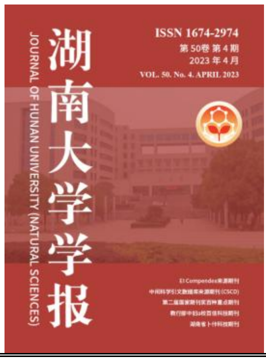

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Irrigation Performance Index Model (Case Study in IPDMIP)

Laode Muhamad Bakti[1]*, Pitojo Tri Juwono[2], Very Dermawan[2], Indradi Wijatmiko[3], Tommy Kurniawan[4], Amin Tohari[5]

[1] Doctoral Program at the Department of Civil Engineering, Faculty of Engineering, University of Brawijaya, Jl. MT Haryono No. 167, Malang, Indonesia

[2] Department of Water Resources, Faculty of Engineering, University of Brawijaya, Jl. MT Haryono No. 167, Malang, Indonesia

[3] Department of Civil Engineering, Faculty of Engineering, University of Brawijaya, Jl. MT Haryono No. 167, Malang, Indonesia

[4] PT Raya Konsult KSO, PT Ciriajasa Engineering Consultants, South Jakarta, Indonesia

[5] Faculty of Economics and Business, University of Nusantara PGRI Kediri, Indonesia

* Corresponding author: laodebakti@pu.go.id

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Abstract: Each irrigation area has its own unique characteristics, depending on its geographical location, topography, population, climate, soil, and others. Based on government regulation, since 2015, all irrigation schemes in Indonesia have to be measured with the irrigation system performance index (IKSI or Indeks Kinerja Sistem Irigasi) every year. Several studies have been conducted since that year, but the IKSI model has not been evaluated yet, especially for surface irrigation. An increasing value of IKSI indicates an increase in the quality of irrigation system services. Conversely, the decreasing value of IKSI means that the efficiency and effectiveness of irrigation system management need further review and improvement. Therefore, this research aims to develop a mathematical model of the irrigation performance index as an evaluation using six parameters that examine the quality of irrigation system management. The research locations are in 947 Central Government Authorized Irrigation Areas, which was chosen considering that the irrigation performance index model had not been evaluated. The methodology consists of a SmartPLS (partial least square) application to analyze and narrow down the variables in this study, the analysis using the GRG (generalized reduced gradient) method to calculate nonlinear equations. In the initial equation, two variables, 12 dimensions, 24 indicators were analyzed. After analyzing the results using PLS-SEM, three indicators were eliminated so that the composition of the new equation became two variables, 12 dimensions, and 21 indicators that were interrelated with one another. Furthermore, GRG analysis using Microsoft Excel solver showed changes in variable weights so that the new model equation for IKSI-Bakti was 0.744 x primary irrigation network + 0.256 x tertiary irrigation network, which applies to the irrigation area of the Central Authority, especially for surface irrigation.

Keywords: irrigation, partial least square, generalized reduced gradient, performance index.

灌溉性能指数模型（IPDMIP 案例研究）

摘要：每个灌区都有其独特的特点，这取决于其地理位置、地形、人口、气候、土壤等

。根据政府规定，自 2015 年以来，印度尼西亚的所有灌溉计划每年都必须使用灌溉系统绩效指数（IKSI 或灌溉系统性能指标）进行衡量。自那年以来进行了多项研究，但尚未对 IKSI 模型进行评估，尤其是对于地表灌溉。IKSI 值的增加表明灌溉系统服务质量的提高。相反，IKSI 值的下降意味着灌溉系统管理的效率和有效性需要进一步审查和改进。因此，本研究旨在开发一个灌溉绩效指标的数学模型，作为使用六个参数来评估灌溉系统管理质量的评估指标。研究地点位于 947 个中央政府授权灌区，选择这些灌区是考虑到尚未评估灌溉绩效指标模型。该方法包括一个智能求助（偏最小二乘）应用程序来分析和缩小本研究中的变量，该分析使用 GRG（广义约简梯度）方法计算非线性方程。在初始方程中，分析了 2 个变量、12 个维度、24 个指标。使用偏光扫描电镜对结果进行分析后，剔除 3 个指标，使新方程的构成成为 2 个变量、12 个维度、21 个相互关联的指标。此外，使用微软 Excel 求解器的 GRG 分析显示变量权重发生变化，因此 IKSI-巴克蒂的新模型方程为 0.744 x 初级灌溉网络 + 0.256 x 三级灌溉网络，适用于中央当局的灌区，特别是地表 灌溉。

关键词：灌溉、偏最小二乘法、广义约化梯度、性能指数。

1. Introduction

IKSI stands for irrigation system performance index, which shows the performance quality of the irrigation system. The irrigation system comprises water, infrastructure, institutions, human resources, and management. These five elements are inseparable and form an irrigation system. Irrigation management is one of the essential activities to achieve national food security. Irrigation systems are closely related to agricultural activities, especially to increase crop productivity.

Irrigation system development needs to be appropriately managed based on a community participation approach. It is necessary to pay attention to the role and aspirations of the community since they are the subject and object of irrigation management. The implementation of asset management activities and measurement of central authority of irrigation system performance is carried out based on Regulation of the Minister of Public Works and Housing No. 12/PRT/M/2015 concerning the exploitation and maintenance of irrigation schemes.

The IKSI assessment aims to periodically examine the condition of the irrigation system. All variables in the IKSI assessment are interrelated, which means that some problems in one part of the irrigation system will affect the overall IKSI value. Each irrigation area has unique characteristics different from those of other irrigation areas, influenced by geographical location, topography, population, climate, soil, and others. These problems can affect the productivity of crops, which can lead to nonoptimal results. One of the causes are the decline in the condition and the function of the physical infrastructure in the irrigation area [1, 2]. An increasing value of the irrigation system performance index (IKSI or Indeks Kinerja Sistem Irigasi) indicates an increase in the quality of irrigation system services. Conversely, the decreasing value of IKSI means that the efficiency and effectiveness of irrigation system management need further review and improvement. Therefore, this research aims to develop a mathematical model of the irrigation performance index as an evaluation of using six parameters that examine the quality of irrigation system management, namely irrigation infrastructure, planting productivity, supporting facilities, documentation, personnel, and water user association. In previous studies, the patterns/trends of IKSI was influenced by rehabilitation infrastructure activities; however, it turned out that rehabilitation was not a determinant factor of the increase in IKSI, which can be seen from the results of the IKSI survey after rehabilitation. Furthermore, although some rehabilitated irrigation areas experienced an increase in IKSI value, nearly half of them experienced a decrease in IKSI after construction. It shows that the other five IKSI parameters (planting productivity, supporting facilities, documentation, personnel, and water user association) also require the same attention to achieve excellent and sustainable irrigation performance [2, 3]. In other words, it is necessary to re-evaluate the percentage weight of the IKSI parameters for better depiction of irrigation performance. In this research, irrigation model development was carried out using PLS-SEM software.

2. Materials and Methods

2.1. Limitations of the Study

In this study, the authors have the following limitations:

1. The location chosen in this study is the irrigation area of the Central Authority on the main and tertiary irrigation networks. The research location was chosen by considering the lack of the irrigation performance index modeling using PLS-SEM.

2. Performance assessment of the primary irrigation system by the River Basin Organization (Balai Wilayah Sungai) is carried out based on the Regulation of the Minister of Public Works and Housing No. 12/PRT/M/2015 concerning the exploitation and maintenance of irrigation networks.

3. Irrigation asset management activities in an irrigation area are carried out based on Irrigation Asset Management (PAI) contained in the Regulation of the Minister of Public Works and Housing No. 23/PRT/M/2015 concerning Irrigation Asset Management (PAI).

4. This research is a quantitative descriptive study based on the data criteria from an assessment of the physical condition of irrigation through the PAKSI electronic application (management of irrigation assets and irrigation system performance) in 2019-2021, which can be accessed at http://103.211.51.198. A total of 947 surface irrigated area data were used.

2.2. Data Collection

The data collection method used in this study was a quantitative data collection method. These primary and secondary data are grouped into two variables:

2.2.1. Primary Irrigation Network Variable

It consists of the following dimensions:

1. The physical dimension consists of the following indicators:

a. Main building;
b. Drains and structures;
c. Entrance/inspection;
d. Building on carrier canal building;
e. Carrier canal;
f. Offices, housing, buildings.

2. The supporting facilities dimension consists of the following indicators:

a. Transportation;
b. Communication devices;
c. Equipment for branches/observer offices/Technical Implementation Unit (UPTD);
d. OM equipment (operations and maintenance).

3. Personnel organization dimension consists of the following indicators:

a. OM organization;
b. Personnel management.

5. Planting productivity dimension consists of the following indicator:

a. Planting productivity (previous year).

6. Documentation dimension consists of the following indicators:

a. Data of irrigation area;
b. Map and drawings.

7. The dimension of the institutional condition of the Water User Farmers Association consists of the following indicator:

a. Water User Farmers Association (P3A).

2.2.2. Tertiary Irrigation Network Variable

It consists of the following dimensions:

1. Physical infrastructure dimension consists of the following indicators:

a. Carrier canal;
b. Building on carrier canal;
c. Drainage structure.

2. Planting productivity dimension consists of the following indicator:

a. Planting productivity.

3. The dimension of operating and maintenance conditions consists of the following indicator:

a. Operating and maintenance conditions.

4. Personnel management dimension consists of the following indicator:

a. Water distribution officer/personnel management.

5. Documentation dimension consists of the following indicator:

a. Documentation.

6. The dimension of Irrigation Water Users' Association (P3A) consists of the following indicator:

a. Irrigation Water Users' Association (P3A).

2.3. Research Concept Framework

Fig. 1 Research concept chart (Research analysis, 2023)

3. Results and Discussion

The determination of the performance index of irrigation performance was determined based on these two variables. Each variable would be supported by various appropriate studies.

3.1. Research Variables

The parameters in this research were grouped into two variables, 12 dimensions, 24 indicators:

3.1.1. Primary Irrigation Network Variable

The research dimensions of the primary irrigation network variable (X1) consist of the following:

1. Physical infrastructure of building ($X_{1.1}$) consists of main building ($x_{1.1.1}$), drainage and building ($x_{1.1.2}$), entry/inspection ($x_{1.1.3}$), building on carrier canal ($x_{1.1.4}$), carrier canal ($x_{1.1.5}$), and office and housing building ($x_{1.1.6}$);
2. Supporting facilities ($X_{1.2}$) consist of transportation ($x_{1.2.1}$), communication devices ($x_{1.2.2}$), equipment for branches/observer offices/technical implementation unit (UPTD) ($x_{1.2.3}$), and OM equipment ($x_{1.2.4}$);
3. Personnel management ($X_{1.3}$) consists of OM ($x_{1.3.1}$) and personnel ($x_{1.3.2}$) management;
4. Planting productivity ($X_{1.4}$) consists of planting productivity (previous year) ($x_{1.4.1}$);
5. Documentation ($X_{1.5}$) consists of data on irrigation area ($x_{1.5.1}$) and map-image ($x_{1.5.2}$);
6. Water User Farmers Association (P3A) ($X_{1.6}$) consists of Water User Farmers Association ($x_{1.6.1}$).

3.1.2. Tertiary Irrigation Network Variable

Research dimensions of the tertiary irrigation network variable (X_2) consist of:

1. Physical infrastructure ($X_{2.1}$) consists of carrier canal ($x_{2.1.1}$), building on carrier canal ($x_{2.1.2}$), and drainage structure ($x_{2.1.3}$);
2. Planting productivity ($X_{2.2}$) consists of planting productivity ($x_{2.2.1}$);
3. Operation and maintenance conditions ($X_{2.3}$) consist of operation and maintenance conditions ($x_{2.3.1}$);
4. Personnel management ($X_{2.4}$) consists of water distribution officer/personnel management ($x_{2.4.1}$);
5. Documentation ($X_{2.5}$) consists of documentation ($x_{2.5.1}$);
6. P3A ($X_{2.6}$) consists of Water User Farmers Association (P3A) ($x_{2.6.1}$).

Table 1 Data requirements (Research data, 2023)

Data Requirements	**Description**
Primary irrigation network variable: i) physical infrastructure, ii) planting productivity, iii) supporting facilities, iv) personnel management, v) documentation, and vi) institutional conditions of P3A.	Data obtained from the 2019–2021 e-PAKSI web
Tertiary irrigation network variable: i) physical infrastructure, ii) planting productivity, iii) operations and maintenance condition, iv) personnel management, v) documentation, and vi) P3A	Data obtained from the 2019–2021 e-PAKSI web

3.2. Irrigation Performance Index

The condition of the irrigation performance was a unified system in which the value of function and usefulness became the reference parameter of evaluation. The value of functions and benefits is crucial since the percentage of each variable – dimension – indicators needs to be recalculated to obtain the real conditions of the irrigation system; for example, the percentage of infrastructure dimension is the largest.

The data obtained was secondary data from all irrigation areas of all central authority managed by river basin organizations (Balai Wilayah Sungai). The variables were filtered using the SmartPLS (partial least squares) tool. The analysis was then carried out using the GRG (generalized reduced gradient) method to solve the nonlinear equation with objectives and constraint assumptions.

3.2.1. Statistical Analysis Using PLS-SEM

This study analyzes the main and tertiary irrigation network variables' effect on the irrigation performance index. Therefore, the analysis was carried out using the partial least squares (PLS) model using the Windows application SmartPLS Version 3. PLS was chosen because it is more powerful and often referred to as soft modeling that ignores assumptions in the ordinary least squares (OLS) technique, where the distribution of residuals does not have to be a multivariate normal distribution. Moreover, the PLS sample does not have to be large, the measurement scale is categorical, and intervals and ordinals can be used in the same model [5]. The model developed in this study is in accordance with Fig. 1 of the research concept chart.

The PLS results are explained in detail as follows:

1. The outer model evaluation (measurement model):

a. Convergent validity

The first evaluation of the outer model is convergent validity. An indicator is considered to meet convergent validity if it has an outer loading value of > 0.7 [6, 7].

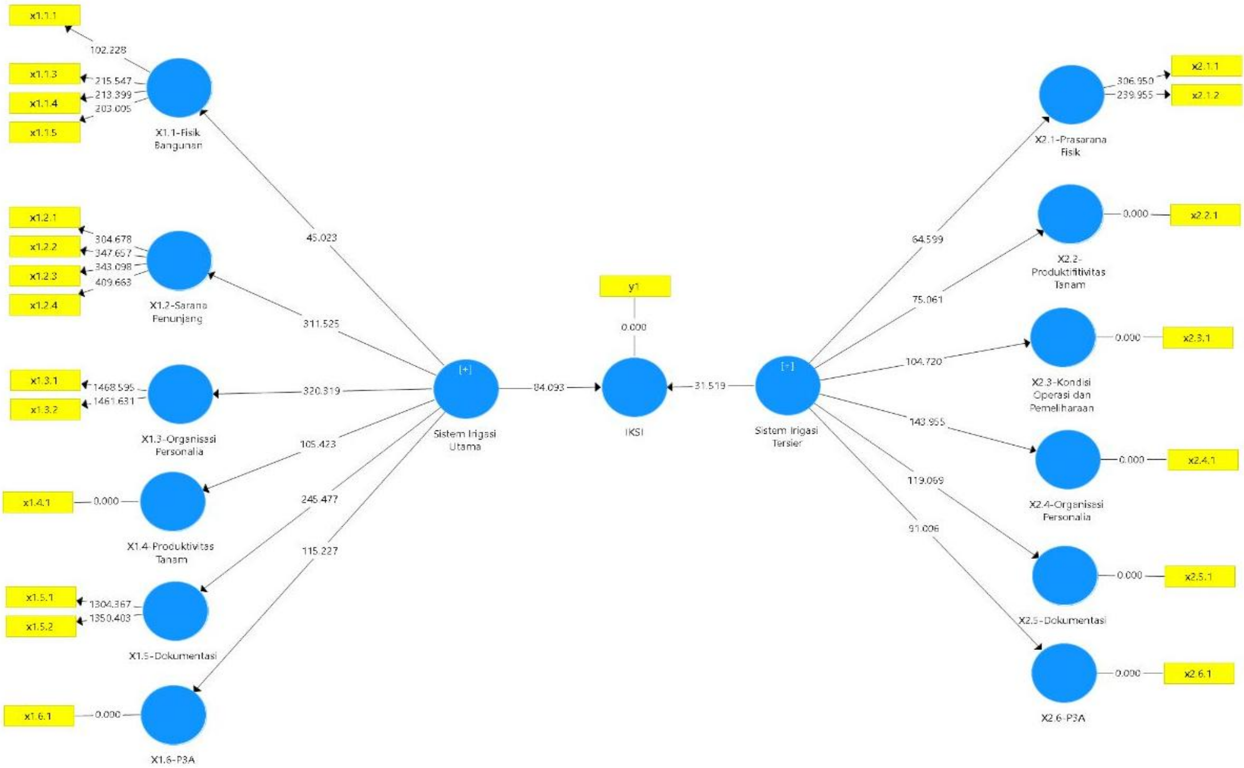

Fig. 2 Second-round measurement model analysis of the main and tertiary irrigation network variables of the irrigation performance index

Based on Fig. 2, it can be seen that all remaining indicators have an outer loading value greater than 0.7. Thus, each indicator in this study met the requirements of convergent validity. In other words, the indicators of the variables of the main and tertiary irrigation canals can be used for further analysis.

b. Discriminant validity

The second evaluation of the outer model is discriminant validity. To measure discriminant validity, cross-loading values can be used. An indicator is said to meet discriminant validity if the cross-loading value of the indicator on the construct is the largest among the other constructs. The following is the cross-loading value of each indicator on dimensions and variables:

Table 2 Results of the cross-loading values on dimensions (Analysis results, 2023)

	IKSI	**Tertiary Irrigation Network**	**Primary Irrigation Network**	**Physical Infrastructure**	**Supporting Facilities**	**Personnel Management**	**Planting Productivity**	**Documentation**
$x_{1.1.1}$	0.767	0.575	0.713	0.903	0.566	0.573	0.583	0.562
$x_{1.1.3}$	0.766	0.596	0.722	0.949	0.563	0.573	0.583	0.562
$x_{1.1.4}$	0.838	0.702	0.796	0.947	0.646	0.669	0.659	0.661
$x_{1.1.5}$	0.818	0.673	0.776	0.952	0.617	0.650	0.626	0.637
$x_{1.2.1}$	0.828	0.716	0.899	0.598	0.963	0.849	0.792	0.848
$x_{1.2.2}$	0.827	0.706	0.899	0.606	0.967	0.844	0.784	0.840
$x_{1.2.3}$	0.871	0.748	0.930	0.629	0.969	0.892	0.830	0.887
$x_{1.2.4}$	0.872	0.742	0.934	0.640	0.973	0.890	0.827	0.887
$x_{1.3.1}$	0.926	0.845	0.948	0.657	0.886	0.995	0.871	0.949
$x_{1.3.2}$	0.927	0.845	0.952	0.655	0.901	0.995	0.876	0.945
$x_{1.4.1}$	0.901	0.782	0.899	0.655	0.835	0.877	1.000	0.854
$x_{1.5.1}$	0.895	0.801	0.935	0.641	0.881	0.939	0.850	0.992
$x_{1.5.2}$	0.901	0.808	0.942	0.644	0.894	0.949	0.844	0.992
$x_{1.6.1}$	0.884	0.766	0.906	0.644	0.845	0.897	0.835	0.869
$x_{2.1.1}$	0.714	0.838	0.623	0.648	0.507	0.589	0.548	0.552
$x_{2.1.2}$	0.660	0.790	0.569	0.586	0.455	0.562	0.493	0.510
$x_{2.2.1}$	0.741	0.845	0.656	0.541	0.570	0.657	0.677	0.635
$x_{2.3.1}$	0.865	0.895	0.856	0.602	0.816	0.876	0.783	0.846
$x_{2.4.1}$	0.863	0.912	0.844	0.579	0.786	0.883	0.796	0.844
$x_{2.5.1}$	0.853	0.891	0.846	0.588	0.796	0.868	0.777	0.862
$x_{2.6.1}$	0.756	0.881	0.663	0.594	0.571	0.656	0.618	0.607
y_1	1.000	0.904	0.977	0.851	0.878	0.931	0.901	0.905

Table 3 Results of the cross-loading values on variables (Analysis results, 2023)

	P3A	**Physical Infrastructure**	**Planting Productivity**	**Operations and Maintenance Condition**	**Personnel Management**	**Documentation**	**P3A**
$x_{1.1.1}$	0.582	0.507	0.477	0.514	0.495	0.517	0.512
$x_{1.1.3}$	0.559	0.573	0.477	0.523	0.493	0.507	0.526
$x_{1.1.4}$	0.646	0.672	0.549	0.621	0.599	0.606	0.606

	P3A	Physical Infrastructure	Planting Productivity	Operations and Maintenance Condition	Personnel Management	Documentation	P3A
$x_{1.1.5}$	0.625	0.654	0.521	0.594	0.577	0.570	0.580
$x_{1.2.1}$	0.797	0.482	0.533	0.781	0.745	0.762	0.539
$x_{1.2.2}$	0.792	0.464	0.532	0.776	0.743	0.752	0.528
$x_{1.2.3}$	0.840	0.500	0.583	0.798	0.780	0.785	0.578
$x_{1.2.4}$	0.842	0.498	0.556	0.806	0.775	0.784	0.564
$x_{1.3.1}$	0.893	0.596	0.655	0.870	0.879	0.866	0.654
$x_{1.3.2}$	0.892	0.599	0.654	0.874	0.879	0.861	0.652
$x_{1.4.1}$	0.835	0.543	0.677	0.783	0.796	0.777	0.618
$x_{1.5.1}$	0.859	0.551	0.625	0.830	0.834	0.855	0.601
$x_{1.5.2}$	0.867	0.549	0.635	0.848	0.842	0.856	0.604
$x_{1.6.1}$	1.000	0.532	0.568	0.801	0.809	0.791	0.603
$x_{2.1.1}$	0.534	0.962	0.679	0.621	0.642	0.611	0.749
$x_{2.1.2}$	0.484	0.957	0.628	0.566	0.585	0.553	0.698
$x_{2.2.1}$	0.568	0.682	1.000	0.648	0.681	0.669	0.826
$x_{2.3.1}$	0.801	0.620	0.648	1.000	0.930	0.907	0.687
$x_{2.4.1}$	0.809	0.641	0.681	0.930	1.000	0.915	0.711
$x_{2.5.1}$	0.791	0.607	0.669	0.907	0.915	1.000	0.681
$x_{2.6.1}$	0.603	0.755	0.826	0.687	0.711	0.681	1.000
y_1	0.884	0.717	0.741	0.865	0.863	0.853	0.756

Based on Tables 2 and 3, the cross-loading value of each indicator on the construct is the largest compared to other constructs. Thus, the indicators used in this study have good discriminant validity in compiling their respective variables.

c. Composite reliability

The last evaluation of the outer model is composite reliability. Composite reliability tests the reliability value of the indicators of a construct. A construct or variable is said to meet composite reliability with a composite reliability value > 0.7. The following is the composite reliability value of each construct:

Table 4 Results of the composite reliability value (Analysis results, 2023)

	Composite Reliability
IKSI	1.000
Tertiary Irrigation System	0.954
Primary Irrigation System	0.979
X1.1-Physical Instructure	0.967
X1.2-Supporting Facilities	0.983
X1.3-Personnel Management	0.995
X1.4-Planting productivity	1.000
X1.5-Documentation	0.992
X1.6-P3A	1.000
X2.1-Physical Instructure	0.958
X2.2-Planting Productivity	1.000
X2.3-Operation and Maintenance Conditions	1.000
X2.4-Personnel Management	1.000
X2.5-Documentation	1.000
X2.6-P3A	1.000

Table 4 shows that the composite reliability value is more than 0.7. Thus, based on the research model, it can be concluded that each variable and dimension met the composite reliability.

2. The evaluation of the inner model (structural model)

The following is a picture of the structural model developed in the analysis of the technical, spatial, social, and regulatory aspects of the river performance index.

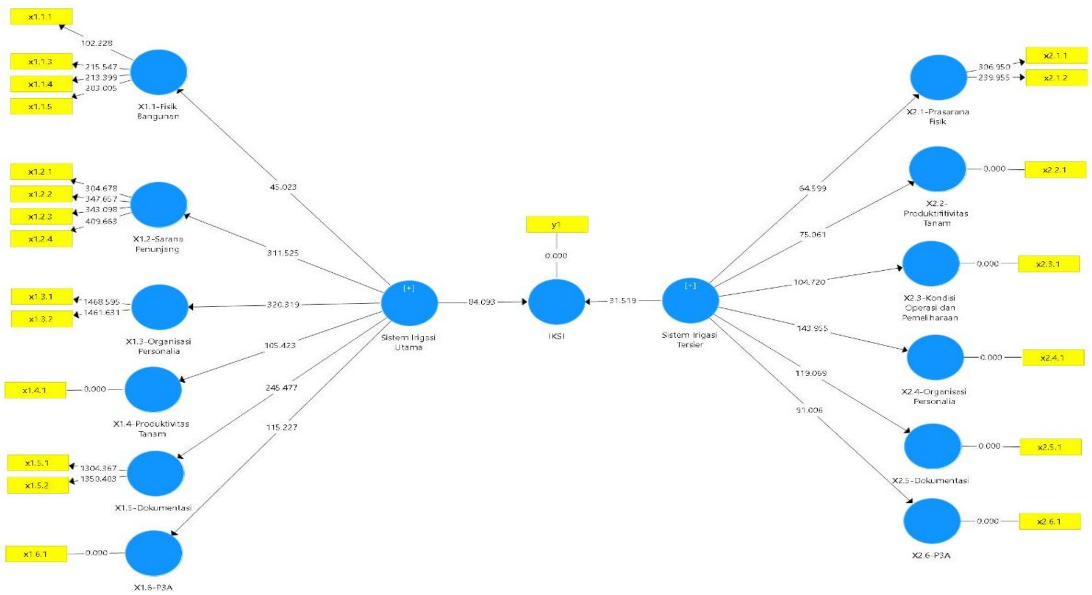

Fig. 3 The structural model of the irrigation performance index variable analysis of the main and tertiary irrigation networks

a. R-square value

The first evaluation of the inner model is observed from the R-square value or the coefficient of determination. The following are the results of the R-square value based on the data processing with PLS:

Table 5 Results of the R-square value (Analysis results, 2023)

Variable	R Square
IKSI	0.978
X1.1-Physical Infrastructure	0.645
X1.2-Supporting Facilities	0.895
X1.3-Personnel Management	0.910
X1.4-Planting productivity	0.809
X1.5-Documentation	0.894
X1.6-P3A	0.821
X2.1- Physical Infrastructure	0.721
X2.2- Planting productivity	0.714
X2.3-Operations and Maintenance Condition	0.801
X2.4-Personnel Management	0.831
X2.5-Documentation	0.794
X2.6-P3A	0.776

The goodness of fit in the PLS model can be seen from the Q^2 value. The Q^2 value had the same meaning as the coefficient of determination (R-square/R^2) in the regression analysis. The higher the R^2, the better the model fits with the data.

b. Causality test

The causality test was used to determine the significance level of the primary and tertiary irrigation network variables on the irrigation performance index. The effect between variables was statistically significant if the p-value < 0.05.

The following are the path coefficient values (original sample estimate) and the p-values in the inner model:

Table 6 Results of the path coefficient and P-value (Analysis results, 2023)

	Original Sample (O)	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**
Tertiary irrigation system → IKSI	0.279	0.009	31.519	0.000
Tertiary irrigation system → X2.1-physical infrastructure	0.849	0.013	64.599	0.000
Tertiary irrigation system → X2.2-planting productivity	0.845	0.011	75.061	0.000
Tertiary irrigation system → X2.3-operation and maintenance conditions	0.895	0.009	104.720	0.000
Tertiary irrigation system → X2.4-personnel management	0.912	0.006	143.955	0.000
Tertiary irrigation system → X2.5-documentation	0.891	0.007	119.069	0.000
Tertiary irrigation system → X2.6-P3A	0.881	0.010	91.006	0.000
Primary irrigation system → IKSI	0.742	0.009	84.093	0.000
Primary irrigation system → X1.1-physical infrastructure	0.803	0.018	45.023	0.000
Primary irrigation system → X1.2-supporting facilities	0.946	0.003	311.525	0.000
Primary irrigation system → X1.3-personnel management	0.954	0.003	320.319	0.000
Primary irrigation system → X1.4-planting productivity	0.899	0.009	105.423	0.000
Primary irrigation system → X1.5-documentation	0.946	0.004	245.477	0.000
Primary irrigation system → X1.6-P3A	0.906	0.008	115.227	0.000

The following is the mathematical equation based on Table 6:

$$\text{Irrigation Performance Index } (Y) = 0.742 \cdot X_1 + 0.279 \cdot X_2$$

where:
Y - irrigation performance index;
X_1 - primary irrigation network variable;
X_2 - tertiary irrigation network variable.

3.2.2. Generalized Reduced Gradient (GRG)

The GRG method with the Solver tool in Microsoft Excel was used to find the respective weights [5]. To make iterative modeling of these aspects, dimensions, indicators, and boundary conditions were required, as mentioned

$0 \leq X_1 \leq 100;\ 0 \leq X_2 \leq 100;\ 0 \leq Y \leq 100;\ X_1 + X_2 = 1$

$x_{1.1.1} + x_{1.1.3} + x_{1.1.4} + x_{1.1.5} = 1;\ x_{1.2.1} + x_{1.2.2} + x_{1.2.3} + x_{1.2.4} = 1$

$x_{1.3.1} + x_{1.3.2} = 1;\ x_{1.4.1} = 1;\ x_{1.5.1} + x_{1.5.2} = 1;\ x_{1.6.1} = 1$

$x_{2.1.1} + x_{2.1.2} = 1;\ x_{2.2.1} = 1;\ x_{2.3.1} = 1;\ x_{2.4.1} = 1;\ x_{2.5.1} = 1;\ x_{2.6.1} = 1$

$0 \leq IK\ Irrigation \leq 100$

3.2.3. Irrigation System Performance Index Model

The value of the primary irrigation network:

$x_{1.1} = 0{,}341 \cdot x_{1.1.1} + 0{,}114 \cdot x_{1.1.3} + 0{,}314 \cdot x_{1.1.4} + 0{,}231 \cdot x_{1.1.5}$

$x_{1.2} = 0{,}176 \cdot x_{1.2.1} + 0{,}234 \cdot x_{1.2.2} + 0{,}355 \cdot x_{1.2.3} + 0{,}236 \cdot x_{1.2.4}$

$x_{1.3} = 0{,}363 \cdot x_{1.3.1} + 0{,}637 \cdot x_{1.3.2}$

$x_{1.4} = 1{,}000 . x_{1.4.1}$
$x_{1.5} = 0{,}384 . x_{1.5.1} + 0{,}616 . x_{1.5.2}$
$x_{1.6} = 1{,}000 . x_{1.6.1}$
$X_1 = 0{,}405 . x_{1.1} + 0{,}106 . x_{1.2} + 0{,}112 . x_{1.3} + 0{,}139 . x_{1.4} + 0{,}063 . x_{1.5} + 0{,}175 . x_{1.6}$

The value of the tertiary irrigation network:

$x_{2.1} = 0{,}420 . x_{2.1.1} + 0{,}580 . x_{2.1.2}$
$x_{2.2} = 1{,}000 . x_{2.2.1}$
$x_{2.3} = 1{,}000 . x_{2.3.1}$
$x_{2.4} = 1{,}000 . x_{2.4.1}$
$x_{2.5} = 1{,}000 . x_{2.5.1}$
$x_{2.6} = 1{,}000 . x_{2.6.1}$
$X_2 = 0{,}367 . x_{2.1} + 0{,}163 . x_{2.2} + 0{,}099 . x_{2.3} + 0{,}107 . x_{2.4} + 0{,}104 . x_{2.5} + 0{,}161 . x_{2.6}$

The performance index model is as follows:

Service Peformance Index (Y) = 0,744 . X_1 *+ 0,256 .* X_2

3.2.4. Irrigation Performance Index Model Value

The irrigation performance index model was obtained by calculating the average index of primary and tertiary irrigation networks.

The value of the primary irrigation network:

$X_1 = 0{,}405 . x_{1.1} + 0{,}106 . x_{1.2} + 0{,}112 . x_{1.3} + 0{,}139 . x_{1.4} + 0{,}063 . x_{1.5} + 0{,}175 . x_{1.6}$
$X_1 = 0{,}405 . 64{,}381 + 0{,}106 . 56{,}917 + 0{,}112 . 68{,}775 + 0{,}139 . 69{,}636 + 0{,}063 . 67{,}038 + 0{,}175 . 41{,}612$
$X_1 = 60{,}991$

The value of the tertiary irrigation network:

$X_2 = 0{,}367 . x_{2.1} + 0{,}163 . x_{2.2} + 0{,}099 . x_{2.3} + 0{,}107 . x_{2.4} + 0{,}104 . x_{2.5} + 0{,}161 . x_{2.6}$
$X_2 = 0{,}367 . 45{,}704 + 0{,}163 . 60{,}882 + 0{,}099 . 61{,}400 + 0{,}107 . 64{,}094 + 0{,}104 . 58{,}204 + 0{,}161 . 55{,}438$
$X_2 = 54{,}558$

Irrigation index value:

IK Irrigation (Y) = 0,744 . X_1 + 0,256 . X_2
IK Irrigation (Y) = 0,744 . 60,991 + 0,256 . 54,558
IK Irrigation (Y) = 59,342

Therefore, the irrigation performance index model had a performance index of 59,342 or moderate performance.

3.2.5. Index Weights and Values

The irrigation performance index model (service index) consisted of two variables: primary and tertiary irrigation networks. The coefficient describes the magnitude of the influence of each variable, dimension, and indicator.

Table 7 The weighted value of the irrigation performance index (Analysis results, 2023)

No.	Primary Irrigation Network Variable		Tertiary Irrigation Network Variable	
1	$x_{1.1}$	0.405	$x_{2.1}$	0.367
2	$x_{1.2}$	0.106	$x_{2.2}$	0.163
3	$x_{1.3}$	0.112	$x_{2.3}$	0.099
4	$x_{1.4}$	0.139	$x_{2.4}$	0.107
5	$x_{1.5}$	0.063	$x_{2.5}$	0.104
6	$x_{1.6}$	0.175	$x_{2.6}$	0.161

3.2.6. Calibration

The calibration was done by calculating the math equation of the index value through calculations with the field index value [8]. The difference between the two shows the relative error value. Suppose the value was not more significant than the specified error rate. In that case, the model could be accepted with compliance with the calibration requirements not exceeding the selected error magnitude. The math model of irrigation was finally developed after the Solver recalculation twice, with the biggest error value of 0.025 and the smallest error value of 0.0000000.

3.2.7. Validation

The index value validation would be done by testing the generated index model formula. This validation should have produced a statistically qualified value. This test was conducted using the t-test by comparing the t-statistics with the t-table. The calculation results showed the value of t-count (0.284) < t-table (1.658). The H0 hypothesis was accepted, where the value of the average irrigation had a performance index of 59.342.

3.3. Interpretation of Using Irrigation Index (Service Index)

In the IKSI assessment, the evaluation of all parameters' weight percentage is vital so that the irrigation manager gets an assessment result close to the actual conditions in the field, as a part of improving the quality of irrigation system management. The evaluation of irrigation system performance and asset management activities can be carried out simultaneously using e-PAKSI. The Regulation of the Ministry of Public Works and Housing No. 12/PRT/M/2015 set the irrigation performance parameters that the physical aspect weighed 45%, cultivation and management productivity weighed 15%, supporting facilities and farmer associations had a weight of 10%, and documentation had a weight of 5% for surface irrigation infrastructure.

Several studies have been carried out on technical and non-technical weights. Previous studies have shown that physical or technical aspects tend to have the highest weight compared to other aspects, which are non-technical or non-infrastructure. Research by [9] shows the drainage index magnitude with a technical aspect weight of 0.73 and a non-technical aspect weight of 0.27. In addition, the research examines the polder system performance index, with the final result showing a weight of 0.53 for the technical aspect and 0.47 for the non-technical aspect. Purwantoro [2] and Noviadriana et al. [10] have also conducted similar studies with a physical aspect weight of 0.63, a social aspect of 0.27, and a regulatory aspect of 0.10. [11, 12]

also conducted similar research on groundwater irrigation networks, weighing 66.86% for the physical aspect, 8.56% for the social aspect, and 24.58% for the management past. Kurniawan [5] completes the research with four variables that affect river performance and river infrastructure, namely the technical variable (0.338), spatial variable (0.026), social variable (0.176), and regulative variable (0.460).

IKSI-Bakti is the equation of the variable weight evaluation results at IKSI, where the weight for the primary irrigation network variable was 74.37%, and that for the tertiary irrigation network was 25.63%. The results showed that the assessment weight of the primary irrigation network was more significant than that of the tertiary irrigation network (Table 8). This indicates that the role of the primary irrigation network was more dominant in channeling water from the intake to the tertiary irrigation network.

1. Suppose the evaluation of the primary irrigation network variable was reviewed in more depth. In that case, the variable values were obtained from six dimensions with new weights: physical infrastructure (40.47%), P3A (17.52%), planting productivity (13,88%), personnel management (11.22%), infrastructure support (10.59%), and documentation (6.32%). The weight values here were more distributed according to the results of the GRG analysis. By comparing the old weight with the research results on the IKSI primary network, it could be observed that the weight for physical infrastructure, which was initially 45%, decreased to 40.47%; P3A weight, which was initially 10%, increased to 17.52%; planting productivity weight, which was initially 15%, decreased to 13.88%; personnel management weight, which was initially 15%, decreased to 11.22%; supporting facilities weight, which was initially 10%, slightly increased to 10.59%; documentation weight, which was initially 5%, increased to 6.32%.

2. These results indicated that the weight of physical infrastructure still had the largest value in the IKSI of the primary network, followed by P3A, which increased significantly. The impact of documentation, which also increased, indicated that this parameter cannot be neglected and must be strengthened, as important as other non-physical parameters to improve the irrigation performance.

3. Suppose the evaluation of the tertiary irrigation network variable was reviewed in more depth. As shown in Table 8, the weight values were obtained for all six dimensions: physical infrastructure (36.65%), P3A (16.11%), planting productivity (16.25%), personnel management (10.68%), OM conditions (9.88%), and documentation (10.43%). The weight values here were more distributed according to the results of the GRG analysis. For the IKSI value in the tertiary irrigation network, the enormous weight obtained is physical infrastructure at 36.65%, P3A at 16.11%, planting productivity at 16.25%, personnel organization at 10.68%, operating and maintenance conditions at 9.88 %, and documentation;

4. In general, the distribution pattern of the weight of all parameters in the tertiary network is similar to that of the parameter of the primary network. The weight of physical infrastructure still has the biggest value, followed by planting productivity and P3A.

Table 8 Weight comparison of the IKSI (Analysis results, 2023)

No.	Item	Existing Weight	Research Result Weight	% of Change
1	Primary irrigation network variable	80.00%	74.37%	-7%
2	Tertiary irrigation network variable	20.00%	25.63%	28%
	Dimensions of the primary irrigation network	100.00%	100.00%	
1	Physical infrastructure	45.00%	40.47%	-10%
2	P3A	10.00%	17.52%	75%
3	Planting productivity	15.00%	13.88%	-7%
4	Personnel management	15.00%	11.22%	-25%
5	Supporting facility	10.00%	10.59%	6%
6	Documentation	5.00%	6.32%	26%
	Dimensions of the tertiary irrigation network	100.00%	100.00%	
1	Physical infrastructure	25.00%	36.65%	47%
2	P3A	20.00%	16.11%	-19%
3	Planting productivity	15.00%	16.25%	8%
4	Personnel management	15.00%	10.68%	-29%
5	Supporting facility	20.00%	9.88%	-51%
6	Documentation	5.00%	10.43%	109%

Table 8 explains as follows:

1. The physical infrastructure significantly affected the irrigation performance in the primary and tertiary networks, with weights of 40.47% and 36.65%, respectively. It was relevant to [13], which showed the vital role of physical infrastructure in the irrigation water service. The stage of handover to the Service User was followed by preparing OM facilitation so that the infrastructure could be operated and maintained with the support of offices, OM equipment, vehicles, communications, cameras, and others.

2. The role of P3A in primary and tertiary irrigation networks also significantly determined the irrigation performance, with weights of 17.52% and

16.25%, respectively. This was consistent with the research by Kurniawan [4], which stated the vital role of P3A empowerment programs and increased participation in irrigation management—for example, filling out the *01-O* blank, maintaining irrigation assets in primary and secondary irrigation networks, and having a work program in the tertiary irrigation network.

3. It turned out that planting productivity was more dominant in affecting the performance of tertiary network irrigation by 16.25%, compared to its effect on primary network irrigation by 13.88%.

4. The personnel management affected the primary irrigation relatively more significantly, namely 11.22%, compared to its effect on the tertiary irrigation network, which was 10.68%. These organizations included observers, irrigation management units, water use management, water resources knowledge management centers, and irrigation commissions.

5. Supporting facilities affect primary irrigation relatively slightly more significantly, namely 10.59%, compared to the influence of OM conditions on tertiary irrigation networks, namely 9.88%. Supporting facilities include OM equipment, vehicles, office equipment, and communications, as stated in the AKNOP.

6. It turned out that the documentation affected the tertiary irrigation network more significantly (10.43%) compared to the effect on the primary irrigation network (6.32%). The increased weight of documentation indicated that information and data management have a significant impact on irrigation performance.

The weight distribution of each irrigation performance indicator could assist the government in determining priority irrigation management programs. Of the six performance indicators, the most prominent indicators were physical infrastructure, P3A, and planting productivity. This means that the balance between improving physical infrastructure should have been followed by strengthening the institutional aspects of farmers (P3A), along with continuous guidance on land management aspects to increase crop productivity. In addition, in the context of maintaining food security and crop productivity, the government indirectly sought to manage the irrigation water balance in an irrigation area.

Water balance is one of the efforts to achieve crop productivity due to many variables related to increasing crop productivity, such as water service management, human resources, irrigation management institutions, availability of fertilizers, and climate. Therefore, based on these research results, this research can be continued with these variables.

4. Conclusion

Irrigation system development needs to be appropriately managed based on a community participation approach. It is necessary to pay attention to the role and aspirations of the community since they are the subject and object of irrigation management. Based on government regulation, since 2015, all irrigation schemes in Indonesia have to be measured with the irrigation system performance index (IKSI or Indeks Kinerja Sistem Irigasi) every year. An increasing value of IKSI indicates an increase in the quality of irrigation system services. Conversely, the decreasing value of IKSI means that the efficiency and effectiveness of irrigation system management need further review and improvement. Several studies have been conducted since ePAKSI (information system of IKSI) was launched, but the IKSI model has not been evaluated yet, especially for surface irrigation.

This study shows that the IKSI equation has been evaluated with a mathematical equation using the PLS-SEM software. The equation of the evaluation results can be called the IKB model as the rapid assessment model equation to assess the irrigation system performance index, especially for surface irrigation. The results of this study can be used as a scientific reference for stakeholders' decisions.

5. Recommendations

Given the limitations of semPLS, further research is recommended for the sub-indicators not calculated in this study. Further research will later reformulate the weight of each sub-indicator in the framework of rapid irrigation performance assessment.

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