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Artificial Intelligence-Based Irrigation Monitoring Information System for Enhancing Irrigation Rehabilitation Work Supervision

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SIMORI; irrigation rehabilitation; artificial intelligence; project monitoring; engineering ethics; transparency

ABSTRACT
The rehabilitation of irrigation networks plays a critical role in enhancing agricultural productivity and supporting national food self-sufficiency targets, as mandated by Presidential Instruction No. 2 of 2025. Traditional monitoring practices still rely on manual reporting, inconsistent documentation, and non–real-time inspections, leading to data inaccuracies and limited transparency. These challenges highlight the need for a more reliable, timely, and objective monitoring system. SIMORI (Sistem Informasi Monitoring Irigasi) is introduced as an AI-powered digital solution capable of providing real-time data, detecting anomalies, and generating accountable automated reports. This study evaluates SIMORI's implementation through a pilot project in Serang Regency, demonstrating significant improvements in monitoring efficiency and accuracy. The Computer Vision module achieved 97.8% accuracy in work type detection and volume measurement, while the Machine Learning module achieved over 90% accuracy in predicting project delays. These advancements resulted in measurable reductions in supervision time and enhanced objectivity in progress assessment. This paper explores the relevance and urgency of SIMORI as a strategic instrument to enhance transparency, accountability, and monitoring quality in irrigation rehabilitation projects, thereby accelerating national food security objectives.

INTRODUCTION

Irrigation management is key to national food security (Zhu et al., 2019; Kambou et al., 2021). Presidential Instruction No. 2 of 2025 concerning the Acceleration of the Achievement of Food Self-Sufficiency requires technical agencies to strengthen irrigation rehabilitation effectively and on time (Kementerian Pertanian, 2025; Suryana et al., 2020). This demands a shift from conventional oversight to more transparent and accurate methods to prevent inefficiencies and construction failures (Fakih & Wulandari, 2019; Hermanto et al., 2022).

According to Presidential Regulation No. 46 of 2025, Commitment Making Officials (PPK) are required to make decisions based on valid field data. However, reality on the ground shows that monitoring still relies on manual methods prone to bias, delay, and non-standardization (Ouknider, 2022).

To address the need for factual and fast data for PPK, the SIMORI (Sistem Informasi Monitoring Irigasi) innovation was developed (Haryanto et al., 2021; Mulyana et al., 2020). The app leverages artificial intelligence (AI), geotagging, and sensors to monitor progress in real-time, detect job anomalies, and provide accurate automated reports (Junaedi & Wibowo, 2022; Rahayu et al., 2021). This technological solution enhances the efficiency and transparency of irrigation monitoring and management (Arianto et al., 2023; Putra & Nugroho, 2020).

In recent years, the integration of Geographic Information Systems (GIS) into irrigation management has demonstrated significant improvements in spatial data accuracy and supervisory efficiency, as evidenced by studies mapping irrigation networks in Central Lombok and Rokan Hilir (Adil & Triwijoyo, 2021; Bakti, 2019). Further advancements are noted in web-based GIS platforms that enhance transparency and accessibility of irrigation infrastructure data, as explored by Ernawati et al. (2014) and Ghozali et al. (2023). Similarly, research by Sumarsono et al. (2023) highlights the critical role of web-based systems in accelerating data communication for irrigation monitoring. However, these existing technological applications predominantly focus on spatial documentation and static data presentation, leaving a substantial gap in dynamic, real-time monitoring and automated analytical capabilities during the contract execution phase of rehabilitation projects.

This research gap is particularly evident in the systemic disconnect between digital procurement platforms, such as the Government Goods/Services Procurement Policy Agency's electronic catalog (LPSE/E-Catalogue), and performance assessment systems like SIKaP, creating a "system vacuum" during project implementation. Current practices remain heavily reliant on manual reporting methods prone to bias, delays, and lack of standardized digital audit trails, as confirmed by field observations. Consequently, there is a pressing need for an integrated solution that not only bridges this informational discontinuity but also introduces intelligent, automated oversight to replace subjective and non-real-time manual inspections, thereby addressing fundamental flaws in transparency and accountability.

The urgency of this research is underscored by stringent regulatory mandates, notably Presidential Instruction No. 2 of 2025 concerning the acceleration of national food self-sufficiency, which demands reliable and timely irrigation rehabilitation. Concurrently, Presidential Regulation No. 46 of 2025 on Government Goods/Services Procurement obligates Commitment Making Officials (PPK) to base decisions on valid and timely field data. The persistence of conventional monitoring methods directly undermines these legal imperatives, risking project delays, cost overruns, and ultimately, the national food security agenda—thereby necessitating immediate technological intervention.

The novelty of this research lies in the development and pilot implementation of SIMORI (Irrigation Monitoring Information System), an artificial intelligence-based platform that synergistically combines Computer Vision (CV) and Machine Learning (ML) for real-time, automated supervision. Unlike prior GIS-centric systems, SIMORI introduces advanced capabilities for automated physical progress detection, anomaly identification, and predictive risk analytics, creating a closed-loop digital monitoring ecosystem that seamlessly integrates with existing government procurement and performance appraisal APIs—thereby filling the identified systemic gap with intelligent automation.

The primary purpose of this study is to design, develop, and evaluate an AI-based irrigation rehabilitation monitoring information system that enhances the effectiveness, efficiency, and transparency of project supervision. This involves creating a system capable of providing real-time data dashboards, automating progress validation through computer vision, predicting delays via machine learning, and facilitating public oversight through an integrated whistleblowing system—all within a unified digital framework aligned with prevailing regulations and engineering ethics.

The anticipated benefits of this research are multifold. For project governance, the system promises to significantly increase transparency and accountability through immutable digital records, reduce supervisory time and costs via real-time data access, and mitigate risks through early warning predictions. For regulatory compliance, it equips PPKs with robust, evidence-based decision-making tools, ensuring adherence to procurement regulations and professional engineering standards. Ultimately, by improving the precision and timeliness of irrigation rehabilitation, the research contributes directly to strengthening irrigation infrastructure, supporting agricultural productivity, and accelerating the achievement of national food self-sufficiency objectives.

METHOD

This methodology adopts a structured system development framework that is validated through a technical proposal with the following stages:

This stage maps out the juridical and conceptual foundations including:

a) Strategic Regulation: Presidential Instruction No. 2 of 2025 (Food Self-Sufficiency) and Presidential Decree No. 46 of 2025 (Procurement of Goods/Services).
b) Professional Standards: Engineer Code of Ethics (KEI) 2021.
c) Technology: Application of AI, Machine Learning (ML), and Computer Vision (CV) in construction.

The results of the observations confirm the dominance of biased and non-real-time manual methods. Further analysis found the "system gap" in the contract implementation monitoring phase, namely the gap between the selection platform (LPSE/E-Catalogue) and performance assessment (SIKaP) which is the focus of SIMORI's solution. AI.

System Needs Analysis

a) Functional: Real-time dashboard, physical progress detection via CV, delay prediction via ML, Chatbot mitigation, and Whistleblowing System (WBS).
b) Non-Functional: The system must be scalable, reliable, and interoperable with government APIs (PUPR/LKPP).
c) Target: CV analysis accuracy of 97.8%.

AI Architecture Design and Development

a) Technical Architecture: Cloud-based and Containerized (Docker), using Python Backend, PostgreSQL Database (PostGIS), and React.js/Vue.js Frontend.
b) AI Module:
   - Visual Monitoring (CV): OpenCV and Google Gemini Vision API integration for automatic physical progress quantification of photos/drones.
   - Risk Prediction (ML): Using Regression and Decision Tree algorithms (Python/TensorFlow) to predict delays based on historical and weather data.
   - Recommendation (NLP): Field assistant chatbot for instant mitigation suggestions.

Evaluation and Analysis

The evaluation was carried out through a pilot project at the Serang Regency PUPR Office which includes: a) Technical Validation: Computer Vision (CV) accuracy was validated using a dataset comprising 500 labeled images of irrigation construction work, including lining, excavation, and rock pairing activities. Performance metrics included precision, recall, and F1-score, with a target accuracy of 97.8%. Machine Learning (ML) prediction accuracy was assessed using historical project data (2020-2024) and validated against actual completion timelines, employing Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) as evaluation metrics. b) Functional Evaluation: Supervision time efficiency was measured by comparing the average time required for manual field inspections and report generation (baseline: 4-6 hours per site visit) against SIMORI-assisted monitoring. The pilot project tracked time savings across 15 irrigation rehabilitation sites over a three-month period, recording reductions in documentation time, report compilation, and decision-making processes. c) Professionalism: Increased objectivity and compliance with professional ethics (KEI).

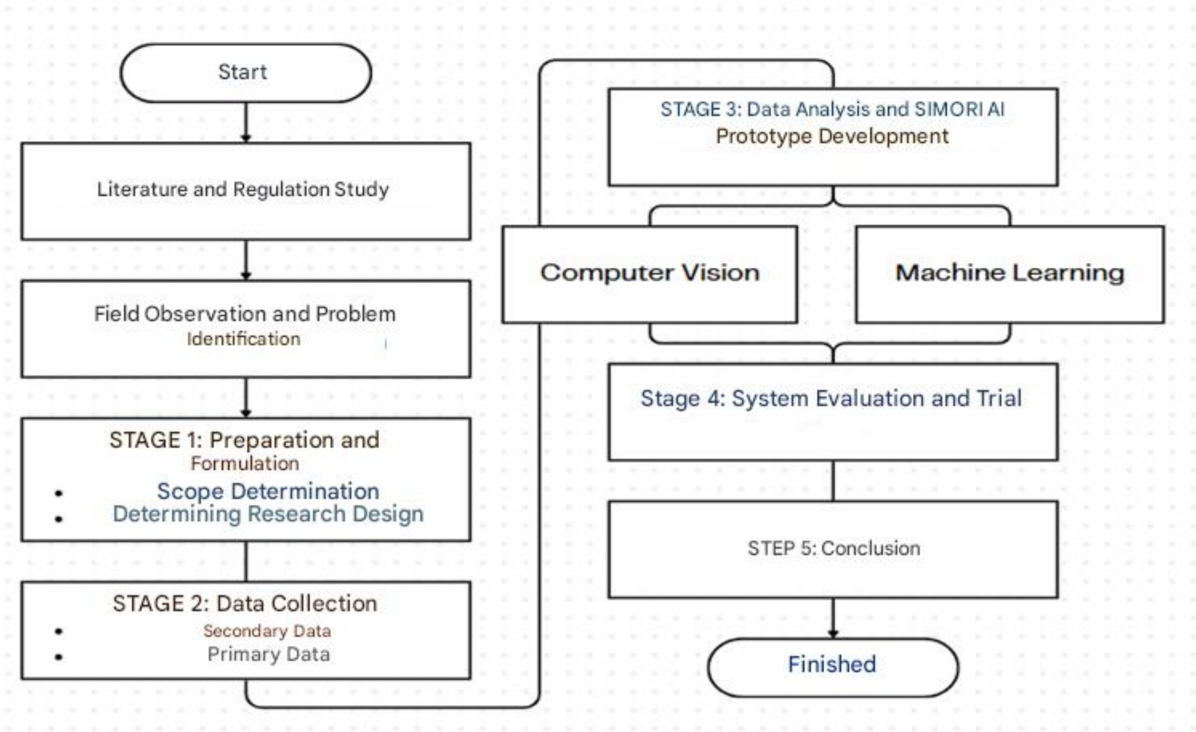

Figure 1. Flow chart of research methods of information monitoring system based Artificial Intelligence for Improved Supervision of Irrigation Rehabilitation Work

RESULTS AND DISCUSSIONS

Results of Identification of Irrigation Rehabilitation Monitoring Problems

The use of information technology in irrigation management has been carried out extensively, including the use of Geographic Information Systems (GIS) for mapping irrigation networks has been proven to improve the accuracy of documentation and the efficiency of field supervision (Adil & Triwijoyo, 2021; Bakti, 2019). In addition, other research shows that the integration of web-based GIS can improve the transparency and availability of spatial data of irrigation networks (Ernawati et al., 2014; Ghozali et al., 2023). Based on these findings, digitalization of monitoring is an urgent need. However, field observations show the existence of fundamental and systemic problems in current practice:

1. Reliance on Manual Reporting: Documentation via private messages and non-standardized physical reports leads to potential bias and data deviation between actual progress and administration.
2. Absence of Digital Trail Audits: The absence of digital footprints makes it difficult to trace supervision and opens gaps for administrative errors and moral hazards.
3. Non-Real-Time Inspection: Reports that are late in result in deviation mitigation not being able to be performed immediately.
4. System Integration Vacancies: There is a "system vacuum" at the contract execution stage—between the LPSE (selection) and SIKaP (performance appraisal) platforms—which are the target of SIMORI's integration.
5. Lack of Objective Validation: Difficulty verifying manual reports objectively, the solution of which will be answered by Computer Vision technology.

The problem of delays in field data flow is in line with the study Sumarsono et al. (2023) which emphasizes the importance of web-based systems to speed up data communication.

Results of Regulatory Analysis and Its Conformity with SIMORI

1. Conformity with Presidential Instruction No. 2 of 2025

SIMORI is aligned with the strategy of accelerating food self-sufficiency which demands the reliability of irrigation infrastructure. This system overcomes slow and inaccurate monitoring by providing real-time progress data, quality validation, and anomaly detection as the basis for strategic decision-making for the PPK.

2. Conformity with Presidential Regulation No. 46 of 2025 (PBJP)

SIMORI functions as an instrument to fulfill the obligations of the PPK to verify physical progress and specifications in a transparent and data-based manner. This is facilitated through automated geotagged reports, anti-tampering digital records, and late detection via Machine Learning, ensuring accountable and auditable contract execution.

Results of AI-Based SIMORI System Development
Computer Vision Module

Achieve 97.8% accuracy in detecting the type of work (lining, excavation, rock pairing), measuring volume through pixel mapping, and comparing field photos with technical standards to ensure objectivity. The Computer Vision Module at SIMORI. AI is seen in Figure 2.

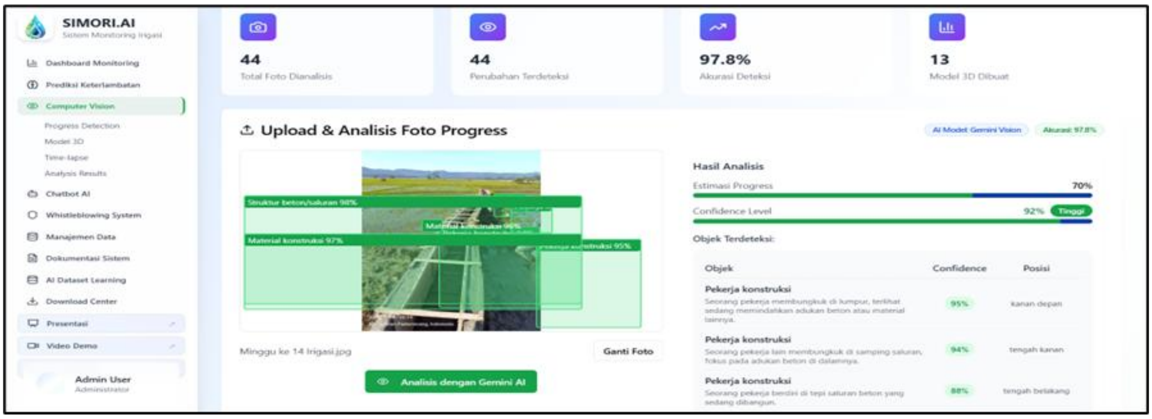

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Figure 2. Computer Vision module on SIMORI. AI

1. Modules Machine Learning for Risk Prediction

With a trend prediction accuracy of >90%, this module processes historical, weather, and S-Curve data to predict potential delays, provide a risk score, and suggest automatic mitigation measures, as shown in Figure 3.

Figure 3. Machine *Learning* Module for Risk Prediction on SIMORI. AI

Dashboard Monitoring Real-Time

A web/mobile-based platform that accelerates monitoring by visually displaying daily physical progress, completion status, geotagging location, and deviation graphs. This makes monitoring faster and more accurate. The Real Time Monitoring Dashboard can be seen in Figure 4.

Figure 4. Real-Time Monitoring Dashboard on SIMORI. AI

Features of the Whistleblowing System (WBS)

Increase the role of public oversight by facilitating the reporting of infrastructure irregularities through the sending of photos, videos, or text messages. The features of the Whistleblowing System are presented in Figure 5.

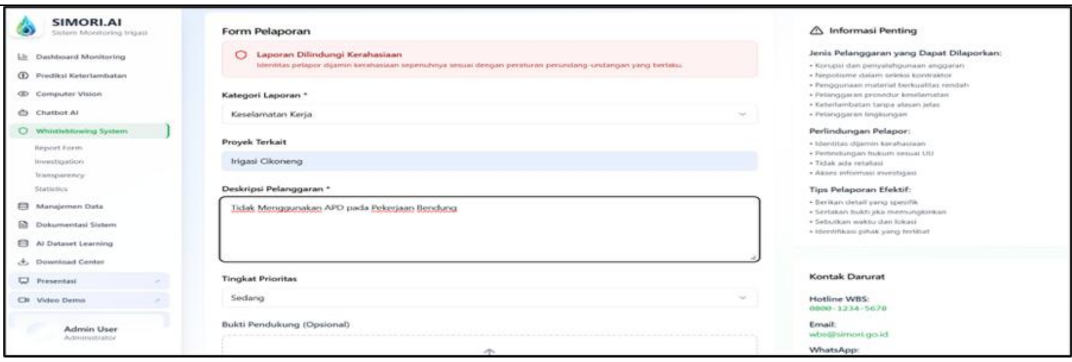

Figure 5. Whistleblowing System (WBS) feature on SIMORI. AI

The Impact of SIMORI Implementation on Irrigation Project Governance

1. Increased Transparency and Accountability: All progress is digitally recorded, documented, and publicly verifiable.
2. Supervision Efficiency: The availability of real-time data cuts down on supervision time as PPK does not have to wait for physical inspections.
3. Risk Reduction: The risk prediction feature provides early warning to minimize project deviations and delays.
4. Strengthening Evidence-Based Decisions: Supporting the PPK in making decisions that are fast, precise, and defensible technically and administratively.

CONCLUSION

Based on the research results, regulatory analysis, system trials, and evaluation of the SIMORI application as an Irrigation Rehabilitation Monitoring Information System based on artificial intelligence, several conclusions can be drawn. The AI-based SIMORI concept, incorporating Computer Vision and Machine Learning, has been successfully developed to address systemic gaps in conventional supervision, such as manual data inaccuracies and the lack of audit trails. SIMORI has proven to improve supervisory effectiveness by enhancing efficiency and transparency through real-time data, automated anomaly detection, and digital audits, minimizing assessment bias, reducing progress deviations, and offering significant advantages over manual methods. The application of AI in risk analysis and automated mitigation recommendations supports the PPK in making quick, accurate, and data-driven technical and administrative decisions, strengthening good governance, PBJP regulation compliance, and the professionalism of engineers. Regarding advice, the system's implementation should be carried out in stages across various irrigation areas in Serang Regency to test technical stability, validate accuracy, and assess organizational readiness. Structured training for operators and PPKs should be prioritized to ensure optimal system utilization and alignment between technology and user competencies. Further development should integrate weather data and river discharge to enhance the accuracy of predicting delays due to natural factors. Long-term impact evaluation is also needed to measure the system's influence on cost efficiency, infrastructure service life, and agricultural productivity. Finally, local governments are encouraged to draft formal regulations to provide a legal foundation for the system's sustainability and standardize project supervision.

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