

Integrating Interpretive Structural Modelling and Decision-Making Trial and Evaluation Laboratory for the Implementation Strategy of Hydrological Information System and Water Quality, Directorate of Water Resources Engineering, Ministry of Public Works and Public Housing, Indonesia

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ABSTRACT

This research aimed to design an implementation strategy for hydrological information system and water quality (SIHKA), a portal managing hydrology and water quality data. SIHKA has been integrated with 37 river basin organisations across Indonesia. Despite being operational, SIHKA's performance was hindered by data complexity and stakeholder dynamics. Using the interpretive structural modelling (ISM) and decision-making trial and evaluation laboratory (DEMATEL) multi-criteria decision-making models, this research identified stakeholders as critical factors, with objectives and constraints serving as causal factors. The integrated approach produced a prioritised, cause-and-effect-based strategy, enabling centralised real-time data management with stakeholder support.

OPSOMMING

Hierdie navorsing het ten doel gehad om 'n implementeringstrategie te ontwerp vir die Hidrologiese en Watergehalte-inligtingstelsel (SIHKA), 'n portaal wat hidrologiese en watergehalte data bestuur. SIHKA is reeds met 37 rivierkomorganisasies regoor Indonesië geïntegreer. Hoewel SIHKA operasioneel is, word die prestasie daarvan deur datakompleksiteit en belanghebbendinamika belemmer. Met behulp van interpretatiewe strukturele modellering (ISM) en die "decision-making trial and evaluation laboratory" (DEMATEL) as multikriteria-besluitnemingsmodelle, het die navorsing belanghebbers as kritieke faktore geïdentifiseer, met doelwitte en beperkings as oorsaaklike faktore. Die geïntegreerde benadering het 'n geprioritiseerde, oorsaak-en-gevolg-gebaseerde strategie opgelewer wat gesentraliseerde intydse databestuur met belanghebbesteun moontlik maak.

1. INTRODUCTION

The One Data Indonesia regulation (Presidential Regulation (PERPRES) No. 39/2019) promotes effective data management by integrating government data for efficient use by communities, businesses, and the government. The Directorate of Water Resources Engineering, under Ministerial Regulation (PERMEN) Ministry of Public Works and Public Housing (PUPR) No. 13/2020, manages data, coordinates environmental analyses, addresses climate change, and oversees water resources engineering, intellectual property, and knowledge systems. PERPRES No. 37/2023 highlights the importance of improving the Water Resources Information System (SISDA), particularly SIH3, for greater efficiency and effectiveness [1]. The Hydrology and Water Quality Information System (SIHKA), integrated with 12 large river basin organisations (BBWS) and 25 river basin organisations (BWS) in Indonesia, serves as a portal for collecting, monitoring, and managing hydrology and water quality data to support the One Data Indonesia policy. However, the initiative encounters difficulties in operating at optimal capacity because of the complexity of the data and the interdependencies among stakeholders.

Figure 1 A shows the stakeholder relationships and information flow in SIH3, a collaboration between PUPR (Hydrology), the Meteorological, Climatological and Geophysical Agency (BMKG) (Hydrometeorology), and the Ministry of Energy and Mineral Resources (ESDM) (Hydrogeology), each managing data in their fields. The Directorate of Water Resources Engineering (BINTEK Water Resources) oversees SIHKA, a hydrology and water quality portal integrating data from 12 BBWSs and 25 BWSs in Indonesia. SIHKA collects, monitors, and manages data from 3,206 hydrological stations and 1,429 telemetry devices, recording river discharge, rainfall, and climate data. It supports the One Data Indonesia policy through integration into SIH3 [2]. Figure 1 B (a) shows the hydrological data, (b) depicts information on the number of posts and type of equipment, (c) presents the percentage of active telemetry equipment below 50% from 37 centres, (d) exemplifies incomplete data on the Automatic Rainfall Recorder (ARR) posts, and (e) denotes 0% availability owing to the failure of B/BWSs to store data in 2024.



Figure 1: Information flow and SIHKA conditions

This research aims to devise an information system implementation strategy that incorporates multi-criteria decision-making models based on ISM and DEMATEL. The methods facilitate identifying causal and hierarchical relationships [3] in strategic initiatives [4], even with small sample sizes [5] [6]. ISM constructs a hierarchical structure of risks [7] and supports expert data analysis [8] by breaking down complex systems [9] into simpler elements [10] [11]. DEMATEL quantifies relationship intensity [12], visualises cause-and-effect connections [13] [14], and identifies key bottlenecks [15]. Together they prioritise factors, integrate problems [16], and create hierarchical diagrams [17] for a clearer understanding of interdependencies [18], enabling decision-makers to enhance productivity [19] and to predict project progress effectively [20]. Figures 1 A and B report the intricate nature of SIHKA during the implementation phase. Therefore, this research leads to the formulation of a draft strategy implemented in the Directorate of SDA Engineering of PUPR.

2. LITERATURE REVIEW

An implementation strategy design for SIHKA was proposed using ISM and methods to identify the most influential factors [21]. The article ‘Intelligent system for pasteurised milk quality assessment and prediction’ [22] highlights that improving the quality system is the top priority for achieving grade A pasteurised milk, making quality improvement the key strategy. ISM uses expert judgement to identify the interrelationships between factors and to improve implementation strategies [23], while DEMATEL assesses the relative influence of these factors [24]. DEMATEL analyses driving factors, clarifies correlations, and converts causality into structural frameworks, making it effective for addressing complex interdependencies and solving diverse issues [25] [26]. Together, ISM and DEMATEL are decision-making tools for designing effective implementation strategies in complex systems, including multi-criteria performance evaluations [5] [27]. The methods rely on experts’ subjective opinions, but involving stakeholders enhances model validity and accuracy. ISM organises system elements into a clear hierarchy, simplifying relationships. DEMATEL, although requiring extensive data, identifies strong influences and relationships between elements. Visualising matrices and causal diagrams clarifies system structure and dynamics. Their integration provides a comprehensive understanding of factors affecting information system implementation strategies.

2.1. Hydrological information system: SIHKA

SIHKA is an information system used to store and manage hydrological and water quality data collected by the BBWSs and BWSs in Indonesia. The system is designed to manage both hydrological data and water quality test results from rivers throughout Indonesia. Hydrological data recorded at these stations is: (1) water level measurements (hourly, daily), (2) river flow discharge records (daily), (3) rainfall data (hourly, daily), (4) climate data (temperature, humidity, wind speed, evaporation, solar radiation), and (5) water quality testing in rivers. As a key producer of hydrological data, PUPR has made SIHKA the sole application representing PUPR to contribute data and information to the public, supporting the One Data Indonesia policy.

2.2. Interpretive structural modelling

The ISM method enhances advanced planning by analysing complex systems with the support of expert judgement, resulting in deeper and more comprehensive insights [28]. In SIHKA, ISM organises programme elements hierarchically, using indicators such as needs, constraints, objectives, and stakeholders [29] [30]. The Saxena model, applied with input from six experts via a VAXO questionnaire, identifies sub-element relationships analysed with ISM software [31]. Key steps were undertaken to identify the elements and sub-elements, based on the results of the FGDs (Focus Group Discussions) with experts. These steps include developing the VAXO questionnaire to define the relationships between variables (V: one-way influence, A: reverse influence, X: mutual influence, O: no connection), preparing the structural self-interaction matrix (SSIM), creating the binary reachability matrix (RM), compiling the final matrix, and estimating the driving power and dependence values to classify variables into four quadrants: autonomous (weak driving/weak dependence), dependent (weak driving/strong dependence), linkage (strong driving/strong dependence), and independent (strong driving/weak dependence) [32]. The ISM model is then structured hierarchically for clarity [33].

2.3. Decision-making trial and evaluation laboratory (DEMATEL)

DEMATEL is used in decision-making through pairwise comparisons to identify cause-and-effect relationships between variables, based on expert assessments of factor intensity [25]. The steps include [34]:

- Design a questionnaire that assesses the influence of the elements.
- Calculating and normalising the direct relationship matrix.
- Calculating the total relationship matrix.
- Determining the threshold value.
- Producing the final cause-and-effect diagram.

The implementation strategy was developed from a DEMATEL assessment of the key factors' interrelationships, with ratings from six interviewees, helping to identify elements, their impact on SIHKA, and potential issues and solutions for a more effective strategy.

3. METHODOLOGY

This research used a flow chart (Figure 2) to select elements and sub-elements confirmed through FGDs. The data were processed using ISM and DEMATEL methods. The research started with interviews and system analysis to understand hydrology, followed by identifying indicators and establishing hierarchical relationships. ISM determined the implementation stages, while DEMATEL analysed the variable relationships.

This research collected data from experts with at least two years' experience in hydrology, data development, and information systems, selected from the Directorate of BINTEK SDA PUPR. The experts included the data and information system development subcoordinator, subcoordinator of strategic environmental assessment and climate change mitigation, subcoordinator of hydrological data management, a junior expert at the Hydrology and Water Environment Center, B/BWS hydrology unit operators, and central operators from the Sub-Directorate of Water Resources Information System.

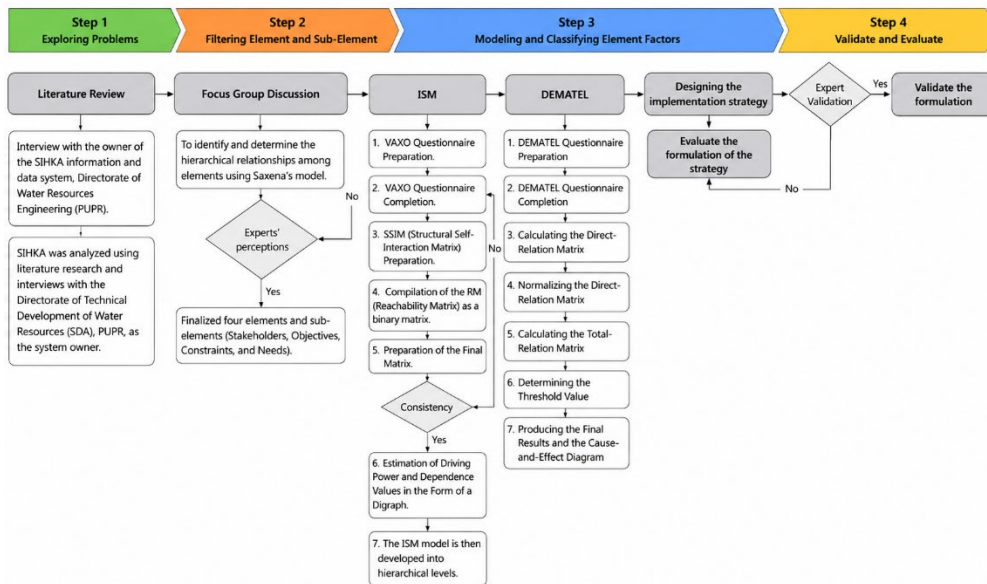


Figure 2: Flow chart diagram of research

3.1. SIHKA problem exploration

This stage involved exploring the problem through observations, interviews, and data analysis with the SIHKA owner, the Directorate of Water Resources Engineering of PUPR. Key elements were needs, constraints, objectives, and stakeholders. Each B/BWS in Indonesia manages hydrology posts built by PUPR for water resource planning, management, and studies. SIHKA stores and manages hydrological and water quality data, including water levels, river discharge, rainfall, climate, and water quality. As a primary instrument supporting the One Data Indonesia policy, the implementation of SIHKA is still not fully optimised.

SIHKA faces technical challenges, such as immature strategies, insufficient guidelines, infrastructure issues (e.g., ransomware attacks), and unreliable telemetry tools. Non-technical issues include the lack of SOPs (Standard Operating Procedures), inadequate training, poor coordination among stakeholders, and limited resources. To optimise SIHKA, it would be crucial to develop SOPs, enhance human resource skills, standardise tools, and strengthen stakeholder coordination.

3.2. Filtering elements and sub-elements

To identify and define the relationships between elements and sub-elements, the data from the interviews and SIHKA analyses were validated through FGDs. Using the Saxena programme and the ISM method, experts identified and confirmed the key elements - needs, constraints, goals, and stakeholders - which were then refined into sub-elements. ISM organised these elements hierarchically, clarifying their interrelationships. The confirmed elements and sub-elements are summarised in Table 1.

Table 1: Summary of confirmed elements and sub-elements

Elements	Sub-elements
A. Stakeholders	A1 PUSDATIN
	A2 Data and information supervisor at the Center (Directorate of Water Resources Specialization)
	A3 Hydrology and Water Quality (HKA) unit at B/BWSs
	A4 SIHKA operator at the Center (DPSISDA)
	A5 Information technology expert at the Center (DPSISDA)
	A6 Water Environment Hydrology Center (BHLK)
	A7 Provincial PUPR office
	A8 SIHKA operator at B/BWSs
	A9 PIC vendor of tool provider in B/BWSs
	A10 BUMN/private (PJT)

Elements	Sub-elements
B. Objective	B1 The objective is to provide support for the recording, collection, and quality control of hydrological data in a centralised real-time way in SIHKA.
	B2 The objective is to assist in the implementation of disaster mitigation strategies.
	B3 The objective is to provide support for the recording, collection, and quality control of hydrological data in a centralised real-time way in SIHKA.
C. Constraints	C1 Absence of regulations governing SIHKA implementation.
	C2 No SOP on hydrological data management (manual/telemetry) in SIHKA application.
	C3 No socialisation of SIHKA operating guidelines for users.
	C4 Lack of competent human resources at the Center (DPSISDA) to monitor data in SIHKA.
	C5 Lack of funds for B/BWSs to conduct workshops on the operation of the SIHKA application.
	C6 Lack of human resources in B/BWSs to complete hydrological data in the field.
	C7 Lack of availability of recommendations for vendors of equipment providers that meet the technical specifications needed in B/BWSs' areas.
	C8 Lack of coordination between B/BWSs, vendors, and the Center to monitor data and information in SIHKA.
D. Needs	D1 The existence of regulations governing the implementation of SIHKA.
	D2 SOP on hydrological data management (manual/telemetry) in SIHKA application is in place.
	D3 Socialisation of SIHKA operating guidelines for users.
	D4 Competence of human resources of the central operator (DPSISDA) to monitor data in SIHKA.
	D5 Availability of funds for B/BWSs to conduct workshops on the SIHKA application.
	D6 Availability (competence) of human resources for B/BWS operators to complete hydrological data in the field.
	D7 Standard specifications of tools (tool quality standards) from vendors that meet the needs of B/BWSs.
	D8 The existence of a central control mechanism (DPSISDA) for vendors.

3.3. Modelling and classifying element factors

The elements and sub-elements that were obtained were converted into a form according to each questionnaire in the decision-making model, with the following steps:

3.3.1. Modelling and classifying with ISM

After identifying the relationships between the elements and sub-elements, the VAXO questionnaire was created and rated by the experts. It was then converted into the SSIM, followed by the initial reachability matrix (IRM), and compiled into a binary RM. Finally, the RM was used to produce the final matrix, as shown in Figure 3.

The final matrix shows the consistency value for each assessment from the experts. The value is the assessment used to obtain the number of revisions and the consistency value of each element. The consistency value should not be more than 10% [35].

3.3.2. Modelling and classifying with DEMATEL

The relationship between the elements and sub-elements was identified using DEMATEL, based on the expert assessments. The questionnaire was presented as a matrix, and direct relationships were calculated. A threshold value was set to determine the total relationship, resulting in a cause-and-effect diagram. The data was processed to identify the direct relationship matrix, followed by calculating the threshold value and presenting the results in the cause-and-effect diagram [36].

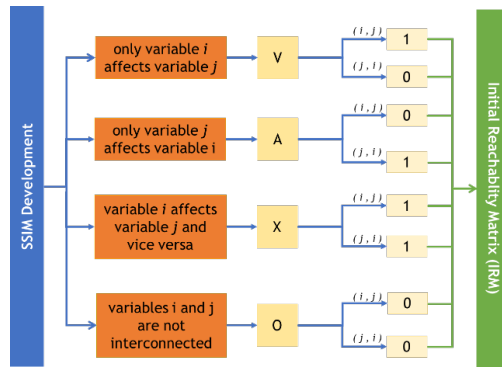


Figure 3: The principles to transform SSIM into IRM

4. RESULTS AND ANALYSES

4.1. Result of identifying elements and sub-elements with ISM

ISM identification determined the interrelationships between the elements in a complex system using VAXO questionnaires completed by six experts during the FGDs. The data was processed into an SSIM, from which the RM was derived to generate the final results, presented as a Dgraph and a hierarchical structure based on level partitioning. The data processing showed a 0% inconsistency value for the stakeholder elements. The ISM identification process is shown in Figure 4.

SSIM	Reachability Matrix	Revision Matrix	Final Matrix	Graph	Structure
NO	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10				
A1		A	A	A	V
A2			V	V	V
A3				V	V
A4					X
A5					
A6					
A7					
A8					
A9					
A10					

SSIM	Reachability Matrix	Revision Matrix	Final Matrix	Graph	Structure
NO	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 DP R				
A1	1 0 0 0 0 0 0 1 0 0 1 3 5				
A2	1 1 1 1 1 1 1 1 1 1 1 10 1				
A3	1 0 1 1 1 1 0 1 1 1 1 8 3				
A4	1 0 0 1 1 0 1 1 1 1 1 7 4				
A5	1 0 0 1 1 0 1 1 1 1 1 7 4				
A6	1 0 1 1 1 1 1 1 1 1 1 9 2				
A7	0 0 0 0 0 0 0 1 0 0 0 1 7				
A8	1 0 0 1 1 0 1 1 1 1 1 7 4				
A9	1 0 0 1 1 0 1 1 1 1 1 7 4				
A10	0 0 0 0 0 0 0 1 0 0 0 1 2 6				
D	8 1 3 7 7 2 10 7 7 9				
L	3 7 5 4 4 6 1 4 4 2				

Figure 4: ISM identification process

4.1.1. Estimation of driven power and dependence values in the form of Dgraphs

Figure 5 below shows the result of estimating the value of the driven power and dependence, in the form of Dgraphs:

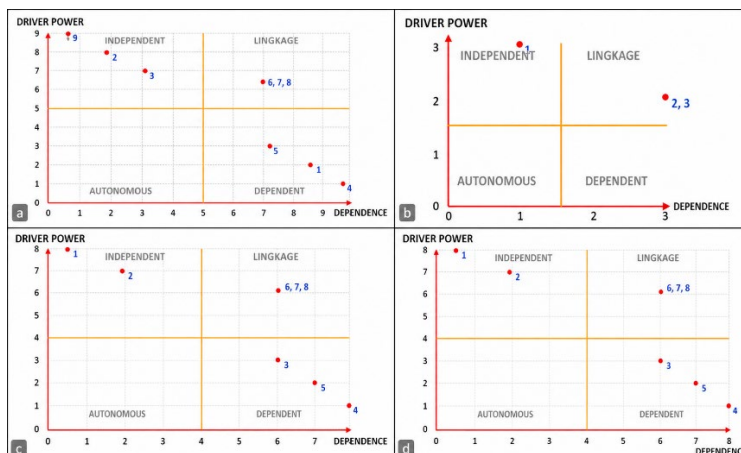


Figure 5: Value of Dgraph ISM

The Dgraphs for the four elements show the distribution of the results in their respective quadrants. For the stakeholders element (Figure 5a), the final matrix falls into Quadrants II to IV, where Quadrant II (dependent) comprises PUSDATIN, PJT, and the Provincial PUPR Office, indicating weak driver / strong dependence; Quadrant III (Linkage) includes SIHKA Operators, IT Experts at the Center, SIHKA Operators at B/BWS, and Vendor PICs (Persons in Charge), which require further examination due to unstable relationships; and Quadrant IV (Independent) contains the Hydrology and Water Quality Unit, the Water Environment Hydrology Center, and the Data and Information Supervisor at the Center, acting as strong driver / weak dependence variables. For the objective element (Figure 5b), the data processing shows 0% inconsistency, with the SSIM analysis placing the results in Quadrants III and IV, where Quadrant III (linkage) includes ‘Assist in disaster mitigation’ and ‘Support natural resource infrastructure development’, both requiring additional investigation, while Quadrant IV (independent) contains ‘Support hydrological data collection and real-time control in SIHKA’, functioning as a strong driver / weak dependence variable. The constraints element (Figure 5c) shows an inconsistency value of 1.56%, with the SSIM analysis categorising the results into Quadrants II, III, and IV; Quadrant II (dependent) includes the lack of SIHKA operation guidelines, insufficient workshop funding, and limited competent human resources at the Center; Quadrant III (linkage) consists of limited human resources at B/BWSs, unavailable vendor recommendations, and weak coordination among B/BWSs, vendors, and the Center; and Quadrant IV (independent) comprises the absence of SOPs for hydrological data management and the lack of regulations for SIHKA implementation. Finally, the needs element (Figure 5d) shows an inconsistency value of 4.69%, with Quadrant II (dependent) including the socialisation of SIHKA operating guidelines, central operator human resource competence, and available funding for B/BWS workshops; Quadrant III (linkage) consists of competent human resources at B/BWSs, standard vendor tool specifications, and a central vendor control mechanism; and Quadrant IV (independent) consists of SOPs for hydrological data management and regulations for SIHKA implementation.

4.1.2. The ISM model results for each element

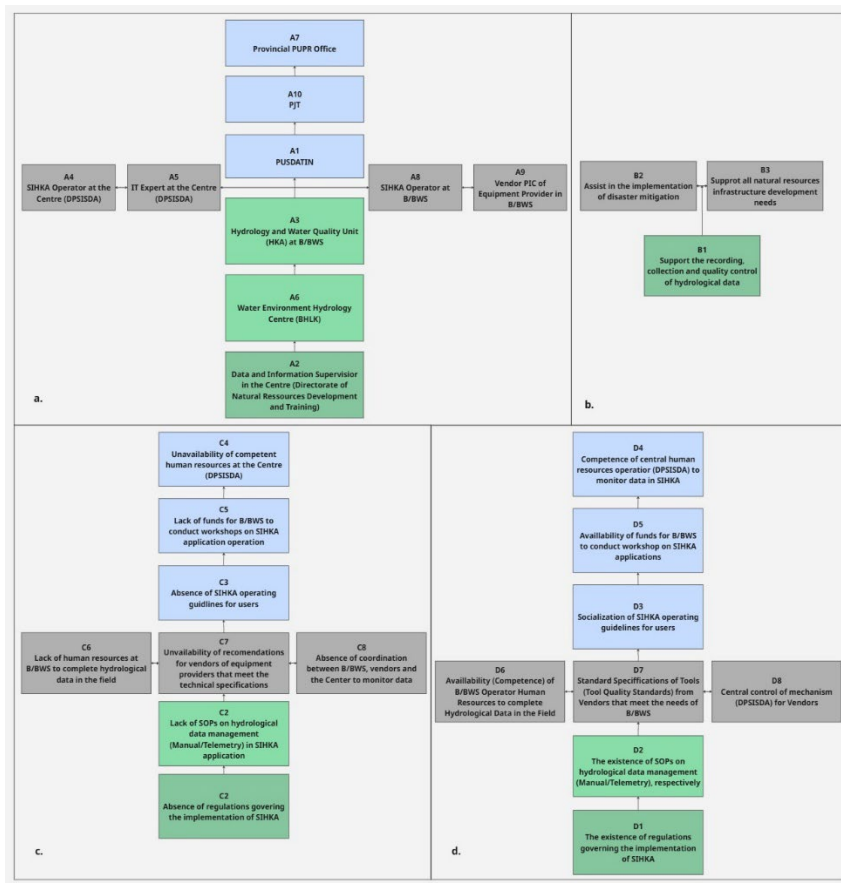


Figure 6: ISM model's structure

The ISM model results for each element reveal a structured hierarchy that reflects the dynamics of SIHKA implementation. For the stakeholders element (Figure 6a), a seven-level hierarchy is formed, placing the data and information supervisor at Level 7, followed by the Water Environment Hydrology Center at Level 6 and the Hydrology and Water Quality Unit at Level 5. The SIHKA operators, information technology experts, and vendor PICs occupy Level 4, while PUSDATIN, PJT, and the Provincial PUPR Office are positioned at Levels 3, 2, and 1 respectively. The objective element (Figure 6b) produces a two-level hierarchy in which the primary objective - 'Support hydrological data recording, collection, and quality control' - is placed at Level 2, and the objectives 'Assist in disaster mitigation' and 'Support natural resource infrastructure development' are situated at Level 1. The constraints element (Figure 6c) generates a six-level hierarchy, placing the absence of SIHKA implementation regulations (C1) at Level 6, followed by the lack of SOPs for hydrological data management (C2) at Level 5. Level 4 includes constraints such as limited human resources at B/BWSs (C6), lack of vendor recommendations (C7), and weak coordination among B/BWSs, vendors, and the Center (C8). Levels 3, 2, and 1 encompass the absence of operational guidelines (C3), insufficient funding for workshops (C5), and the shortage of competent human resources at the Center (C4). Finally, the needs element (Figure 6d) forms a six-level hierarchy, with SIHKA regulations (D1) and SOPs for hydrological data management (D2) placed at Levels 6 and 5. Level 4 contains the availability of competent B/BWS operator human resources (D6), standard vendor tool specifications (D7), and a centralised vendor control mechanism (D8). Levels 3, 2, and 1 include the socialisation of SIHKA operating guidelines (D3), the availability of funding for B/BWS workshops (D5), and the competence of central human resources who are responsible for data monitoring (D4).

4.2. Result of identifying elements with DEMATEL

The element identification process using DEMATEL facilitated decision-making through pairwise comparisons, enabling the identification of causal models between variables. The results revealed the causal relationships and the influence exerted by the factors under investigation. The stages of data processing using DEMATEL were as follows:

4.2.1. Direct relationship matrix

An $n \times n$ matrix was created to model the relationships between the criteria, with each row representing the influence of the elements on the columns. Expert opinions were used to populate the matrix, and their arithmetic average was used to generate the direct relationship matrix X, as shown in Table 2.

Table 2: Direct relationship matrix

	Stakeholders	Goals	Constraints	Needs
Stakeholders	0	3.333	3.667	3.833
Goals	3.667	0	1	3.333
Constraints	3.5	1.333	0	1
Needs	3.833	3	0.833	0

4.2.2. Normalisation of direct relationship matrix and total relationship matrix calculation

To normalise the matrix, the sum of all rows and columns was calculated, and the largest sum (k) was identified. Each element of the direct relationship matrix was divided by (k) to form the normalised matrix. The total relationship matrix was then derived by subtracting an identity matrix from the normalised matrix and multiplying the inverse of the result with the normalised matrix, capturing the overall relationships.

4.2.3. Establishment of threshold values

A threshold value of 0.775 was applied to the total relationship matrix (T matrix) to filter out weak relationships. Only relationships with T matrix values exceeding the threshold were included in the network relationship map, while values below the threshold were set to zero. The threshold was determined based on the average value of the T matrix, thereby highlighting the most significant causal relationships. Table 3 presents the total relationship matrix after the application of the threshold.

Table 3: Total relationship matrix with threshold value considerations

	Stakeholders	Goals	Constraints	Needs
Stakeholders	0.953	0.978	0.82	1.052
Goals	1.039	0	0	0.907
Constraints	0.841	0	0	0
Needs	1.028	0.83	0	0

4.2.4. Cause-and-effect diagram

The next phase calculated the sum of each row (D) and column (R) of the T matrix. D+R represents the importance of factor (i), while D-R shows its net effect. The final DEMATEL results are shown in Table 4.

Table 4: Final result matrix

	Stakeholders	Goals	Constraints	Needs
Stakeholders	3.861	3.803	7.663	-0.058
Goals	3.023	3.14	6.163	0.118
Constraints	2.305	2.399	4.704	0.094
Needs	3.213	3.06	6.274	-0.153

The results are shown in a cause-and-effect diagram (Figure 7), with (D + R) values on the horizontal axis and (D - R) values on the vertical axis. Each factor's position and interaction, represented as coordinates (D + R, D - R), illustrates the system's significant relationship model.

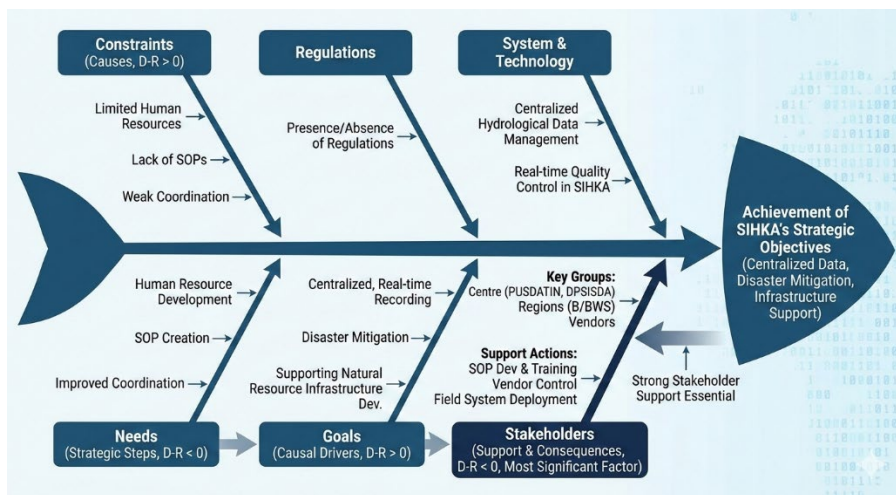


Figure 7: Cause-and-effect diagram

The cause-and-effect diagram in Figure 7 evaluates each factor, based on two criteria:

- The horizontal vector D + R shows the factor's importance in the system, indicating its impact on the system and on others. Stakeholders are at the initial level, followed by needs, **goals**, and constraints.
- The vertical vector D - R shows a factor's influence on the system. Positive values represent cause variables, while negative values represent effects. In this research, objectives and constraints are cause variables, and stakeholders and needs are effects.

4.3. Designing SIHKA implementation strategy

The key elements included centralised hydrological data management, real-time quality control in SIHKA, and the presence or absence of regulations. The DEMATEL analysis identified stakeholders as the most significant factor, with goals and constraints as causal variables and stakeholders and needs as consequences. Strategies should be prioritised on the basis of their importance, cause-and-effect relationships, and implementation needs.

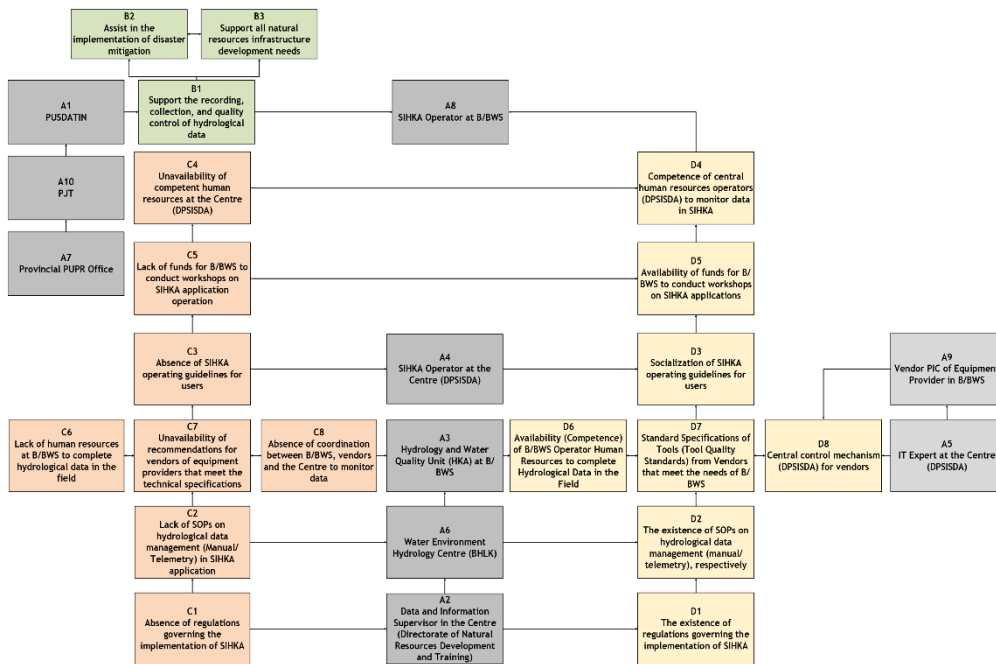


Figure 8: SIHKA implementation strategy

The strategy model in Figure 8 shows the close relationship between constraints, needs, and goals, with the sub-elements hierarchically connected and supported by the stakeholders. Constraints such as limited human resources, lack of SOPs, and weak coordination drive strategic needs such as human resource development, SOP creation, and improved coordination. These needs aim to achieve SIHKA’s main objectives: centralised, real-time hydrological data recording, disaster mitigation, and supporting natural resource infrastructure development.

The integration of these methods identifies constraints as causes, needs as strategic steps, and goals as outcomes. The key stakeholders - that is, the Center (PUSDATIN, DPSISDA), regions (B/BWSs), and vendors - support implementation through SOP development, training, vendor control, and field system deployment. The model shows a cause-and-effect mechanism, in which addressing constraints and meeting needs would be crucial to achieving SIHKA’s objectives. Strong stakeholder support would be essential for successful implementation.

4.4. Validate and evaluate

The integration of ISM and DEMATEL effectively designed an implementation strategy for SIHKA at BINTEK SDA PUPR, addressing key elements such as stakeholder roles, regulations, and real-time data management. The ISM analysis achieved a 98% consistency score, validating the model’s reliability. Combining ISM with DEMATEL clarified the cause-and-effect relationships between constraints, needs, and goals, supporting strategic decisions. However, successful SIHKA implementation would require collaboration between authorities and stakeholders. Problems such as insufficient skilled resources, the absence of SOPs, and weak coordination would require resolution through enhanced stakeholder collaboration.

5. CONCLUSION

The implementation of SIHKA aimed to manage essential components effectively and to ensure system efficacy. The integration of ISM and DEMATEL provided a comprehensive framework for SIHKA's implementation in the Directorate of BINTEK SDA PUPR, offering a structured approach to addressing issues such as stakeholder involvement, regulatory formulation, and data management. The analysis highlighted the need to address human resource constraints, develop technical guidelines, and strengthen coordination among stakeholders. Strategic initiatives such as capacity building, proper budgeting, and procedure standardisation would be crucial to achieving accurate, real-time hydrological data management. Ultimately, the combination of ISM and DEMATEL should lay a solid foundation for developing policies and strategies to ensure the sustainable and successful implementation of SIHKA.

This research was limited to four of nine elements for programming strategies, and excluded representatives from BWSs of the Directorate of Technical Development of SDA PUPR. Future research should incorporate additional elements and BWS expertise to enable more comprehensive programme implementation.

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