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Index Model of Polder System Service using General Reduced Gradient

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***Abstract:** Polders were one of the construction that built to minimize the impact of flood, because polders have pond to create a room for water as one of the method in flood risk management. Polders usually build in low land area where water could not flow by gravity with components inside of it, which are pond, pumps, water gate and trash racks. Many cities in Indonesia has already build polders to manage the flood in an area, such as DKI Jakarta, Semarang, Bandung, East Kalimantan and others. To maintain those polder's function, need an effort and government's consistency to regulate activity and maintenance cost of each polder. Guideline to find out the service index of those polder are not yet available. This guideline will become important to make prioritize of managing polders. This research analyze technical and non-technical indicators would give impacts to polder's function and formulate the service of polder system for assessment purposes. As points of this research, eight polders in DKI Jakarta which have complete components were chosen for modelling. The result of this research are technical component are mostly effected to polder system operating than non- technical component. Its proportion are 53% technical aspect and 47% non-technical aspect.*

***Keywords:** polder system, retention pond, service index, technical aspect, non-technical aspect*

I. INTRODUCTION

Each region has their own vulnerabilities, Jakarta as a capital of Indonesia endangered by flood that often happened[1], [2]. In fact, not only floods but DKI Jakarta and other big cities in Indonesia has complex disaster problems. So to lessen the flood detriment, as a rule was done by create space for the river, such as making bypasses to shorten the route of waterflow, and build polders[3].

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Government of DKI Jakarta has constructed polders to minimize flood's damage. In addition, regular maintenance such as normalization has been done. In some cases, polder systems cannot occupy the designated target of polder's service [4]. As written in database of flood incident in The Agency of Water Resources of DKI Jakarta, it found 70 inundation area within the polder system in 2018. The depth of the floods was approximately between 10 – 50 cm and it was occurred during 30 minutes to 1 hour. This incident happened probably because of inadequate polder's maintenance which was not matched to the level of each polder service. The polder's management haven't had guideline yet to find out polder's service level. It resulted there's no feasible budget allocation for restore polders which not based on priority rate. To standardize principle of polder's state, the Index Model of Polder System Service that combines technical and non-technical indicators will be important and urgently needed to arrange polder maintenance. Technical indicators used to rate the function of polders, while non-technical indicators, used to asses service of polders [5] as well the society participation and people related to polders[6].

Objective of this study to represent the most affecting factor for capacity of polder operation and services. Meanwhile, the benefits of this research are to facilitate the assessment of polder services. For next level, it can be used as reference by Government Agencies in Indonesia especially Water Resources Agencies to do so. By discover the capability of polder service, the Water Resources Agencies able to decide an effective decision for maintaining and optimizing the polders function and service.

This research located in DKI Jakarta. It was the right choice because Jakarta is the capital of Indonesia and it has many problems related to flood mitigation at rainy season. In DKI Jakarta, polder has been construction by the Agency as an effort to minimize damage from floods. DKI Jakarta had already build 36 polders. 11 polders among them have complete components, which are pond, pumps, water gates, trash racks and generator sets to support electricity. The Agency divide polder's management into 3 districts, western district, central district and eastern district. 8 polders among those 11 polders were chosen for modelling the service index of polder system, which are Polder South Sunter and Polder Kodamar in Eastern District, Polder West Setia Budi and Polder Melati in Central District, also Polder Tomang, Polder Teluk Gong and Polder Grogol in Western District.To manage the flood in DKI Jakarta, a concept was made in 1973, written in Masterplan of DKI Jakarta Drainage System.

In 2012 and previously, flood control was described based on distances of people from the flood by constructing the river rehabilitation, channel diversion, levee and other water infrastructure to control the flood. Then, in the Book of Flood Control System in DKI Jakarta Province [7], technology of flood control has been improved become more effective and efficient. It also explain the basis of flood control transformed into flood mitigation and how to decrease the flood loses. Basic concept of flood control in DKI Jakarta are:

1. The water from higher area (upstream) flows to the sea through the outer channel of Jakarta;
2. If the area has significant difference of land elevation and slope, the water could flow by gravity in area which have;
3. In downstream area, usually water could not flow by gravity because the slope was relatively flat, so the water pumped to the sea and using a polder system;
4. Maintenance of storage such as retention pond in upstream area should be done to reduce runoff to the downstream.

To reduce the effect of flood in DKI Jakarta, structural and non-structural efforts are seriously needed. Reforestation and construction of water storage in upstream area, normalizing river and channel by dredging, create new channel to accommodate the water, and built polders in downstream area could be efforts in structural method. Non-structural effort also needed in order to reduce flood effect, it can be done by developing mitigation system, such as making hazardous map, early warning system, role sharing and community awareness.

Polder interpreted as a reformed area by upper water level and bordered from hydrological regime over it, which allows to control the water level [8]. On other hand, polders define as an area with stable or periodic water level, which causes it detached from hydrological regime over it so water level can be controlled [9]. Polders also define as a drainage system handler that has an isolated catchment area and could controls the water levels of flood in a system plan basis[10]. Commonly, definition of polder used was a technology to control the flood which completed by structural components, such as system of drainage, retention or detention pond, sluice gate and pump that provided as integrated management of water resources [11].

From those interpellations, has been concluded by Zulfan that polder systems have the characteristic as: 1) solitary as one system of hydrological; 2) managed water level; and 3) inundated area handled to natural condition. Swamp are the most suitable area for polder system. The downstream areas usually formed as a watershed, so drained water from surrounding area are collected to a retention or detention pond then pumped leak out from the system into the channel or river and then drained to the sea [12].

Another definition by the Agency is Polder as a drainage area, which has levee or higher surface than the area as the boundary. Some of them have storage (either retention or detention pond) and pump with specific characteristics. Storage in polder system used to collect water from drainage system before it pumped out to channel, river, or sea. By polder system, flooding area bordered clearly, so water level, water flow, and volumes of water that will release can be conducted. Figure below show typical system of polder.

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

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II. MATERIAL AND METHODS

Previous studies were using PCA and PLS Method to point out the indicators used for modelling the index of polder's service. Those methods selected indicators which have strong interrelated among others. Indicators that less disclosed and have not been impacted on polder service might be deducted.

To decide beneficial indicators for modelling that index, the result of previous research used as primary data. Both indicators from the result of PLS and PCA compared to decide pointless indicators to be reduced. In PLS method, used indicators identify by outer loading number > 0.50, meanwhile for PCA method, used indicators identify by outer loading number > 0.30. The difference of used indicators from both methods, then would be selected explained each other by experience and observation.

After used indicator and variables were analysed, to get coefficient value of each technical and non-technical variables and indicators, iterated using solver analysis in Microsoft excel. Method that used in this research is GRG – Generalized Reduce Gradient Method. Iteration of coefficient value of each criteria used to obtain result of calculation using index value similar to real condition in sites with minimum error. As constrain input in excel are:

1. Index value of technical and non-technical less than 5
2. Total amount of coefficient index technical and non-technical is 1
3. Total amount of coefficient each criteria is 1

III. RESULT AND ANALYSIS

In advance, technical and non-technical aspect of indicators and variables analyzed using PCA. It resulted as variables used for service index polder analysis. From the result of PCA, indicators with loading number < 0.3 reduced for next step. Meanwhile from the result of PLS, indicators with very low correlation seen by it loading number < 0.5 also reduced. Table below shows the result of each indicators using PCA and PLS analysis.

Table- I. Result of each indicator using PCA and PLS Analysis

Code	Indicators	PCA		PLS	
t_{1a}	Time of concentration	-0.326	unqualified	0.166	unqualified
t_{1b}	Land coverage	0.897	qualified	0.679	qualified
t_{2a}	Storage capacity	0.152	unqualified	0.913	qualified
t_{2b}	Sluice gate condition	-0.771	unqualified	-0.121	unqualified
t_{2c}	Condition of pump	0.879	qualified	0.620	qualified
t_{2d}	Age of pump	0.634	qualified	0.848	qualified
t_{2e}	Trash rack condition	0.780	qualified	0.654	qualified
t_{2f}	Generator set condition	0.887	qualified	0.837	qualified
t_{2g}	Rate of changing land use	0.863	qualified	0.679	qualified
t_{3a}	Inundation area	0.151	unqualified	0.230	qualified
t_{3b}	Inundation depth	0.864	qualified	0.137	unqualified
t_{3c}	Inundation period	0.968	qualified	0.698	qualified
t_{3d}	Frequency of inundation	0.962	qualified	0.373	qualified
t_{4a}	Operating expenses	0.844	qualified	0.354	qualified
t_{4b}	Maintenance expenses	0.748	qualified	0.619	qualified
t_{4c}	Age of the polders	0.464	unqualified	0.398	qualified
t_{4d}	Increase value of polder assets	0.833	qualified	0.118	qualified
nt_{1a}	Type of organizational Structure	0.837	qualified	0.572	qualified
nt_{1b}	Decision making	0.849	qualified	0.613	qualified
nt_{1c}	Human resources / operator	0.573	qualified	0.504	qualified
nt_{1d}	Supervisory Agency	0.653	qualified	0.589	qualified
nt_{1e}	Standard Operation Procedure	0.537	qualified	0.561	qualified
nt_{1f}	Master Plan	0.598	qualified	0.470	qualified
nt_{2a}	Community Forums	0,237	unqualified	0.237	unqualified
nt_{2b}	Public and private participation	0,167	unqualified	0.367	unqualified
nt_{3a}	Monitoring of laws and regulations	0.711	qualified	0.373	qualified
nt_{3b}	Law enforcement	0.695	qualified	0.389	qualified
nt_{3c}	Appreciation	-0.050	qualified	0.268	qualified
nt_{4a}	Education level	-0.887	unqualified	-.,117	qualified
nt_{4b}	Income level	0.917	qualified	0.485	unqualified
nt_{4c}	Economic activity close to polder	0.655	qualified	0.533	qualified
nt_{5a}	Flood losses	1.00	qualified	0.572	qualified

As the show results in table above, there were divergence among PCA and PLS analysis result, specifically regarding capacity of storage (t_{2a}), inundation area (t_{3a}), depth of inundation occur (t_{3b}), age of the polders (t_{4c}), level of education (nt_{4a}), and income level (nt_{4b}). In order to formulate the service index of polder system as the next step of previous research, the following was the logical explanation as to whether the indicators should be kept or eliminated.

1. Polders capacity

   Capacity of storage in polder system assessed based on the proportion of storage capacity against the original or designated storage capacity. As observed at pointed location, decreasing of polder capacity causes by sediment impacted to pump performance and operational cost. While pump not in good condition, inundated occurred. Because its urgency, polder's capacity are needed as an indicators for service polder index.

2. Inundation area
Inundation area represent polder service. The wider inundation area represent decreasing function and service of polder. As observed, there is not relevancy between inundated area and pump condition in polder system. Inundated area regularly happened in Polder Tomang, meanwhile pump and polder system condition in Polder Tomang are in good condition. It happened because of terrain and topography in those area. Because it not really relevant to polder service index, inundation area is not needed.
3. Inundation height
Inundation height indicates polder service. The higher the inundation represent decreasing function and service of polder system. As observed, inundated area occurred regularly in Polder Grogol with high depth, it happened because of pump malfunction and polder system condition not functioning properly. As soon as the pump operated, height of inundated dropped drastically. Because it relevant to polder service index, height of inundation is needed.
4. Age of the polders
Polders age indicates service of polder system. If the needed of operational and maintenance cost are not balance, there a trend of decreasing function of polder that has been built for a long time ago. Based on observation in Polder Setiabudi Barat which built in 1980, its performances are good and can reduces inundated near polder area. Because irrelevancy to polder service index, age of polders is not needed.
5. Education level
Education level of community near the polder effected to awareness in managing polder. Higher level of education tend to more aware to their neighborhood. In fact, by observation education level are not impact to polder service index. In polder Sunter Utara, with mostly population have low education level, polder are in good condition. It because polder's operation system held by the Agency. Because of irrelevancy, education level is not needed.
6. Income level
The higher income level from the people near polder, their awareness will be higher in managing the polder. In fact, by observation income level little bit impact to polder service index. In polder Sunter Utara, with mostly population have low income level, polder guard are strict. It because population around Polder Sunter Utara in odd moments steal operator's assets. It disturbing focus of operator in polders. Because it found relevancy to polder service index, income level are needed.

Based on description and analysis above, used indicators for next step are shows in table below.

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Table- II. Technical Variables and Indicators for Polder Service Index Assessment

No	Variable	Indicator
1	Flowing Pattern (T_1)	Land coverage (in percentage) (t_{1b})
2	Structural Condition and Capacity (T_2)	Capacity of storage (m^3) (t_{2a})
		Pump condition (m^3/s) (t_{2c})
		Pump's age (in years) (t_{2d})
		Condition of trash-rack (in percentage of defectiveness) (t_{2e})
		Condition of generator set in percentage of defectiveness) (t_{2f})
		Speed of land-use alteration (percentage each year) (t_{2g})
3	Inundated (T_3)	Inundation height (in centimeter) (t_{3b})
		Average duration of inundated (minutes) (t_{3c})
		Frequency of inundated (times) (t_{3d})
4	Technical Economic (T_4)	Operation cost (in rupiah) (t_{4a})
		Maintenance cost (in rupiah) (t_{4b})
		Accretion number of polder's assets (t_{4d})

Table- III. Non-technical Variables and Indicators for Polder Service Index Assessment

No	Variable	Indicator
1	Organization (NT_1)	Type of organizational 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})
2	Law and Regulation (NT_3)	Monitoring of laws and regulations (nt_{3a})
		Law enforcement (nt_{3b})
3	Socio-cultural and economic (NT_4)	Income level (nt_{4b})
		Economic activity near polder (nt_{4c})
4	Flood disadvantages (NT_5)	Inundate disadvantages (nt_{5a})

Those indicators were continued to analyse and index number of each indicators as shown on figure and table below.

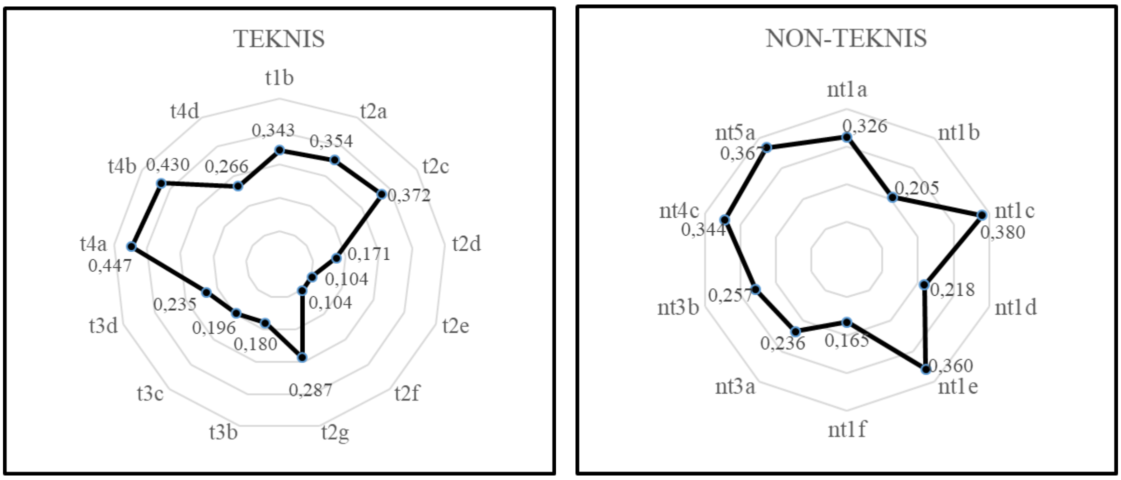

Fig. 3 Indicators of service index

Table-IV Indicators of service index

α = 0,53				β = 0,47			
a_1	0,200	a_3	0,156	b_1	0,504	b_3	0,164
a_{1b}	0,343	a_{3b}	0,180	b_{1a}	0,326	b_{3a}	0,236
a_2	0,282	a_{3c}	0,196	b_{1b}	0,205	b_{3b}	0,257
a_{2a}	0,354	a_{3d}	0,235	b_{1c}	0,380	b_4	0,164
a_{2c}	0,372	a_4	0,362	b_{1d}	0,218	b_{4c}	0,344
a_{2d}	0,171	a_{4a}	0,447	b_{1e}	0,360	b_5	0,168
a_{2e}	0,104	a_{4b}	0,430	b_{1f}	0,165	b_{5a}	0,367
a_{2f}	0,104	a_{4d}	0,266				
a_{2g}	0,287						

To calculate index number of polder's service (ILASPOD) could use this formula:

$ILP = 0.53\ IL_T + 0.47\ IL_{NT}$

As a result of this research technical aspect effected to polder service more than non-technical aspect. The proportion of technical aspect is 53% and non-technical aspect is 47%.

After modelling for Service Index of Polder System, to confirm this model suitable or not for using in other polders and also this model valid or not, continued assessment have been done, such as calibration, validation and verification. Calibration and Validation have been assessed with 8 polders which used for modelling and 2 polders which have not been used for modelling, which are Polder Setiabudi Timur and Rawa Badak. Verification have been assessed with 2 polders which have not been used for modelling, 1 polder in Jakarta city, which was Polder Sunter Selatan and 1 polder in Semarang city, which was Polder Banger. The result of calibration of 8 Polders as shown on table below

Table-V The result of calibration of 8 polders:

No	Name of Polder	Counted ILP	Observed ILP	Error (%)
1	Grogol	3.783	4	4.36%
2	Tomang	3.634	3	3.12%
3	Melati	3.304	3	0.04%
4	Setiabudi Barat	3.698	3	5.25%
5	Teluk Gong	3.359	3	5.44%
6	Sunter Utara	3.538	3	8.15%
7	Pulomas	3.851	4	3.10%
8	Kodamar	3.684	3	4.12%

From the table above, shown that the Model of ILASPOD has minor relative error or below 10%. The biggest relative error was 8.15% on Polder Sunter Utara and the smallest relative error was 0.04% on Polder Melati.

It means that the Model of ILASPOD was more suitable on Polder Melati than Polder Sunter Utara. In average, the relative error for 8 polders only 4.2%.The result of calibration of 2 Polders as shown on table below:

Table-VI The result of calibration of 2 Polders

No	Name of Polder	Counted ILP	Observed ILP	Error (%)
1	Setibudi Timur	4.118	4	2.35%
2	Rawa Badak	3.925	4	1.51%

From the table above, shown that the Model of ILASPOD has minor relative error or below 10%. So, the ILASPOD could use for calculate the index of polder service.

The result of validation as shown on table below
:

Table-VII The result of validation

No.	Name of Polder	Counted ILP	Observed ILP	Δ	Δ^2
1	Grogol	3.783	4	0.217	0.0471
2	Tomang	3.634	3	-0.634	0.4026
3	Melati	3.304	3	-0.302	0.0915
4	Setiabudi Barat	3.698	3	-0.698	0.4865
5	Teluk Gong	3.359	3	-0.359	0.1287
6	Sunter Utara	3.538	3	-0.538	0.2895
7	Pulomas	3.851	4	0.149	0.0223
8	Kodamar	3.684	3	-0.684	0.4680
	Total	28.849	26	-2.849	1.9362
				S^2 =	3.6061
				S =	0.1943
				T calculated =	2.176

From the table above, shown that the Model of ILASPOD valid for 8 polders which have been used for modelling.

The calculation of T = 2.176 bellowed than the T from distribution table, which was 2.365. The result of calibration of 2 Polders as shown on table below:

Table- VIII The result of calibration of 2 polders

No.	Name of Polder	Counted ILP	Observed ILP	Δ	Δ^2
1	Setiabudi Timur	4.118	4	-0.118	0.0138
2	Rawa Badak	3.925	4	0.075	0.0057
	Total	8.043	8	-0.042	0.0195
				S^2 =	4.0211
				S =	1.366
				T calculated =	0.437

From the table above, shown that the Model of ILASPOD valid for 2 polders which have not been used for modelling. The calculation of T = 0,437 bellowed than the T from distribution table, which was 4,303. The result of verification as shown on table below:

Table- IX The result of verification

No	Name of Polder	Counted ILP	Observed ILP	Error (%)
1	Sunter Selatan	4.142	4	2.83%
2	Banger	3.827	4	3.26%

From the table above, shown that the Model of ILASPOD has minor relative error or below 10%. So, the ILASPOD could use for calculate the index of polder service.

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IV. CONCLUSION

After the assessment of calibration, validation and verification, the result of Model of Service Index of Polder System or ILASPOD was satisfied or appropriate with the requirements. For future, the Model of Service Index of Polder System or ILASPOD with the formula of ILP = 0.53 IL_T + 0.47 IL_{NT} could use effectively to calculate and find out the service index of polder system.

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