Indicators of Index for Polder Services use Partial Least Square and Personal Component Analysis Method

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Abstract. Every year downstream area such DKI Jakarta city suffers from flood and it could disturb the economic life. High sea level, increasing number of rains, land subsidence, and conversion land use into built up area around upstream caused some damage flood in downstream area. To minimize the impact, the government of DKI Jakarta Province already constructed 36 polders system since 1973 and 11 polders planned to construct. Some of those polders have retention pond and other components to support the system. Those built up polders needs routine maintenance according to its budget in order to keep its function. Guideline to allocate budget for each polder’s yearly maintenance not yet available. This research analyses indicators that give impacts to polder’s services by using PLS and PCA Method, which based on 160 samples of questionnaire and result of site survey. As an object of this research, 8 polders in DKI Jakarta which have retention pond, pumps, water gate and trash rack are chosen. They are Polder Grogol, Polder Teluk Gong, Polder Melati, Polder West Setiabudi, Polder Pulomas, Polder Tomang, Polder North Sunter and Polder South Sunter. As a result, there are 23 indicators that affected in service index of polder system.

Keywords: polders, pond, catchment, indicators, system

1. Introduction

DKI Jakarta as capital of Indonesia has complex disaster problems. Based on the risk analysis in 2017 by Regional Disaster Mitigation Agency of DKI Jakarta Province, flood is one of the threatening disasters that regularly occur [1]. In order to minimize the flood damage, common practice was done by making a room for the river, such as canals or bypasses, and making polders [2]. DKI Jakarta Province Government has constructed many of polders as effort to prevent floods damage, in addition of some regular maintenances, which are canals normalization (dredging), flood and rob embankment, retention pond, and drainage system revitalization [3]. Nowadays, the polder service could not reach the designed target [4]. Based on the data from the Agency of Water Resources of DKI Jakarta, during 2018, there were 70 inundations areas happened inside the polder system with the height of flood between 10 and 50 cm and the duration of flood between 30 minutes and 1 hour. These inundations might be occurred because of ineffectiveness of the polder’s maintenance, which were not based on the level of polder’s services. DKI Jakarta Province not yet have guidelines to determine the service level of the polders, which result in improper allocation of the budget for revitalizing polders and not
planned according on the priority. The model of service index of polder systems is needed urgently in order to make the standard of polder’s condition criteria. This model should combine the technical aspects and non-technical aspects for prioritize polder maintenance, because both aspects would support the water resources management in future [5]. Technical aspects have connection with the function of polders, while organization, budgeting, economic, social and legal aspects as non-technical aspects could examine the polder services [6]. Besides that, the stakeholder’s participation and the community live in the polders [7].

Based on the literature review, there are no previous studies that took the topic of the model of service index of polder systems and integrated all indicators of technical and non-technical aspects. Therefore, the problem that occurred is how to formulate variables and indicators, both technical or non-technical, which are used to assess and analyse polder services. This research will include new indicators, they are frequency of flood occurrence and increase of assets.

The research’s main purpose is to indicate which factors are affecting the capability of polder function and services. The benefit of this research is to simplify assessment of polder services, which can then be used as a reference by the Water Resources Agency in Indonesia to do so. By knowing the capabilities of polder services, the Water Resources Agency can make Better decision and take action to maintain and optimize the intended functions of polders.

DKI Jakarta Province was chosen as a location of study, because DKI Jakarta as the metropolitan city has many problems in water management, such as the mitigation of floods in rainy season and the access to clean water in dry season. The Government of DKI Jakarta Province has built polders as effort to preventing floods damage. Totally, they already constructed and developed 36 polders. Management of those polders are divided in 3 regions, which are western region, central region and eastern region. For 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 Setia Budi and Polder Melati in Central Region, Polder Pulomas, Polder South Sunter and Polder North Sunter in East Region. Figure 1 above shown polder’s location in DKI Jakarta.

Figure 1. Location of Polder System in DKI Jakarta [3]
2. Material and Methods

The concept of flood control in DKI Jakarta was conceived in 1973, in DKI Jakarta Drainage Master Plan. Before 2012, flood control was defined as distancing people from floods by the construction of diversion channel, levees, river improvement and many other flood control structures. In the Book of Flood Control System of DKI Jakarta Province (2012), flood control technology has been increasing more effective and efficient. In that book, the principle of flood control was changed to flood mitigation and was focused on decreasing flood losses. The following are the basic concepts of flood control in DKI Jakarta:

1. In DKI Jakarta, water flows from upstream areas to the sea through floodway on the outer side of Jakarta;
2. In the area with enough slope and height, water flows by the gravity;
3. In the lower area, in Centre and North Jakarta, the polder system is used and water is pumped to the sea;
4. Retention ponds in upstream area must be maintained in order to store rainfall and reduce the water flow to the downstream areas.

In fact, to minimize flood impact in Jakarta, structural and non-structural efforts are needed. Some examples of structural efforts are by making water storage and reforestation in upstream areas, dredging, making floodway and polders in downstream area. Example of non-structural efforts are improving mitigation system, such as early warning system, community awareness, making hazard maps and sharing roles.

Volker [8] defined polder as reclamation area with high water level that isolated from hydrological regime around it, it makes water level can be controlled [8]. Meanwhile, Segeren [9] defines polder as a land with permanent or periodical water level, that it is separated from hydrological regime around it control water level [9]. 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, water gate and pump that should be maintained as inseparable and integrated water resources management. Al Falah [10] defines polder as a handling of drainage system which makes its catchment area isolated from water overflow outside the area and controls the water level of flood in the system based on a plan [10].

Zulfan [11] from those definitions above concludes the polder system has following characteristic: 1) isolated as one hydrological system; 2) water level and groundwater can be controlled; and 3) the polder area is inundated in natural condition. Basically, the swamp area is most potential for the polder areas [11]. 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 that polder area is a drainage area and bordered by dikes or surface higher than the areas, even some of them have storage pond and pumps as the specific characteristic [4]. The rain water in the drainage system collected in storage pond and then by using those pumps, it will be released to floodway, rivers, or sea. So, flooding area bordered clearly by polders, and thus water levels, discharges, and water volumes released could be controlled. Below is the picture of typical of polder system.

Previous studies using PCA and PLS method, have resulted in indicators that can be used for polder’s service index. The result of PCA and PLS can be interrelated between indicators. The indicators which did not related and impact for polder service, could be deducted. The indicators were not precisely between the two, table below presents the outer loading value of each indicator of polder service index based on previous studies.
Figure 2. Typical of Polder System [12]

Table 1. Outer Loading Number Indicators of Polder Service Index

| NO | Indicator                                      | Outer Loading |
|----|-----------------------------------------------|---------------|
|    |                                               | PLS | PCA |
| 1  | Time of concentration (t_{1a})                | -0.326 | 0.166 |
| 2  | Land cover (t_{1b})                           | 0.897 | 0.679 |
| 3  | Pond capacity (t_{2a})                        | 0.152 | 0.913 |
| 4  | Sluice gate condition (t_{2b})                | -0.771 | -0.121 |
| 5  | Pump condition (t_{2c})                       | 0.879 | 0.620 |
| 6  | Age of pump (t_{3d})                          | 0.634 | 0.848 |
| 7  | Trash-rack condition (t_{3e})                 | 0.780 | 0.654 |
| 8  | Generator set condition (t_{3f})              | 0.887 | 0.837 |
| 9  | Rate of land use change (t_{2g})              | 0.863 | 0.679 |
| 10 | Inundation area (t_{3a})                      | 0.151 | 0.230 |
| 11 | Inundation depth (t_{3b})                     | 0.864 | 0.137 |
| 12 | Inundation duration (t_{3c})                  | 0.968 | 0.698 |
| 13 | Frequency of inundation occurs (t_{3d})       | 0.962 | 0.373 |
| 14 | Operating cost (t_{4a})                       | 0.844 | 0.354 |
| 15 | Maintenance cost (t_{4b})                     | 0.748 | 0.619 |
| 16 | Age of the polders (t_{4c})                   | 0.464 | 0.398 |
| 17 | Increase value of polder assets (t_{4d})      | 0.833 | 0.318 |
| 18 | Type and structure of organization (nt_{1a})   | 0.837 | 0.572 |
| 19 | Decision making (nt_{1b})                     | 0.849 | 0.613 |
| 20 | Human resources / operator (nt_{1c})          | 0.573 | 0.504 |
| 21 | Supervisory agency (nt_{1d})                  | 0.653 | 0.589 |
| 22 | Standard Operation Procedure (SOP) (nt_{1e})   | 0.537 | 0.561 |
| 23 | Master Plan (nt_{1f})                         | 0.598 | 0.470 |
| 24 | Community forums (nt_{2a})                    | 0.145 | 0.237 |
| 25 | Participation of public and private sector (nt_{2b}) | 0.288 | 0.167 |
| 26 | Monitoring of laws and regulations (nt_{3a})   | 0.711 | 0.373 |
| 27 | Law enforcement (nt_{3b})                     | 0.917 | 0.389 |
| 28 | Community reward (nt_{3c})                    | 0.655 | 0.268 |
| 29 | Level of education (nt_{4a})                  | -0.887 | 0.117 |
| 30 | Level of income (nt_{4b})                     | 0.917 | 0.285 |
| 31 | Economic activity near polder (nt_{4c})       | 0.655 | 0.533 |
| 32 | Flood losses (nt_{5a})                        | 1.000 | 0.572 |
In this research, to determine useful indicators to analyze polder service index, the result of previous studies was used as the main data. Result from PLS and PCA Analysis were compared to determine which indicators were not useful and could be eliminated. For PLS analysis result, useful indicators are identified by outer loading number > 0.50, while for PCA analysis result useful indicators are identified by outer loading number > 0.30. The difference of selected indicators from PCA and PLS analysis explained each other by experience and observation.

3. Result and Discussion

From previous research, in PCA analysis, all indicators and variables of technical aspect and non-technical aspect compared to reduce or add another necessary variable used for polder service index analysis. From the result of PCA, variables with loading values < 0.3 can be removed from further analysis, and the rest can be used for further analysis. From 32 analyzed indicators, there were 9 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$_{2a}$), participation of public and private sector (nt$_{2b}$), community reward (nt$_{3c}$), level of education (nt$_{4a}$), and level of income (nt$_{4b}$). For further purpose, those 9 indicators would not be analyzed.

Based on PLS analysis, from 32 indicators distributed to 9 latent variables from prior observation and literature review analysis above, there were 9 indicators that have very low correlation to each other and to polder service index. This is represented by a loading value less than 0.5. They are time of concentration ($t_{1a}$), pond capacity ($t_{2a}$), sluice gate condition ($t_{2b}$), inundated area ($t_{3a}$), age of polder ($t_{4c}$), community forums (nt$_{2a}$), participation of public and private sector (nt$_{2b}$), community reward (nt$_{3c}$), and level of education(nt$_{4a}$). For further purpose, analysis of those 9 indicators would not be needed. Recapitulation of used indicators as seen on table below.

From the result presented in Table 2, there are differences between the result of PCA and PLS analysis, which are the pond capacity ($t_{2a}$), inundation depth ($t_{3b}$), age of polders ($t_{4c}$), and level of income (nt$_{4b}$). In order to model service index of polder system on the next step of this research, the following are the logic explanations as to whether those indicators should be kept or removed.

1. Capacity of pond ($t_{2a}$)
   The capacity of the retention pond designed in a certain volume. Assessment of the service level of polder system based on the percentage of the capacity of the retention pond against the initial capacity volume of the design. From observation, decreased capacity of ponds caused by sediments in turn causes increased pump performance and operational costs. If the pumps were not in good condition, inundation would occur in polder area. Because its urgency, this indicator should be kept as an indicator for polder service index.

2. Inundation depth ($t_{3b}$)
   Inundation depth indicates the service of polder system. Inundation occurs in surrounding polder area indicates the decreasing of polder service. From observation, area that regularly inundated caused by malfunction of pump in polder system. In polder Grogol, inundation regularly occurred, but after the pump operated normally, the height of inundated drastically dropped. Because it relevant to polder service index, inundation depth should be kept.

3. Age of polders
   Age of polders could indicate polder service. The function and the service of the polder that has been constructed for a long time tends to decrease. Based on observation of West Setiabudi Polder, which was constructed in 1980, it still performs well and could reduce inundation around polder area. Because it not quite relevant to polder service index, age of polders should be removed.

4. Level of income
   Higher level of income of the people who live around a polder should be contribute to awareness of the people in managing the polder. People who has high income should be expected to support the management of polders. Yet by observation, income level has no
significant impact to polder service index. In South Sunter and Melati polder, the people who lives around polder area mostly have high incomes. They live in large houses and apartments. Although some of them were chosen to be interviewed, they know nothing about the function of those polders. On the other hand, the people who live around North Sunter polder, have low incomes. They knew about the function of polder, but they did not care about those polders, and even removed steel components from the polders. Assigning a guard would be an extra effort to prevent unexpected activities from the people. Since it has no real relevance to polder service index, income level should not be removed.

Table 2. The Result of PLS and PCA Method for Service Index Indicators

| No | Indicator                                           | Qualify | PLS | PCA |
|----|----------------------------------------------------|---------|-----|-----|
| 1  | Time of concentration (t1a)                        | -       | -   | -   |
| 2  | Land cover (t1b)                                   | v       | v   | v   |
| 3  | Pond capacity (t2a)                                 | -       | -   | v   |
| 4  | Sluice gate condition (t2b)                        | -       | -   | v   |
| 5  | Pump condition (t2c)                                | v       | v   | v   |
| 6  | Age of pump (t2d)                                  | v       | v   | v   |
| 7  | Trash-rack condition (t2e)                         | v       | v   | v   |
| 8  | Generator set condition (t2f)                      | v       | v   | v   |
| 9  | Rate of land use change (t3a)                       | v       | v   | v   |
| 10 | Inundation area (t3a)                              | -       | -   | -   |
| 11 | Inundation depth (t3b)                             | v       | -   | v   |
| 12 | Inundation duration (t3c)                          | v       | v   | v   |
| 13 | Frequency of inundation occurs (t3d)               | v       | v   | v   |
| 14 | Operating cost (t4a)                               | v       | v   | v   |
| 15 | Maintenance cost (t4b)                             | v       | v   | v   |
| 16 | Age of the polders (t4c)                           | -       | -   | v   |
| 17 | Increase value of polder assets (t4d)              | v       | v   | v   |
| 18 | Type and structure of organization (nt1a)           | v       | v   | v   |
| 19 | Decision making (nt1b)                             | v       | v   | v   |
| 20 | Human resources / operator (nt1c)                  | v       | v   | v   |
| 21 | Supervisory agency (nt1d)                          | v       | v   | v   |
| 22 | Standard Operation Procedure (SOP) (nt1e)          | v       | v   | v   |
| 23 | Master Plan (nt1f)                                 | v       | v   | v   |
| 24 | Community forums (nt2a)                            | -       | -   | v   |
| 25 | Participation of public and private sector (nt2b)   | -       | -   | v   |
| 26 | Monitoring of laws and regulations (nt3a)          | v       | v   | v   |
| 27 | Law enforcement (nt3b)                             | v       | v   | v   |
| 28 | Community reward (nt3c)                            | -       | -   | v   |
| 29 | Level of education (nt4a)                          | -       | -   | v   |
| 30 | Level of income (nt4b)                             | v       | v   | v   |
| 31 | Economic activity near polder (nt4c)               | v       | v   | v   |
| 32 | Flood losses (nt5a)                                | v       | v   | v   |

As a result of this research, there were 23 indicators that will be used for analyzing polder system service level. Those indicators were separated into 2 aspects, technical and non-technical aspects. Respectively, table 3 and 4 below presented that the technical aspects was represented by 13 indicators and the non-technical aspects was represented by 10 indicators.
Table 3. Variables and Indicators of Technical Aspects

| No | Variable | Indicator |
|----|----------|----------|
| 1  | Flowing Pattern (T₁) | Land cover (%) (t₁b) |
| 2  | Structural Condition and Capacity (T₂) | Capacity of pond (m³) (t₂a), Condition of pump (m³/s) (t₂c), Age of pump (years) (t₂d), Trash-rack condition (% of broken) (t₂e), Generator set condition (% of broken) (t₂f), Rate of land-use changing (% per year) (t₂g) |
| 3  | Inundated (T₃) | Inundation depth (t₃b), Inundation duration (hours) (t₃c), Frequent of inundation (times/year) (t₃d) |
| 4  | Technical Economic (T₄) | Operation cost (rupiah) (t₄a), Maintenance cost (rupiah) (t₄b), Increasing value of polder’s assets (t₄d) |

Table 4. Variables and Indicators of Non-Technical Aspects

| No | Variable | Indicator |
|----|----------|----------|
| 1  | Organization (NT₁) | Type and Structure of Organization (nt₁a), Decision making (nt₁b), Human resources / operator (nt₁c), Supervisory Agency (nt₁d), Standard Operation Procedure (SOP) (nt₁e), Master Plan (nt₁f) |
| 2  | Law and Regulation (NT₃) | Monitoring of laws and regulations (nt₃a), Law enforcement (nt₃b) |
| 4  | Socio-cultural and economic (NT₄) | Economic activity near polder (nt₄a) |
| 5  | Flood disadvantages (NT₅) | Inundate disadvantages (nt₅a) |

4. Conclusion and Recommendation

In summary, out of 32 indicators included in questionnaire and analyzed using PCA, PLS, and self-adjustment based on experience, there are 9 indicators that do not greatly relate to service index of polder system, which are 4 indicators from technical aspects and 5 indicators from non-technical aspects. From PLS analysis there are 9 indicators that do not greatly relate to service index of polder system, which are time of concentration, pond capacity, sluice gate condition, inundation area, age of the polder, community forum, contribution of public and private sector, community reward and level of education. From PCA analysis, the indicators do not greatly relate to service index of polder system are time concentration, sluice gate condition, inundation area, inundation depth, community forum, contribution of public and private sector, community reward, level of education and level of income. These less related indicators were analyzed using experience and observation to keep the indicators are more related. This research results in 23 related indicators, which are percentage of land cover (t₁b), pond capacity (t₂a), pump condition (t₂c), age of pump (t₂d), trash rack condition (t₂e), generator set condition (t₂f), rate of land use changing (t₂g), inundation depth (t₃b), inundation duration (t₃c), frequent of inundation (t₃d), operation cost (t₄a), maintenance cost (t₄b), increasing value of polder’s assets (t₄d), type and structure of organization (nt₁a), decision making (nt₁b), human resources / operator (nt₁c), supervisory agency (nt₁d), Standard Operation Procedure (SOP) (nt₁e), master plan (nt₁f), monitoring of laws and regulations (nt₁a), law enforcement (nt₃b), economic activity near polder (nt₄a), and inundate...
disadvantages (nts). For further purposes, further research will be needed to create a polder system service index model.

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