological land use planning developed a model called the layer-cake which is GIS as the analysis and reclamation sustainability index as (RSI) the tools.

MATERIAL AND METHOD

At various stages throughout the study, a range of geographic information system has been used for: (i) areas of reclamation activities which were mapped using a GIS-based procedure; (ii) digitised spatial pattern; (iii) analysis of the sustainability reclamation area using the RSI using Moreover, the study focused on assessing the sustainability of the reclamation area as a specific manner and tools for managing the coastal area. [14].

A. Study Area

The assessment using RSI is tested in reclamation area of Jakarta. It covers a total area of about 3.638,54 hectares (ha), and it extended toward the Northern part of Jakarta (fig 1).

In the era of globalization, the impact of economic developments strengthened the tendency of concentration of various funds in Jakarta. The very real implications of this population growth are the increased demand of urban space. Physically, the developments of Jakarta since last four decades is characterized by the large area of the city development, meanwhile open area which was originally planned as a conservation area of the city is also diminishing, especially in the area of suburbs [15].

On the other hand, Jakarta which covers the area of 662 km2 since the expansion of the city in 1972, cannot enlarge its area because of the law. Approximately 67% of the land area of Jakarta has been developed and 33% area has not been established. Therefore, in the 1990s it had contemplated the possibility of opening new land areas through technology development reclaimed island in the northern coast of Jakarta [15].

B. Developing Assessment for Sustainability Index

The ideal indicator should be able to reduce large quantities of data to its simplest form of where it still retains the essential meaning of the questions asked of the data [16]. The main purposes of urban ecosystem sustainability assessment are to: (i) define sustainable development targets and assess progress made in meeting those targets; (ii) revise the effectiveness of current planning policies and help in making the necessary corrections in response to changing realities, and; (iii) make comparisons over time and across space by performance evaluation as well as provide a basis for planning future actions. In other words, urban ecosystem sustainability assessment is a powerful tool to connect past and present activities to future development goals [13].

From previous paper in this research, the research revealed five steps of building tool for the reclamation sustainability index which are [5]:

Step 1. Determination of Evaluation Index System

Step 2: Weighting of Indices with AHP

Step 3: Arranging Matrix by expert choices

Step 4: Testing Consistency

Step 5: Determination of priority by computer

The application of ecological city theory on assessing the sustainable development of reclamation area of Jakarta used the previous paper that has simplify many indices with AHP and expert choices and found only 26 indices for assessing the sustainability of the reclamation area with GIS using the indices. The sustainability of the reclamation area was identified based on the Land sat ETM+ images, that has been derived from Pleiades Satellite images. The results obtained as shown in Figure 2, revealed that sustainability indicators in the current study were focused on nine factors; open space coverage rate (%), the availability space for water conservation, per capita coverage of land (ha), distance from environmentally sensitive estuaries and coastal wetlands (DES), distance from nature reserves and ecological reserves (DNR), the density of building in their area, adequate road network, availability of public transport with weights and distance from main transportation routes (DMT) [5].

The AHP-Expert Choice evaluation method has been refined into four steps [17]; Determination of Evaluation Index System, Weighting of Indices, Arranging Matrix, Testing Consistency, and Determination of Priority. The AHP structure of the indices can be seen in fig. 2.

To simplify the indices, this research is analyzed through AHP and Expert choice. There were three types of experts who served as respondents whose opinions are considered and included in the matrix. They were from professional fields, government staffs and academics. They chose the most important indicators by pair wise system, using expert choice [5].

The summarized criteria obtained from experts' opinion from 72 criteria disclosed 26 applicable indicators, and from AHP, it listed 9 indicators which were most important according to the experts' choice. The experts assessed whether an indicator has more important influence than other indicators with a range of assessment 1 – 9, then ranked and graded. Top rank is environment effort rather than manmade, consistent across all interviewees, as shown in table 1.

C. Digital Image Processing

The studied area was represented by Pleiades satellite images dated from 2013. The images were geometrically corrected. Rectification method (image for map) was followed. The geometric model used in the rectification process was second order polynomial, and the sampling method is the nearest neighbour method. The processes have simplified the collection of data [8]. Geographic Information System (GIS) has previously been used as tools for advanced ecosystem management in collecting remotely sensed data that can facilitate synoptic analyses of land use/cover patterns, and changes and projecting it to global scales over time [8].

To start a GIS analysis of the Jakarta reclamation area, the data had to be gathered, organized and analysed. Data was gathered through different approaches;

- Literature review etc
- Official reports and maps acquired from Jakarta Development Board, Ministry of Public Work.

- Analysis of Pleiades satellite images from 2013 acquired from France to monitor the land use of reclamation development projection UTM Zone 485, Datum WGS 84. Four scenes were needed to cover the reclamation area.

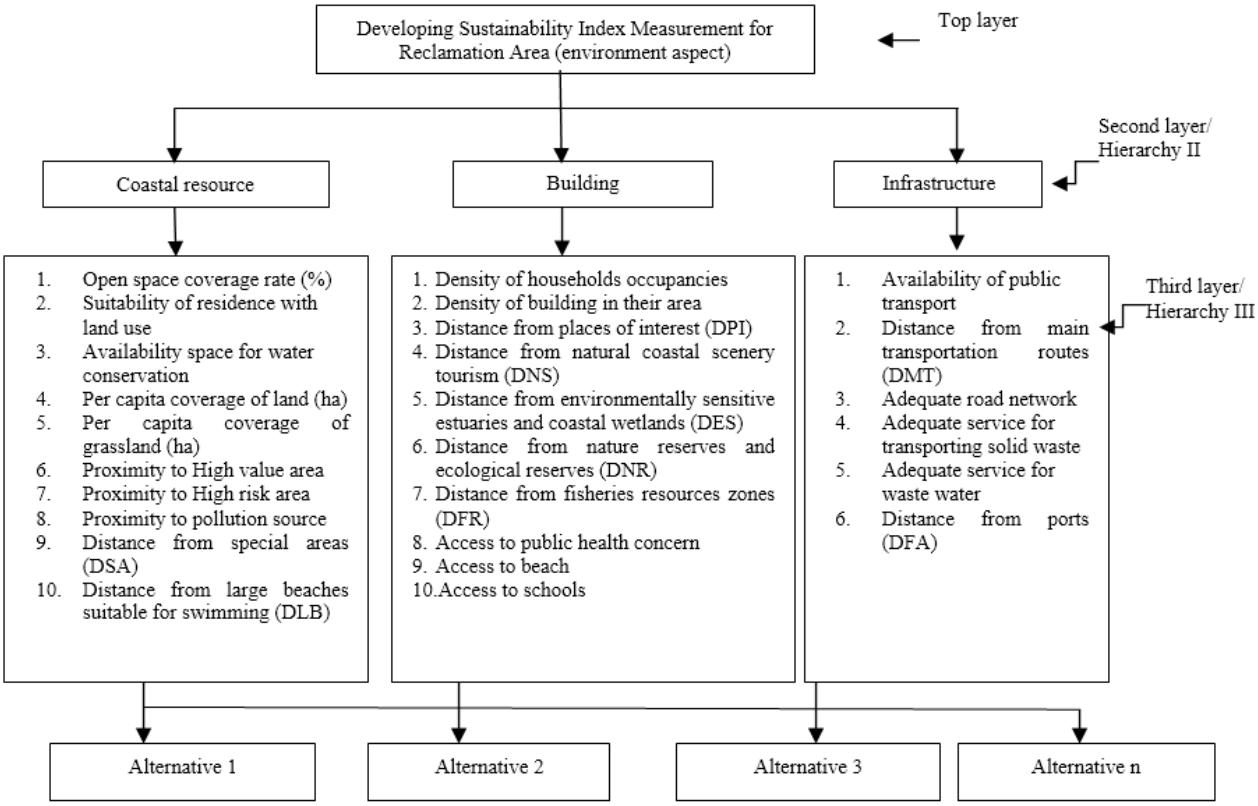

Figure 2: Structure of Analytic Hierarchy Process (AHP) [5]

Table 1: Indicator and Indices in reclamation sustainability index

Category	Indicator	Sustainability Indices		
		Good	**poor**	**bad**
Coastal resource	Open space coverage rate (%)	>30 % of the area:	10–30 % of the area:	0–10% of the area:
	Availability Space for water conservation	available:	. less available	no available
	Per capita coverage of land (ha)	Ha	Ha	Ha
Building	Distance from environmentally sensitive estuaries and coastal wetlands (DES)	>500m away from DES :	1–500m away from DES	Within DES
	Distance from nature reserves and ecological reserves (DNR)	>500m away from DNR:	1–500m away from DNR	Within DNR
	The Density of building in their area	Suitable:	less Suitable	not Suitable
Infrastructure	Adequate road network	available:	less available	no available
	Availability of public transport	available	less available	no available
	Distance from main transportation routes (DMT)	100-200 away from DMT	200–500m away from DMT	>500m away from DMT

Source: the result of analysis, 2016

RESULTS AND DISCUSSION

The result of the paper consist of three parts of paper, i.e. explanation of the process of the developing tools for assessing the sustainability of the reclamation using RSI, the process of the data organised by GIS and explanation on the result of the assessment by GIS.

A. Developing Tools of Assessment the Reclamation

Assessment of sustainable development is performed via applying different approaches and tools ranging from indicators to comprehensive models. The selection of the appropriate assessment method will depend on the subject of the assessment, the nature and complexity of the environmental impacts as well as time and scale aspects [13].

The determination of district based on purposive sampling, Penjaringan district in North of Jakarta region is chosen because it lies in the border of reclamation area and it will be affected directly from the impact of reclamation projects. This area is planning to be revitalized along with the reclamation plan [15].

B. Data Organization

To help understand and analyze such huge and complex array of data, a GIS database was created as a framework for organizing all of it [18], with the aim of gaining a clearer view of the Jakarta Reclamation Area, that explained as follows:

1) Coastal Resource

Simple overall polygons of all the land use patterns in Jakarta reclamation area were, used for land patch division, for example green open space, availability space for water conservation, and per capita coverage of land (ha). Source of data is Detail Spatial Planning of Jakarta Reclamation Area from Jakarta Development Board and Ministry of Public Work and Public Housing.

2) Building

GIS analysis of the map of Jakarta reclamation area, was used for counting the distance and the density of area, for example distance from environmentally sensitive estuaries and coastal wetlands (DES), distance from nature reserves and ecological reserves (DNR), the density of building in their area.

Source of data is Detail spatial Planning of Jakarta Reclamation Area from Jakarta Development Board and Ministry of Public Work and Public Housing.

3) Infrastructure

Simple continuous single lines of the transportation infrastructure in Jakarta reclamation area, were used for counting the adequate of infrastructure, for example adequate road network, availability of public transport with weights and distance from main transportation routes (DMT).

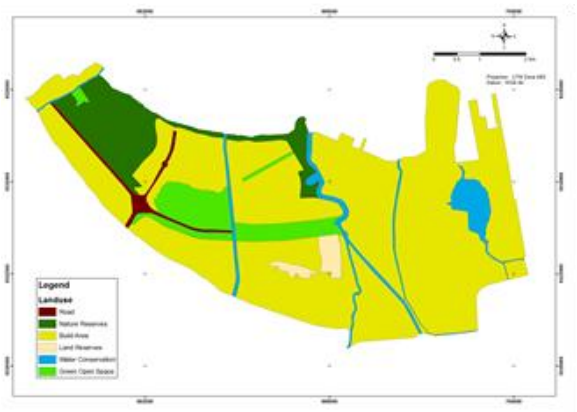

Figure 3: Map of Land Use Pattern of Coastal Resources (Source: Result of Analysis)

Source of data is road network map from Detail Spatial Planning of Jakarta Reclamation Area from Jakarta Development Board and Ministry of Public Work and Public Housing.

C. Assessing of Sustainable Development of Reclamation

From the analysis of GIS the results of condition of reclamation area which consists of three indicators have been found out. They are coastal resources indicators, building indicators and infrastructure indicators that will be explained successively in the following.

1) Coastal Resources Index

The indicator of coastal resources has shown that the reclamation area from green coverage index accounts only for 7.216%. It consist of park, green belt and field as wide as 262.57 ha, as shown in Fig 3. It means that the area is not sustainable because it less than 30% as defined by law on spatial planning which assigns roughly 30% of the area.

The water conservation is about 184.91 ha, or about 5.082% and from ground confirmation it is shown that the area is still sustainable, which means the development of reclamation is still sustainable, as shown in the table 2. The comparative land use shown in Fig 4, that dominated by build area.

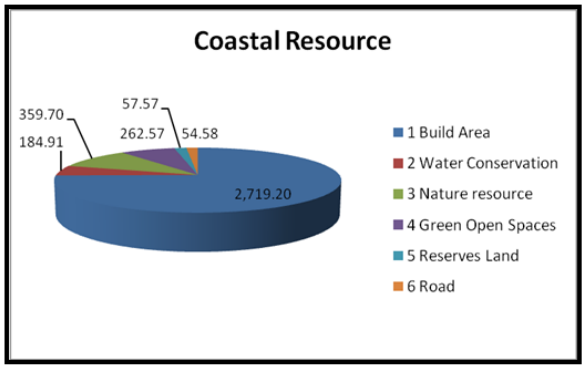

Figure 4: Percentage of Land Use Pattern of Coastal Resources

In this area there is the area of the watershed, a region of swamps and lakes that serve as flood control. Water conservation area is about 5.082% or 184.91Ha. But per capita land coverage can not be count because there is no secondary data or primary data can be found. It can be said that the reclamation area from coastal resource point of view is less sustainable as shown in fig 4.

Table 2: The Result of Coastal Resource

No.	Land Use	Area (ha)	Percentage (%)
1	Build Area	2,719.20	74.733
2	Water Conservation	184.91	5.082
3	Nature resource	359.70	9.886
4	Green Open Spaces	262.57	7.216
5	Reserves Land	57.57	1.582
6	Road	54.58	1.500
Total		3,638.54	100.000

2) Building index

From the GIS analysis, it has found out that for indicator of coastal resources, the building density is accounts for about 74.733% of the reclamation area, which means that the development of reclamation is less sustainable. Spatial utilization shift promotes intensive land use conversion. This phenomenon expands to morphological changes at the fringe area, causing complex spatial expression and making framework of dominance over reproduction of space happen [9].

According to the previous literature it said that the reclamation is less sustainable if the estuaries and the nature reserves are in the reclamation area. From GIS analysis it was found that the Jakarta reclamation area's estuary area is in the reclamation area so it can be said that it is not sustainable. In the same way, nature reserves are in the reclamation area so it is not sustainable reclamation development. The result of the GIS is analysis shown in the table 3 and Fig 5 and Fig 6.

Table 3: The Result of Building Index

No	Item	Variable	Value
1	Building Density	Percentage	74.733
2	Estuaries	Metre	0.000
3	Nature reserves	Metre	0.000

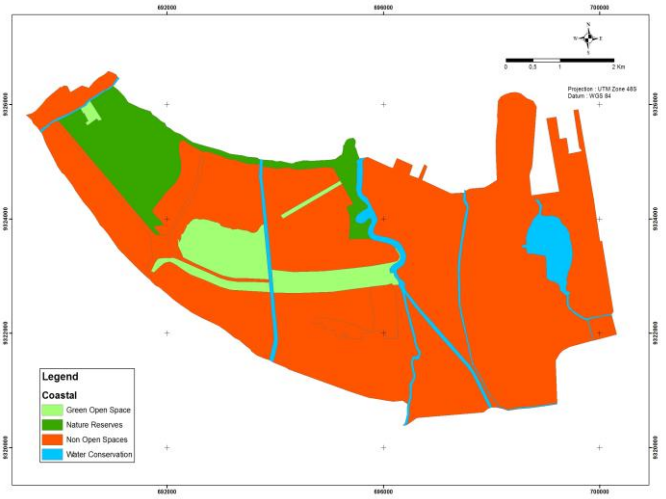

Figure 5: Map of Building Index
(Source : Result of Analysis)

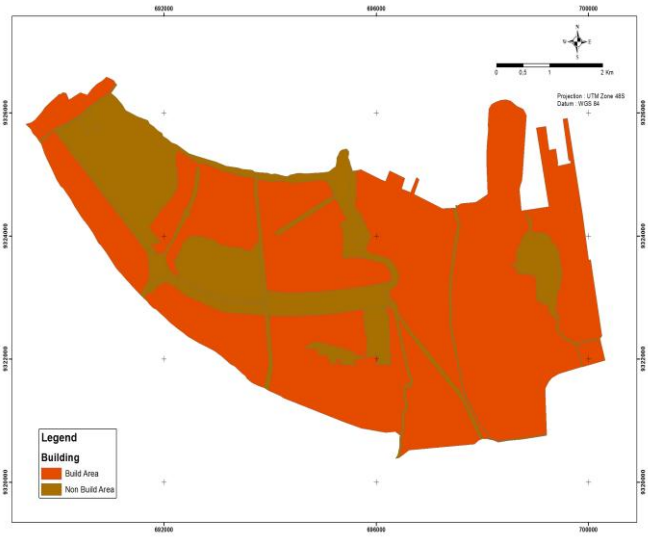

Figure 6: Map of Building Coverage
(Source : Result of Analysis)

3) Infrastructure index

From the analysis of GIS has found out that indicator of infrastructure index that has road network indicator is available it means sustainable. The Jakarta reclamation Area has sufficient public transport it means sustainable and the main transport about 1.100 metres from reclamation area, according to the literature if more than 500 metres it bad sustainable, which means the development of reclamation is less sustainable, as shown Fig. 7.

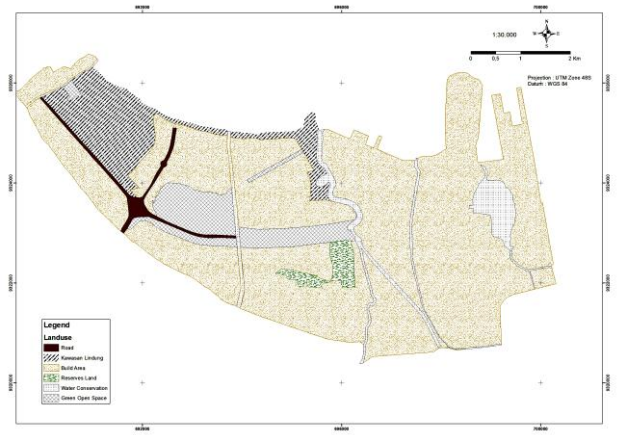

Figure 7: Map of Infrastructure Index
(Source : Result of Analysis)

The Result Stages of Sustainability Status

The status of the reclamation area can be said to be sustainable or not, starting with classifying categories and indicators based on weighted results with the value of an indicator condition. Assessment of the indicator is then done by assigning a value to the classification of the condition of each indicator. The assessment is: a value of 1 if the existing indicators fall into bad classification; Value 2 if the indicator included in the classification is less sustainable; And a value of 3 if the indicator is included in either classification (Apriyanto, 2015 #5122).

The formulation of the sustainability index is based on the highest total value (good) and the lowest (bad) value that may be achieved from the multiplication between the scores (data of the reclamation area of Jakarta) and the weighting. The highest possible value is 3, while the lowest value is 1. Furthermore, using the interval class calculated based on the range of the highest and lowest values, and then the sustainability status of a reclamation area is presented in Table 2.

The final value of this calculation is a composite index of 3 (three) categories of sustainable development (coastal resources, buildings and infrastructure) derived from one of the pillars of sustainable development i.e. from the physical side of the environment.

Table 4: Sustainability Indices

INDICATOR	CRITERIA TOTAL VALUE
SUSTAINABLE	TOTAL VALUE 2.35 - 3.00, ONE VALUE INDICATOR IS NOT LESS THAN 0.75
POOR	TOTAL VALUE 1.67 – 2.34
BAD	TOTAL VALUE 1.00 – 1.66

Source : (Apriyanto, 2015 #5122)

Based on the calculation weight of the sustainability on table 5 of North coast Jakarta Reclamation, it is found that the area is at a poor sustainable stage with an accumulated value of 1.73. According to the table 4 sustainability indices, the value of 1.73 is poor sustainable, in the range of 1.67-2.34.

Table 5: Rating Result of North Coast Jakarta Reclamation

Category	Indicator	Data of Jakarta City Reclamation Area	Classification value	Weight	Weight of index	Value of index
Coastal resource	Open space coverage rate (%)	7.2 %,	1	0.25	0.12	0.12
	Availability Space for water conservation	5.08%	2	0.17	0.08	0.17
	Per capita coverage of land (ha)	-	1	0.16	0.08	0.08
Building	Distance from environmentally sensitive estuaries and coastal wetlands (DES)	The location in environmentally sensitive estuaries and coastal wetlands	1	0.29	0.14	0.14
	Distance from nature reserves and ecological reserves (DNR)	The location in nature reserves and ecological reserves	1	0.22	0.11	0.11
	The Density of building in their area	74.73%	1	0.12	0.06	0.06
Infrastructure	Adequate road network	Adequate	3	0.35	0.17	0.51
	Availability of public transport	Available	3	0.31	0.15	0.46
	Distance from main transportation routes (DMT)	1.100 meter	1	0.16	0.08	0.08
				2.03	**1.00**	**1.73**

Source: result of analysis 2017

CONCLUSIONS

This paper has explored the applications of GIS in assessing the sustainability of a coastal reclamation area with emphasis on the environmental impacts in the Jakarta Reclamation Area of Indonesia. The paper presented another overview of the issues in the literature that has been found from the previous paper, i.e. a set of index of sustainability so-called Reclamation Sustainability Index (RSI), with three major physical environmental factors associated with the coastal resource, building and infrastructure measures. Not with standing previous initiatives paper, there has not been any major effort in the literature to undertake a GIS-based assessment of the sustainability of the coastal reclamation zone environments in the study area. In spite of concerted efforts and initiatives to address the problems, the results reveal that the study area experienced some significant changes in its coastal environments. These changes are attributed to environmental variables especially in tree indicators that are coastal resource, building and infrastructure factors.

Based on the calculation weight of the sustainability on table 5 of North coast Jakarta Reclamation, it is found that the area is at a poor sustainable stage with an accumulated value of 1.73. According to the table 4 sustainability indices, the value of 1.73 is poor sustainable, in the range of 1.67-2.34.

The results points are the decline of the green open space, and water catchment area. According to the previous literature it said that the reclamation is less sustainable if the estuaries and the nature reserves are in the reclamation area. So it can be said that the reclamation area of North Jakarta is less sustainable because the estuaries and the nature reserves are in the area.

On the other hand, per capita land coverage cannot be counted because there is no standard for it. The other interesting findings touched on the density of the reclamation area are potentials for a high density of building and the implications will have impact on the infrastructure demand. This will not only threaten the carrying capacity of an already fragile ecosystem, but also it poses enormous challenges for environmental and resource managers, and policy makers in the region if not confronted with urgency. The practical use involving GIS tool for the assessment of sustainability reclamation environmental change provides some interesting results for coastal resources management in the Jakarta reclamation area.

Furthermore, the paper serves as an essential tool for the design of geo-spatial decision support systems for coastal resource managers especially in the assessment of environmental impacts of reclamation development.

Theoretically the results of the research are expected to provide a novelty approach for the science of reclamation development that is creating formulation of sustainability index in reclamation area. Practically, the results of the study are expected to provide the tools of decision-making to assist the Government for development on the reclamation area in the coastal area in a sustainable way.

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