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Service Index Indicator of Polder System with Retention Pond using PCA Method

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***Abstract:** Indonesia as an archipelago country with 2nd longest coastal line in the world mostly has routine disaster such as flood. Jakarta as capital and economic center of Indonesia has flooding problem every year. To minimalize the impact, the government of DKI Jakarta already constructed 36 polder systems since 1973. In the future there are 11 polders planned to construct. Those 36 built up polders need maintenance to keep its function. Budgeting system of polder's maintenance cost not yet available, so to allocating budget for polder's maintenance based on previous amount and it found ineffective. This research analyzes indicators that can be used for indexing the service of polders as an initial research. As an object of this research, 8 polders in DKI Jakarta are chosen, they are Polder Grogol, Polder Teluk Gong, Polder Melati, Polder West Setiabudi, Polder South Sunter, Polder Tomang, Polder North Sunter, and Polder Pulomas. Probably indicator affecting polder's capacity analyze using Principal Component Analysis (PCA) and resulted there are 24 indicators that can be used for analyzing polder system service level. Those indicators are separated into 2 aspects, technical and non-technical aspects.*

***Keywords**: polder, indicator, service index, retention pond*

I. INTRODUCTION

Human activities give many impacts on the ecosystems that have long been recognized [1]. However, human activities have been mostly documented as one of the urgent and simultaneous changes of driving forces in natural environments [2]. In further, the availability of ecosystem goods and services [3], the spatial pattern of a landscape [4][5], and the increase vulnerability of regional biomes and human well-being to the climate change [6]. The problems of flooding are more critical to change in climate in general and rainfall pattern/intensity particularly [7].

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During the monsoon months that are from June to September, all these kinds of rivers are in spate with bank-full discharges and it causes the flooding and inundation in several parts [1][8].

Flood is one of threatening disaster that regularly happened in DKI Jakarta besides another complex disaster problems (BPBD 2017). DKI Jakarta as a coastal area has relatively flat topography with average height below sea level that causes floods (BPBD, 2017). Increasing number of population, activities, and changing land use also causes flood in DKI Jakarta. In downstream area, such as DKI Jakarta, inundated area can found easily in rain season. In order to minimalize the number of inundated area polder, a system that pump out the water in low areas and drain these low areas, is recommended solution {BPBD, 2010). In another research Zhao, *et al* [9] concluded that polder's system can reduce peak flood in right handling. To optimize reducing flood impact, the probably impact of flood must be analyzed, including social economic analysis in order to planning water bodies [10]. To reach service polder target's, risk management and regional management are really needed [11]. Volker [12] defined polder as reclamation area with high water level that isolated from hydrological regime around it, it makes water level can be controlled. Meanwhile, Segeren [12] defines polder as a land with permanent or periodical water level, which makes it separated from hydrological regime around it so water level can be controlled. Common definition used was stated by the International Commission on Irrigation and Drainage (ICID) in 1996, which defined polder as the flood control technology completed by physical equipment, such as drainage system, retention pond, and water gate and pump that should be maintained as inseparable and integrated water resources management. Al Falah [13] defines polder as a handling of drainage system which makes its catchment area isolated from water overflow outside the area and control the flood water level in the system based on a plan. From those definitions, Zulfan [14] concludes that the objects of polder system are the area with following characteristic: 1) isolated as one hydrological system; 2) water level and groundwater can be controlled; and 3) inundated area in natural condition. Potential polder areas were located in swamp area. These low areas mostly formed as a basin where the drainage water should be collected to a storage pond and then pumped into the river. Meanwhile, Water Resources Agency (2018) defines polder as a drainage area, which is bordered by dike or surface higher than the area and some of them have storage pond and pump as the specific characteristic. The storage is used to collect water from drainage system before it released to floodway, river, or sea using pumps.

By polder system, flooding area bordered clearly, so water level, debit, and water volumes that will release can be controlled. Below is the picture of typical of polder system. Fig. 1 presents the typical of polder system

Fig. 1 Typical of Polder System
Source: Public Works Minister Regulation No. 12 year 2014, First Attachment

The Government of DKI Jakarta Province has built polders as effort to preventing floods damage besides some regular maintenance such as canals normalization (dredging), flood and rob embankment, retention pond, and drainage system revitalization (Public works Agency of DKI Jakarta, 2012). Currently, in some cases the polder service could not reach the designed service target (Water Resources Agency of DKI Jakarta, 2018). During 2018, based on the data from Water Resources Agency of DKI Jakarta, there were 70 inundations areas happened inside the polder system with 10 - 50 cm in height and 30 minutes to 1 hour for duration of flood. These may occur due to ineffectiveness of the maintenance of the polders which are not based on the service of each polder. There are no available guidelines to determine the service level of the polders, result in not proper budget allocation for revitalizing polders and not planned based on priority scale. In order to standardize the criteria of polder's condition, the Model of Polder System Service Index which collaborate technical aspects and non-technical aspects for prioritize polder maintenance are urgently needed. Either technical or non-technical aspects are integrated to support water resources management in future [11]. Technical aspects could be used to see the function of polders, meanwhile non-technical aspects, such as organizational, budgeting, economic aspect, social and legal aspects could be used to see the polders service [15] also the participation of stakeholders and the community lives in the polders [16].

Main purpose of this research is to indicate which factors that affecting the polder's capability in function and services.
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By knowing the polder's service capability, Water Resources Agency of DKI Jakarta can make decision and take action easily in order to maintain and optimize polder's function as it should be. As a location of study, DKI Jakarta Province was chosen because as a capital of Indonesia, this city has a lot of problems due to water management, including access to clean water and flood mitigation during rainy weather. The Government of DKI Jakarta Province has built polders as effort to preventing floods damage. Totally, there were 36 polders built in and developed. Management of those polders are divided in 3 regions, they are western region, central region and eastern region. In this research eight polders used as an object which has a pond inside the polder systems. Those polders are Polder Grogol, Polder Teluk Gong and Polder Tomang in West region, Polder West Setiabudi and Polder Melati in Central Region, Polder Pulomas, Polder North Sunter and Polder South Sunter in East Region.

II. MATERIALS AND METHODS

A. Logical Framework

This research uses the previous research indicators as a secondary data, compiled with experience and survey for primary data, will decide indicators that can be used for analyze polder's service index in further research. From previous research and experience, indicators that mostly used for indexing service polder is presented as in the Table- I

Table- I. The indicators for indexing the service polder

No.	Aspects	Variables	Indicators	Definition
1	Technical	Flow pattern (T1)	Time of concentration (t_{1a})	Faster concentration time causes lower service of polder
			land cover (t_{1b})	Increased built-up area causing changes in time concentration become faster than before
		Condition and capacity of structure and equipment in polder (T_2)	Capacity of polders in (t_{2a})	If the pond has no optimal capacity, the pond will not be able to accommodate the volume of water from the catchment area of the polder. This condition will cause inundation in polder area that lower polder service
			Condition of sluice gate (t_{2b})	In good condition, sluice gate can be easily to operate, so while water in sea or river higher than water level in the pond, back water that caused inundated in polder area can be prevented
			Condition of pump (t_{2c})	If condition of the pump is not in a good condition, it will reduce the speed of pump capacity to move the water, and causes inundation in polder area during heavy rain
			Age of pump (t_{2d})	Longer age of pump with low maintenance can causes delaying time of pumping, then it causes inundation and decreasing polder service
			Condition of Trash-rack (t_{2e})	Condition of trash-rack affects optimization of the performance of trash rack to filter waste in the polder pond/ reservoir.
			Condition of Generator set (t_{2f})	Condition of the generator set will affect the performance of the pump when the electricity goes out
			Rate of land use change (t_{2g})	The rate of land use change that is increasing every year will affect the speed of water seeping into the soil, this condition causes inundation
		Inundation (T_3)	Inundation area (t_{3a})	The wider the inundation indicates the decreasing of polder service.
			Inundation depth (t_{3b})	The higher the inundation indicates the decreasing of polder service.
			Inundation duration (t_{3c})	The longer the inundation indicates the decreasing of polder service.
			Frequency of inundation occurs (t_{3d})	More frequent inundates occur indicate that there are components in the polder that are not working optimally
		Technical economics (T_4)	Operating cost (t_{4a})	allocation of operating costs, which are less than the allocation needed, will affect the decline in the performance of the components contained in a polder
			Maintenance cost (t_{4b})	allocation of maintenance costs, which are less than the allocation needed, will affect the decline in the performance of the components contained in a polder

No.	Aspects	Variables	Indicators	Definition
			Age of the polders (t_{4c})	if it is not balanced with the needed operational and maintenance costs, the function of the polder that has been built for a long time tends to decrease
			Increase value of polder assets (t_{4d})	additional asset values in a polder system, such as adding pumps, adding garbage filters, or adding sluice gates, occurs because the existing polder system is not optimal in meeting established service targets
2	Non-technical	Institutional (NT_1)	Organization Type and Structure (nt_{1a})	The organization is a tool for implementing management. Success or failure of a management depends on the type, structure and management of the organization.
			Decision making (nt_{1b})	A prolonged decision-making process will cause delays in handling a polder and causes inundation
			Human Resources (nt_{1c})	suitability of the number and ability of the operators with the needs is closely related to the assessment of the services of a polder
			Supervisory Agency (nt_{1d})	The presence of a supervisory body can help polder managers to monitor and evaluate the performance of the manager in managing the polder every year, then will guide the polder manager to maintain the polder for optimal result
			Standard Operation Procedure (SOP) (nt_{1e})	Standard Operation Procedure (SOP) provides guidance for polder managers in carrying out the operation and maintenance of the polder
			Master Plan (nt_{1f})	Using polder master plan, polder managers can review the capabilities of a polder
		Role Management (NT_2)	Community Forums (nt_{2a})	Participation of the community in the operation and maintenance can help maintain and improve the service of the polder system
			Public and private participation (nt_{2b})	Participation of the private sector in the operation and maintenance can help maintain and improve the service of the polder system
		Law and Regulation (NT_3)	Monitoring of laws and regulations (nt_{3a})	By monitoring of laws and regulations, everything related to the polder management efforts can be carried out properly, so the polder service is maintained
			Law enforcement (nt_{3b})	Law enforcement efforts will minimize the occurrence of offenses committed by the community that can disrupt the sustainability and function of the polder, so that the polder service is maintained
			Reward to community (nt_{3c})	Reward for the community will increase the spirit of the community to participate in the management of the polder
		Socio-cultural and economic (NT_4)	Education level (nt_{4a})	The higher level of education from the community around the polder, the community awareness will be higher in managing the polder

No.	Aspects	Variables	Indicators	Definition
			Income level (nt_{4b})	The higher level of income of the community lives in polder area, the community awareness to contribute to manage the polder will be even higher
			Economic activity near polder (nt_{4c})	More economic activities carried out in the polder area, the more problems will arise, such as garbage problems, illegal houses and environmental pollution which will affect the sustainability of polder function
		Flood Losses (NT_5)	Flood losses (nt_{5a})	A good polder system service will minimize losses due to inundation in an area, which in turn will provide feedback on the performance of the polder system itself

Those indicators are arranged in questionnaire and distributed to sub-district offices and village offices surrounding polders area with total 160 samples. Based on those questionnaires, each indicator from each sample is scored and analyzed using Principal Component Analysis (PCA).

Principal Component Analysis (PCA) is a multivariate statistical technique that can find hidden data characteristics. It can be used to reduce the dimensions or size of a data without significantly reducing the characteristics of the data. This method can transform origin variables that are correlated into new variables that are not correlated with each other by reducing a number of these variables so that they have smaller dimensions but can explain most of the diversity of the original variables.

III. RESULTS AND DISCUSSION

Questionnaire that consist those indicators were distributed and analyzed in 8 chosen polders using scoring method. Number of sample for analyze is 160 sample. For technical aspect, result of investigation compiled with secondary data. To reduce those variable (technical and non-technical) based on its correlation used PCA. KMO value as seen on table 3 founds 0,710 it means there's enough sample for service polder index in this research. Number of Berlet Test of Sphericity is 408,216 at significant of 0,000. It means that in this research there is the correlation between each variable. Table- II presents the measure of sampling

Table- II. KMO – Measure of Sampling

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.710
Bartlett's Test of Sphericity	Approx. Chi-Square	408.216
	Df	78
	Sig.	.000

Table- III presents the result of PCA

Table- III. Result of PCA Analysis

Rotated Component Matrix[a]

	Component							
	1	2	3	4	5	6	7	8
NT1a		,572	,227	,106	,134		-,353	,436
NT1b	-,287	,613	,220	,240	,141		-,208	,266
NT1c	,105	,504	,228	,203		-,154	-,315	
NT1d	-,289	,589	,299	,129				
NT1e		,561	,116	,116	,168			,265
NT1f		,470			-,391	,192		-,409
NT2b	,163	-,320	-,355	,204	-,300	,237	-,440	,181
NT3a		,170	,182	,367	,173	,155	-,453	-,160
NT3b		,373	-,241	,342	,360			-,428
NT3c	,252	,389	-,468	,277	-,238	,308	,147	
NT4a	-,366			-,387	,268	-,114		

Rotated Component Matrix[a]

	Component							
	1	2	3	4	5	6	7	8
NT4b	-,395	-,234	-,240	-,531	-,311	-,117		
NT4c	,432	-,260	,485	-,406		-,242		-,104
NT5a	-,256		,241		-,381	-,245	,533	,230
T1a	,166		-,297	-,701	-,483	-,310	-,127	
T1b	,679	-,535		,159		,396		
T2a	,177		,913	-,171		-,158	,120	
T2b	-,885	-,303	-,307	-,121				
T2c	,294		-,329	-,378	,620	,205	,211	-,158
T2d	-,132	-,294		,848	,218		,206	
T2e	-,591	,654	-,189			-,325		
T2f	-,296			-,101	-,212	,837	-,188	,142
T2g	,679		-,488	-,260		-,236	-,136	,235
T3a	-,682	-,419	-,438		,222	,163	,230	
T3b	-,571	-,423	-,625	,103			,137	
T3c	,698	,532	,291			,205	,179	
T3d		,373	-,656	-,384	,357	-,291		,123
T4a	-,841	,354	-,142		,206	,206		
T4b	,619	,282	-,186	-,108	-,483	-,376	-,194	-,142
T4c	-,360	-,594	,381	,398	,276	-,213	,173	
T4d	-,868	,118		-,180	-,142			-,231

In this PCA analysis, all indicators and variables in technical aspect and non-technical aspect are compared to reduce or add another necessary variable used for service index polder analysis. From the result of PCA, loading number < 0,3 can be reduced from further analysis, and the rest of that can be used for further analysis. From 32 analyzed indicators, there are 8 indicators with loading number < 0,3. They are time of concentration (t_{1a}), sluice gate condition (t_{2b}), inundation area (t_{3a}), inundation depth (t_{3b}), community forums (nt_{2a}), public and private participation (nt_{2b}), reward to community (nt_{3c}), education level (nt_{4a}), and income level (nt_{4b}). For further purpose, analysis of those 9 indicators is not needed.

IV. CONCLUSION

To sum up, there are 23 indicators that can be used for analyzing polder system service level. Those indicators are separated into 2 aspects, technical and non-technical aspect, as shown in the Table- III and Table- Iv respectively .

Table- III. Technical Aspects Variable and Indicator for Assessment of Polder's Service

No	Variable	Indicator
1	Flowing Pattern (T_1)	Land cover (%) (t_{1b})
2	Structural Condition and Capacity (T_2)	Storage capacity (m^3) (t_{2a}) Pump condition (m^3/s) (t_{2c}) Pump's age (years) (t_{2d}) Trash-rack condition (% of broken) (t_{2e}) Generator set condition (% of broken) (t_{2f}) Speed of land-use changing (% per year) (t_{2g})
3	Inundated (T_3)	Average duration of inundated (hours) (t_{3c}) Frequent of inundated (times) (t_{3d})
4	Technical Economic (T_4)	Operation cost (rupiah) (t_{4a}) Maintenance cost (rupiah) (t_{4b}) Polder's age (t_{4c})

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		Increasing value of polder's assets (t_{4d})

Table- IV. Non-Technical Aspects Variable and Indicator for Assessment of Polder's Service

No	Variable	Indicator
1	Organization (NT_1)	Organization Type and Structure (nt_{1a}) Decision making (nt_{1b}) Human resources / operator (nt_{1c}) Supervisory Agency (nt_{1d}) Standard Operation Procedure (SOP) (nt_{1e}) Master Plan (nt_{1f})
3	Law and Regulation (NT_3)	Monitoring of laws and regulations (nt_{3a}) Law enforcement (nt_{3b})
4	Socio-cultural and economic (NT_4)	Economic activity near polder (nt_{4c})
5	Flood disadvantages (NT_5)	Inundation disadvantages (nt_{5a})

For further purposes, further research is needed to create a polder system service index model.

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