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Evaluation of P2TL Operation Digitalization: Analysis of Factors Affecting Digitalization Effectiveness and Its Impact on P2TL Performance at PLN UID Kaltimra

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ABSTRACT

This study examines the factors influencing the effectiveness of the *Efficiency Program Monitoring (EPM)* application, implemented by PLN UID KALTIMRA in mid-2024 to enhance customer inspection and improve the *Electricity Usage Control (P2TL)* process. The research addresses a critical gap in understanding the challenges faced during the digitalization of operational processes, specifically the impact of digital tools on key performance indicators (KPIs) in utility companies. Despite the implementation of the EPM application, field findings showed a decline in inspection results, highlighting the need for deeper exploration of the reasons behind this outcome. Using a quantitative research approach, this study adopts a case study strategy with survey design. Primary data were collected through questionnaires distributed to all field officers and relevant staff, while secondary data were sourced from PLN UID KALTIMRA's internal reports. Data were analyzed using Structural Equation Modeling (SEM) to identify relationships between application stability, process-technology fit, user-friendliness, management support, and digitalization effectiveness. The findings indicate that application stability, process-technology fit, and user-friendliness positively affect the effectiveness of the EPM, while management support did not significantly influence outcomes. Furthermore, while the EPM implementation positively affected job satisfaction, it did not significantly improve P2TL kWh realization. This suggests that the success of digital transformation in utility companies hinges not only on technological adoption but also on aligning processes with technology and ensuring user engagement. The study offers practical recommendations for enhancing user experience and increasing the effectiveness of digital tools in operational settings.

Keywords: digitalization; efficiency; job satisfaction; electricity theft; digital transformation

INTRODUCTION

Energy constitutes a fundamental necessity in contemporary human existence, with electrical energy serving as the cornerstone of modern civilization. In the current era of globalization and digitalization, virtually all aspects of human life depend on the availability of reliable and sustainable electricity supply (Oliveira et al., 2022; IEA, 2023; REN21, 2023; Zhao et al., 2020). The global energy landscape is experiencing unprecedented transformation, driven by technological advancement and environmental consciousness, fundamentally reshaping how energy is produced, distributed, and consumed (Verhoef et al., 2021).

Global capacity for renewable electricity generation has developed at an unprecedented pace over the last three decades, according to the International Energy Agency, coinciding with an accelerated transition from fossil fuels to renewable energy sources (Verhoef et al., 2021;

IRENA, 2023). This transformation reflects a broader paradigm shift in global energy policy and technological innovation. The agency projects that by 2025, renewable energy will surpass coal to become the world's primary electricity source, with wind and solar photovoltaic power generation expected to exceed nuclear power generation by 2025 and 2026, respectively. Furthermore, by 2028, an estimated 68 countries will establish renewable energy as their primary electricity source, demonstrating the magnitude of this global energy transition (Oliveira et al., 2022).

According to the World Economic Forum 2024 report, Indonesia ranks among Southeast Asian countries with the highest energy transition index in 2024, achieving an index score of 56.7, comprising 69.9 points for the system performance dimension and 36.9 points for the transition readiness dimension, positioning the country 54th globally. However, this achievement contrasts sharply with Indonesia's electricity consumption patterns. Based on Ministry of Energy and Mineral Resources (ESDM) data, electricity consumption realization in 2023 reached 1,337 kWh per capita, significantly below the ASEAN average of 3,896 kWh per capita. While countries like the Philippines, Myanmar, Cambodia, and Timor Leste demonstrate lower consumption than Indonesia, nations such as Vietnam, Thailand, Malaysia, Laos, Singapore, and Brunei Darussalam exhibit substantially higher per capita electricity consumption rates (Lund et al., 2015; Zhang et al., 2021).

This consumption gap presents both challenges and opportunities for Indonesia's state-owned electricity company, PT Perusahaan Listrik Negara (PLN), which bears responsibility for electricity supply to Indonesian society and industry. PLN has implemented comprehensive strategies to increase electricity consumption, including Electrifying Lifestyle programs encouraging households to adopt electricity-based appliances such as induction cookers and electric vehicles; Electrifying Agriculture and Marine initiatives replacing fossil fuel usage with electricity in agricultural and marine activities; Captive Power acquisition replacing company-owned generators with PLN supply; Electric Vehicle Infrastructure development with a 299% increase in public charging stations throughout 2024; Incentive Programs for power addition offering discounts during specific periods; and Service Enhancement through digitalization, including the PLN Mobile application for streamlined connection processes (Heizer et al., 2017).

These efforts to increase electricity consumption cannot be separated from the imperative to maintain distribution system efficiency. Enhanced electricity sales must be accompanied by reliable network management with minimal energy losses. One critical indicator in distribution system efficiency is distribution losses, defined by PLN Director Regulation No. 0021.P/DIR/2018 as energy differences (kWh) between energy received on the transmission side and energy sold to customers after deducting energy used for internal transmission and distribution purposes. Distribution losses comprise technical losses influenced by material properties such as conductor cables and distribution transformers, and non-technical losses uninfluenced by material properties, including electricity theft, meter reading errors, and unauthorized public street lighting (Firoozi & Rajabi Mashhadi, 2022).

To prevent energy loss due to electricity theft, PLN conducts *Electricity Usage Control (P2TL)* activities based on PLN Director Regulation No. 0028.P/DIR/2023. *P2TL* encompasses planning, inspection, technical and/or legal actions, and resolution activities conducted by PLN toward PLN installations and/or Customer Electrical Installations. Four violation types exist:

Type I violations affecting power limits but not energy measurement; Type II violations affecting energy measurement but not power limits; Type III violations affecting both power limits and energy measurement; and Type IV violations committed by non-customers (Diyarto et al., 2022).

Under PLN's Distribution Director, three Regional Distribution Operations exist: Sumatra-Kalimantan Regional, Java-Madura-Bali Regional, and Sulawesi-Maluku-Papua-Nusa Tenggara Regional, with Sumatra-Kalimantan Regional exhibiting the highest distribution losses. Among 10 Distribution Business Units under Sumatra-Kalimantan Regional, *UID KALTIMRA* ranks third in distribution loss achievement relative to targets, following *UID Lampung* and *UID Bangka Belitung*. However, *P2TL* achievement at *UID KALTIMRA* failed to reach 2024 targets, declining 6.83% compared to 2023 performance.

P2TL implementation at PLN *UID KALTIMRA* is conducted by third parties determined through E-Proc auction systems. *P2TL* contracts at PLN *UID KALTIMRA* commenced January 1, 2024, based on PLN Implementation Regulation No. 0055.E/DIR/2023 regarding Outsourcing Management Standard Procedures. Contracts follow volume-based systems, with *P2TL* cost calculations based on realized inspection quantities and discovered kWh or energy findings. According to Appleton (2017), Key Performance Indicators (KPIs) serve as managerial tools designed to measure and monitor strategic organizational goal achievement, functioning as calculable, pre-agreed measures directly reflecting organizational success factors.

For Distribution Network Efficiency achievement, two performance indicators exist at each UP3: Distribution Losses without E-min and *P2TL* kWh Acquisition. *P2TL* target achievement at PLN *UID KALTIMRA* demonstrates concerning trends. In 2023, *P2TL* targets were missed three times—in April, July, and November—but in 2024, targets were achieved only in December. *P2TL* achievement in 2023 reached 17,668,525 kWh against a target of 16,762,549 kWh (positive polarity), while 2024 *P2TL* achievement was 16,461,033 kWh against a target of 20,318,804 kWh, representing significant underperformance.

According to Kushariyadi et al. (2025), KPI implementation demonstrates a significant positive correlation with organizational effectiveness. However, KPI implementation faces challenges, particularly in organizations experiencing difficulties determining appropriate KPI quantities and types, causing confusion in priority determination. Technological developments enable real-time KPI monitoring, yet many companies face constraints in accurate KPI data collection. KPI establishment for Losses at UID level and Losses plus *P2TL* at UP3 and ULP levels creates specific challenges for PLN units, where *P2TL* achievement doesn't necessarily boost Loss achievement, and conversely, Distribution Loss achievement isn't necessarily caused by *P2TL* achievement.

As a performance improvement effort, *P2TL* implementation has utilized the *Efficiency Program Monitoring (EPM)* customer inspection application since July 15, 2024, following PLN Headquarters letter No. 37723/DIS.01.02/F01050300/2024 dated July 8, 2024, regarding *EPM* Application Implementation. This application draws inspiration from one Distribution sub-field responsible for Losses and *P2TL*: EPMSD (Efficiency, Measurement, and Distribution System Quality) sub-field. The letter states that *EPM* application implementation constitutes one performance target in Corporate Application Digitalization Implementation for 2024, mandatory for all units down to the smallest units. This application contains important information including customer and meter identity, measured voltage and current, meter deviation or error, inspection time, meter constants, and inspection result notes.

However, *EPM* application implementation has not been specifically studied for its contribution to *P2TL* performance and effectiveness achievement. *EPM* usage has also failed to increase *P2TL* kWh realization, as shown by the 2024 realization of 16,461,033 kWh being lower than the 2023 realization of 17,668,525 kWh. Although *EPM* is expected to improve field officer work effectiveness, several technical constraints create new challenges potentially affecting job satisfaction. Some officers report frequent application access issues due to corporate server disruptions or weak cellular networks at inspection locations. Additionally, the system does not support repeated inspections within six months, while field conditions demand flexibility in customer tracking. When technical constraints occur, internal admin teams respond slowly, impacting work delays and officer psychological burden.

Digital transformation in operations management reflects not only cutting-edge technology usage but also demands systematic shifts in business processes and decision-making. According to Heizer et al. (2017), operational digital transformation is achieved through integrated technology applications like Enterprise Resource Planning (ERP), artificial intelligence (AI), and cloud computing to respond to continuously changing market needs. Digital transformation can be defined as performing activities differently through new business design creation utilizing digital technology applications, encompassing not just digitalization or automation of existing processes, but business model restructuring, value chain adjustment, and product and service innovation (Kahveci, 2025).

Research urgency emerges from the gap between *EPM* implementation expectations and actual *P2TL* performance results. According to Dimitriou et al. (2024), Total Quality Management constitutes a management philosophy aimed at achieving comprehensive customer satisfaction, minimizing costs, and actively involving all organizational members in continuous quality improvement. In *P2TL* implementation, twenty *P2TL* teams spread across six UP3 exist, with each team comprising three people. PLN *UID Kaltimra* previously used a local application called *P2TL* inspection application (AP2TL) with several deficiencies including inadequate data security due to paid web hosting data storage, limited capacity adjusted to unit operational budgets, high data leak possibilities, absence of crucial information and documentation like customer signatures and ID copies, and incomplete *P2TL* procedure support.

Previous research has predominantly focused on machine learning approaches for electricity theft detection rather than digitalization effectiveness in operational processes. Studies by Taruna et al. (2025) and Lepolesa et al. (2022) concentrated on technical detection methods using deep neural networks and machine learning algorithms. However, limited research examines digitalization impact on field officer satisfaction and operational performance in electricity companies. Research by Abril-Jiménez et al. (2024) developed a worker-centered KPI methodology for Industry 5.0, emphasizing human factors in digital transformation success assessment rather than pure automation approaches.

The novelty of this research lies in its comprehensive examination of digitalization effectiveness factors in electricity sector operational processes, specifically *P2TL* activities. Unlike previous studies focusing on technical detection aspects, this research investigates human factors, organizational support, and technology-process alignment in digital transformation success. Furthermore, this study uniquely examines third-party contractor perspectives in digitalization implementation, addressing a research gap in digital transformation literature that typically focuses on internal employee experiences.

This research aims to analyze factors influencing *EPM* application implementation effectiveness and examine its impact on *P2TL* kWh realization and field officer job satisfaction. Specifically, the study seeks to determine how application stability, management support, process-technology fit, and user-friendliness influence *EPM* implementation effectiveness, and subsequently how this effectiveness affects organizational performance and employee satisfaction.

The practical benefits include helping PLN *UID KALTIMRA* determine targeted work programs for distribution loss reduction and evaluate *P2TL* kWh achievement strategies more effectively by understanding *EPM-P2TL* correlations. Additionally, findings will assist in improving *P2TL* field officer capabilities and quality. Theoretically, this research contributes to digital transformation literature by providing empirical evidence of effectiveness factors in public utility digitalization, particularly regarding third-party contractor adaptation to digital systems.

Research implications extend to policy recommendations for PLN's broader digital transformation strategy, offering insights for effective technology implementation in operational processes. For academia, this study contributes to understanding digital transformation success factors in developing country contexts, particularly in essential service sectors. The findings also provide practical frameworks for organizations implementing digital solutions with mixed internal-external workforce structures, addressing challenges in change management and technology adoption across different employment relationships.

METHOD

This research used a causal quantitative approach with a case study strategy and a cross-sectional survey design. The study examined how factors such as application stability, management support, process-technology fit, and user-friendliness influenced *EPM* implementation effectiveness, which then impacted *P2TL* kWh realization and job satisfaction.

The population consisted of 103 people, including 74 field officers and 29 internal employees involved in *P2TL* activities at PLN *UID KALTIMRA*. Based on the Krejcie & Morgan table for a population of 100, the minimum sample size was 80 respondents. Primary data were collected through questionnaires using a Likert scale (1–5) measuring respondent perceptions, while secondary data came from PLN *UID KALTIMRA* internal reports covering July 2024 to April 2025.

Data analysis used Structural Equation Modeling-Partial Least Squares (SEM-PLS) to test relationships between variables simultaneously. Model evaluation included outer model assessment (indicator reliability, internal consistency reliability, convergent validity, discriminant validity) and inner model assessment (multicollinearity, explanatory power, predictive relevance). Hypothesis testing used the bootstrapping method with a significance level of $\alpha = 0.05$.

Mathematically, the SEM-PLS model is written as:

$\eta = B\eta + \Gamma\xi + \zeta$ (1)

Where:

a. ξ = exogenous variables (X1-X4)
b. η = endogenous variables (Y, Z1, Z2)
c. Γ = coefficient of effect from exogenous to endogenous
d. B = coefficient between endogenous variables (Y to Z1/Z2)
e. ζ = residual or error

RESULTS AND DISCUSSION

Respondent Characteristics and Descriptive Data

The research involved 103 respondents from two categories of companies involved in P2TL implementation at PLN UID KALTIMRA. The first category comprised PT Dinamika Energi Indonesia (PT DEI), representing 72% or 74 field officers who serve as third-party P2TL implementation personnel. The second category consisted of PT PLN UID KALTIMRA employees, accounting for 28% or 29 internal staff including Team Leaders at Customer Service Units (ULP) and Customer Service Implementation Units (UP3). This distribution demonstrates that P2TL activities heavily depend on third-party contractor competencies in identifying violations.

Table 1. Respondent Characteristics by Company

Company	Frequency	Percentage
PT DEI	74	72%
PT PLN UID KALTIMRA	29	28%
Total	103	100%

The distribution across six work units showed UP3 Samarinda contributing 34% of respondents and UP3 Balikpapan 25%. This indicates that UP3 Samarinda and Balikpapan cover extensive work areas, requiring more personnel compared to other UP3s including UP3 Berau, UP3 Bontang, UP3 Kaltara, and UP3 Nusantara.

Table 2. Respondent Characteristics by Work Unit

Work Unit	Frequency	Percentage
UP3 Samarinda	35	34%
UP3 Balikpapan	26	25%
UP3 Berau	11	11%
UP3 Bontang	10	10%
UP3 Kaltara	11	11%
UP3 Nusantara	10	10%
Total	103	100%

Data Interpretation Framework

The interpretation of questionnaire scores utilized a five-point scale framework where values were categorized as follows: 20%-36% (Very Poor), 36%-52% (Poor), 52%-68% (Adequate), 68%-84% (Good), and 84%-100% (Very Good). This framework provided standardized assessment criteria for all research variables.

Variable Analysis and Descriptive Statistics

Application Stability Variable Analysis

Application stability emerged as a critical factor in EPM implementation effectiveness. The variable demonstrated an average score of 3.1 across five indicators, indicating adequate but concerning performance levels. The analysis revealed significant variations among indicators, with X1.3 (EPM stability despite poor network conditions) recording the lowest mean of 2.5, representing the only indicator with "Poor" interpretation at 50%.

Table 3. Application Stability Descriptive Statistics

Indicator	Description	Min	Max	Mean	Std. Dev
X1.1	EPM runs smoothly without technical disruptions	1	5	3.3	0.9
X1.2	Application rarely experiences errors when used	1	5	3.1	0.9
X1.3	EPM remains stable despite poor network conditions	1	5	2.5	0.8
X1.4	EPM can be relied upon at all times	1	5	3.3	0.8
X1.5	Application is always responsive when used	2	5	3.4	0.8
Overall		1	5	3.1	0.9

Table 4. Application Stability Score Distribution

Indicator	Score Distribution					Total Score	Ideal Score	Percentage	Interpretation
	1	2	3	4	5				
X1.1	1	38	117	152	30	338	515	66%	Adequate
X1.2	2	54	105	140	20	321	515	62%	Adequate
X1.3	7	102	96	44	10	259	515	50%	Poor
X1.4	1	34	123	160	20	338	515	66%	Adequate
X1.5	0	30	108	192	20	350	515	68%	Good
Total	**11**	**258**	**549**	**688**	**100**	**1606**	**2575**	**62%**	**Adequate**

The concerning aspect of application stability lies in the fact that four indicators recorded minimum values of 1, indicating significant user dissatisfaction with EPM stability. The X1.3 indicator's poor performance specifically highlights infrastructure challenges in field environments where network connectivity remains inconsistent.

Management Support Variable Analysis

Management support demonstrated significantly better performance with an overall average of 3.8, achieving "Good" interpretation at 76%. All five indicators received "Good" ratings, suggesting that PLN UID KALTIMRA management provides adequate support for EPM implementation across various dimensions.

Table 5. Management Support Descriptive Statistics

Indicator	Description	Min	Max	Mean	Std. Dev
X2.1	UID management fully supports EPM usage	2	5	4.0	0.6
X2.2	Received adequate EPM training	1	5	3.4	0.8
X2.3	Received guidance from UID management	2	5	3.7	0.7
X2.4	UID management is open to EPM feedback	2	5	3.9	0.6
X2.5	UID management actively monitors EPM usage	1	5	4.0	0.7
Overall		1	5	3.8	0.7

Table 6. Management Support Score Distribution

Indicator	Score Distribution					Total Score	Ideal Score	Percentage	Interpretation
	1	2	3	4	5				
X2.1	0	2	54	260	95	411	515	80%	Good
X2.2	2	16	132	168	35	353	515	69%	Good
X2.3	0	6	99	224	55	384	515	75%	Good
X2.4	0	2	66	268	65	401	515	78%	Good
X2.5	1	0	48	256	110	415	515	81%	Good
Total	**3**	**26**	**399**	**1176**	**360**	**1964**	**2575**	**76%**	**Good**

The management support variable showed consistent high performance, with X2.1 (full management support) and X2.5 (active monitoring) achieving the highest scores at 80% and 81% respectively. However, X2.2 (adequate training) recorded the lowest score at 69%, indicating potential improvement areas in training provision.

Process-Technology Fit Variable Analysis

Process-technology fit achieved strong performance with an overall average of 3.8 and "Good" interpretation at 77%. All indicators demonstrated consistent performance, suggesting successful alignment between EPM application features and P2TL operational requirements.

Table 7. Process-Technology Fit Descriptive Statistics

Indicator	Description	Min	Max	Mean	Std. Dev
X3.1	EPM facilitates field task implementation	2	5	3.8	0.7
X3.2	EPM indicators match required inspection activities	2	5	3.8	0.7
X3.3	P2TL work processes are structured with EPM	2	5	3.9	0.6
X3.4	EPM features match applicable SOPs	3	5	4.0	0.5
X3.5	EPM supports daily work smoothness	2	5	3.8	0.7
Overall		2	5	3.8	0.6

Notably, X3.4 (SOP compliance) achieved the highest score at 79%, with no respondents expressing dissatisfaction (no score 1 responses), indicating excellent alignment between EPM features and standard operating procedures.

User-Friendliness Variable Analysis

User-friendliness demonstrated good performance with an overall average of 3.6 and 72% achievement. However, this variable showed more variability in user satisfaction compared to process-technology fit.

Table 9. User-Friendliness Descriptive Statistics

Indicator	Description	Min	Max	Mean	Std. Dev
X4.1	EPM is easy to use from the first time	1	5	3.5	0.8
X4.2	Navigation in EPM application is easy to follow	2	5	3.7	0.7
X4.3	Short time required to understand EPM	2	5	3.6	0.7
X4.4	EPM has an attractive interface	2	5	3.5	0.7
X4.5	Feel comfortable using EPM application daily	1	5	3.6	0.8
Overall		1	5	3.6	0.7

Two indicators (X4.1 and X4.5) recorded minimum values of 1, indicating some users found EPM extremely difficult to use initially and felt very uncomfortable with daily usage.

EPM Implementation Effectiveness Variable Analysis

EPM implementation effectiveness achieved an overall average of 3.7 with "Good" interpretation at 75%. This variable represents the central construct measuring digitalization success in P2TL operations.

Table 10. EPM Implementation Effectiveness Descriptive Statistics

Indicator	Description	Min	Max	Mean	Std. Dev
Y.1	EPM helps improve P2TL inspection quality	2	5	3.8	0.7
Y.2	EPM facilitates field data recording	2	5	3.8	0.7
Y.3	EPM makes work more efficient	2	5	3.7	0.8
Y.4	EPM supports inspection data accuracy	2	5	3.9	0.6
Y.5	EPM implementation meets expectations	1	5	3.5	0.7
Overall		1	5	3.7	0.7

Y.5 (meeting expectations) recorded the lowest mean at 3.5 and was the only indicator with minimum value 1, suggesting some respondents felt EPM implementation requires further improvement.

Job Satisfaction Variable Analysis

Job satisfaction demonstrated consistent performance with an overall average of 3.6 and "Good" interpretation at 72%. This variable measures the human impact of digitalization on workforce satisfaction.

Table 11. Job Satisfaction Descriptive Statistics

Indicator	Description	Min	Max	Mean	Std. Dev
Z2.1	Feel satisfied with EPM application	1	5	3.6	0.7
Z2.2	Feel motivated working with EPM application	2	5	3.6	0.7
Z2.3	Feel comfortable with EPM application	2	5	3.6	0.7
Z2.4	Feel productive with EPM application	2	5	3.7	0.6
Z2.5	Experience work ease with EPM application	1	5	3.7	0.8
Overall		1	5	3.6	0.7

P2TL kWh Realization Variable Analysis

P2TL kWh realization data derived from PLN UID KALTIMRA internal reports spanning July 2024 to April 2025. The analysis divided the ten-month period into five bi-monthly indicators, each scored based on target achievement percentages.

Table 12. P2TL kWh Realization Performance Data

Period	Target (kWh)	Realization (kWh)	Achievement (%)	Score Assignment
Jul-Aug 2024	3,369,067	2,769,460	82.2%	4
Sep-Oct 2024	3,369,067	2,641,925	78.4%	4
Nov-Dec 2024	3,369,067	3,062,713	90.9%	5
Jan-Feb 2025	3,333,333	3,297,720	98.9%	5
Mar-Apr 2025	3,333,333	2,823,858	84.7%	4

Table 13. P2TL kWh Realization Score Distribution

Indicator	Score Distribution					Total Score	Ideal Score	Percentage	Interpretation
	1	2	3	4	5				
Z1.1 (Jul-Aug 2024)	0	0	168	28	200	396	515	77%	Good
Z1.2 (Sep-Oct 2024)	1	10	111	196	55	373	515	72%	Good
Z1.3 (Nov-Dec 2024)	0	4	18	320	75	417	515	81%	Good
Z1.4 (Jan-Feb 2025)	1	0	15	116	340	472	515	92%	Very Good
Z1.5 (Mar-Apr 2025)	0	8	90	140	170	408	515	79%	Good
Total	**2**	**22**	**402**	**800**	**840**	**2066**	**2575**	**80%**	**Good**

The P2TL kWh realization variable achieved the highest overall performance at 80% with "Good" interpretation. Notably, Z1.4 (January-February 2025) recorded "Very Good" performance at 92%, indicating improving P2TL effectiveness in recent periods.

Measurement Model Evaluation

Outer Model Assessment

The measurement model evaluation employed Partial Least Squares Structural Equation Modeling (PLS-SEM) approach, beginning with outer model assessment to ensure indicator reliability and validity.

Outer Loading Analysis

Outer loading values indicate the strength of relationships between indicators and their respective constructs. Hair et al. (2022) recommend outer loading values above 0.708, with values between 0.40-0.70 acceptable under specific conditions.

Table 14. Outer Loading Results Summary

Variable	Indicator Range	Loading Range	Status
Application Stability (X1)	SA1-SA5	0.606-0.867	Mixed (some below 0.7)
Management Support (X2)	DM1-DM5	0.757-0.844	All acceptable
Process-Technology Fit (X3)	KPA1-KPA5	0.779-0.906	All acceptable
User-Friendliness (X4)	KP1-KP5	0.754-0.842	All acceptable
EPM Implementation Effectiveness (Y)	EI1-EI5	0.750-0.893	All acceptable
P2TL kWh Realization (Z1)	TL1-TL5	0.362-0.909	Mixed (some below 0.4)
Job Satisfaction (Z2)	KK1-KK5	0.855-0.915	All acceptable

Variables X2, X3, X4, Y, and Z2 demonstrated satisfactory outer loading values. Variables X1 and Z1 showed some indicators below recommended thresholds but were retained due to conceptual importance and theoretical relevance.

Internal Consistency Reliability

Three reliability measures assessed internal consistency: Cronbach's Alpha, Composite Reliability (rho_c), and rho_A.

Table 15. Reliability Assessment Results

Variable	Cronbach's Alpha	Composite Reliability (rho_c)	rho_A	AVE	Status
X1	0.825	0.876	0.855	0.589	Acceptable
X2	0.859	0.899	0.860	0.640	Good
X3	0.917	0.938	0.920	0.753	Excellent
X4	0.856	0.896	0.864	0.634	Good
Y	0.903	0.928	0.904	0.723	Excellent
Z1	0.806	0.804	0.547	0.469	Problematic
Z2	0.932	0.948	0.933	0.786	Excellent

All variables except Z1 demonstrated adequate to excellent reliability. Z1's lower values reflect the complexity of measuring organizational performance through bi-monthly achievement indicators.

Convergent Validity Assessment

Average Variance Extracted (AVE) values assess convergent validity, with minimum threshold of 0.5 indicating that constructs explain at least 50% of indicator variance.

Six variables achieved adequate convergent validity (AVE > 0.5), while Z1 fell slightly below at 0.469. Despite statistical limitations, Z1 was retained due to its critical role in measuring digitalization impact on organizational performance.

Discriminant Validity Testing

Heterotrait-Monotrait Ratio (HTMT) assessment revealed some construct correlations exceeding 0.90 threshold, particularly between X3-X4 (0.938), X3-Y (0.942), X4-Y (0.932), X4-Z2 (0.917), and Y-Z2 (0.918). These high correlations suggest conceptual overlap but were deemed acceptable given strong theoretical distinctions between constructs.

Structural Model Evaluation

Multicollinearity Assessment

Variance Inflation Factor (VIF) testing examined multicollinearity potential among predictor constructs.

Table 16. VIF Assessment Results

Structural Path	VIF Value	Assessment
X1 → Y	2.194	Good (< 3)
X2 → Y	2.727	Good (< 3)
X3 → Y	4.094	Acceptable (< 5)
X4 → Y	4.003	Acceptable (< 5)
Y → Z1	1.000	Excellent
Y → Z2	1.000	Excellent

All VIF values remained below the critical threshold of 5, indicating acceptable multicollinearity levels for PLS-SEM analysis.

Model Explanatory Power

R^2 values measure the proportion of variance in endogenous constructs explained by their predictors.

Table 17. R^2 and Effect Size Analysis

Endogenous Variable	R^2 Value	Interpretation	f^2 Effects
EPM Implementation Effectiveness (Y)	0.798	Substantial	X3→Y: 0.304 (medium-large)
P2TL kWh Realization (Z1)	0.035	Weak	Y→Z1: 0.036 (small)
Job Satisfaction (Z2)	0.710	Moderate	Y→Z2: 2.451 (large)

The model demonstrates strong explanatory power for EPM implementation effectiveness (79.8%) and moderate power for job satisfaction (71.0%), but weak explanatory power for P2TL kWh realization (3.5%).

Effect size analysis using Cohen's f^2 criteria revealed:

a. X3 (Process-Technology Fit) shows medium to large effect on Y
b. X1 (Application Stability) and X4 (User-Friendliness) show small effects on Y
c. X2 (Management Support) shows negligible effect on Y
d. Y shows large effect on Z2 but small effect on Z1

Predictive Relevance Assessment

Stone-Geisser's Q^2 values assess model predictive relevance using blindfolding technique.

Table 18. Predictive Relevance Results

Construct	SSO	SSE	Q^2 (=1-SSE/SSO)	Interpretation
Y	400.000	177.577	0.556	Strong predictive relevance
Z1	400.000	401.970	-0.005	No predictive relevance
Z2	400.000	179.978	0.550	Strong predictive relevance

Q^2 values above zero indicate predictive relevance. Y and Z2 demonstrate strong predictive relevance, while Z1 shows no predictive capability.

Hypothesis Testing Results

Bootstrapping analysis with 5,000 subsamples tested six hypotheses at 95% confidence level ($\alpha = 0.05$).

Table 19. Comprehensive Hypothesis Testing Results

Hypothesis	Structural Path	Original Sample (β)	Sample Mean	Standard Deviation	T Statistics	P Values	95% CI Lower	95% CI Upper	Decision
H1	X1 → Y	0.210	0.217	0.086	2.433	0.015	0.041	0.379	Accepted
H2	X2 → Y	0.013	0.012	0.086	0.155	0.877	-0.155	0.181	Rejected
H3	X3 → Y	0.502	0.501	0.109	4.613	0.000	0.289	0.715	Accepted
H4	X4 → Y	0.249	0.243	0.106	2.348	0.019	0.041	0.457	Accepted
H5	Y → Z1	-0.187	-0.171	0.210	0.893	0.372	-0.598	0.224	Rejected
H6	Y → Z2	0.843	0.844	0.037	22.741	0.000	0.770	0.916	Accepted

Detailed Hypothesis Analysis

H1: Application Stability → EPM Implementation Effectiveness (ACCEPTED)

The relationship between application stability and EPM implementation effectiveness proved statistically significant (β = 0.210, t = 2.433, p = 0.015). This indicates that improved application stability—characterized by smoother operation, fewer errors, network resilience, reliability, and responsiveness—significantly enhances perceived digitalization effectiveness. The finding aligns with DeLone & McLean (2003) information system success model and Jeyaraj (2020) meta-analysis emphasizing system quality importance in digital transformation success.

H2: Management Support → EPM Implementation Effectiveness (REJECTED)

Management support demonstrated no significant effect on EPM implementation effectiveness (β = 0.013, t = 0.155, p = 0.877). This unexpected finding contradicts established literature by Porfírio et al. (2021) and Zhang (2024) emphasizing leadership importance in digital transformation. However, it aligns with Chang & Chen (2025) findings in similar contexts. The result likely reflects the mandatory nature of EPM usage for third-party contractors, making perceived management support less influential on implementation effectiveness.

H3: Process-Technology Fit → EPM Implementation Effectiveness (ACCEPTED)

Process-technology fit showed the strongest relationship with EPM implementation effectiveness (β = 0.502, t = 4.613, p = 0.000). This highly significant relationship supports task-technology fit theory and aligns with Robu & Lazar (2021) findings that digitalization designed to support business strategy and employee work methods enhances transformation effectiveness. The strong coefficient indicates that alignment between EPM features and P2TL operational processes serves as the primary driver of implementation success.

H4: User-Friendliness → EPM Implementation Effectiveness (ACCEPTED)

User-friendliness significantly influences EPM implementation effectiveness (β = 0.249, t = 2.348, p = 0.019). This finding supports technology acceptance model principles and aligns with research by Ali et al. (2024) and Höyng & Lau (2023). Ease of use, intuitive navigation, quick learning curves, attractive interfaces, and daily usage comfort collectively enhance digitalization effectiveness perceptions.

H5: EPM Implementation Effectiveness → P2TL kWh Realization (REJECTED)

EPM implementation effectiveness does not significantly affect P2TL kWh realization (β = -0.187, t = 0.893, p = 0.372). This surprising finding indicates that perceived digitalization effectiveness doesn't automatically translate into improved organizational performance metrics. The result contrasts with expectations from Moro-Visconti et al. (2025) but supports Ancillai & Pascucci (2023) research suggesting digital transformation doesn't automatically improve performance in complex ecosystems. Several factors may explain this finding:

1) Implementation Maturity: EPM represents a monitoring tool rather than comprehensive analytical system
2) External Factors: P2TL performance depends on various factors beyond application effectiveness
3) Measurement Timeline: The study captured relatively early implementation stages
4) Performance Lag: Digital transformation benefits may require longer periods to manifest in performance metrics

H6: EPM Implementation Effectiveness → Job Satisfaction (ACCEPTED)

EPM implementation effectiveness demonstrates a strong positive relationship with job satisfaction (β = 0.843, t = 22.741, p = 0.000). This highly significant finding represents the strongest relationship in the model, indicating that effective digitalization substantially improves employee satisfaction. The result strongly supports Bolli & Pusterla (2022) research showing workplace digitalization positively impacts job satisfaction through enhanced work efficiency, task variety, and autonomy.

Theoretical Implications

The research findings contribute several important theoretical insights to digital transformation literature. First, the study validates the critical importance of process-technology fit in digitalization success, supporting task-technology fit theory in organizational contexts. The strongest relationship observed between process-technology fit and implementation effectiveness emphasizes that successful digital transformation requires careful alignment between technological capabilities and operational requirements.

Second, the unexpected non-significance of management support challenges traditional change management theories emphasizing leadership importance. This finding suggests that in mandatory technology adoption contexts, particularly involving third-party contractors, perceived management support may be less influential than previously assumed. This contributes to nuanced understanding of digital transformation success factors across different organizational relationships.

Third, the strong relationship between implementation effectiveness and job satisfaction while lacking impact on performance metrics reveals the complexity of digital transformation outcomes. This finding suggests that employee satisfaction benefits may emerge more quickly than organizational performance improvements, indicating different temporal patterns for various digitalization outcomes.

Practical Implications

The findings provide several actionable insights for PLN UID KALTIMRA and similar organizations implementing digital transformation initiatives:

Application Development Priorities: The strong influence of application stability and process-technology fit suggests that technical development efforts should prioritize system reliability and operational alignment over advanced features. Continuous technical improvements focusing on stability, error reduction, and field network resilience will yield greater implementation effectiveness.

Training and Support Strategies: While management support showed limited influence on implementation effectiveness, the strong relationship with job satisfaction indicates that employee-centered approaches remain valuable for workforce satisfaction and retention. Organizations should balance technical excellence with human-centered implementation strategies.

Performance Measurement Approaches: The disconnect between implementation effectiveness and P2TL kWh realization suggests need for more sophisticated performance measurement frameworks that account for digital transformation maturity stages and external influencing factors.

Limitations and Future Research Directions

The study acknowledges several limitations that provide opportunities for future research. First, the predominance of third-party contractor respondents may limit generalizability to internal employee populations. Future research should examine whether digitalization effectiveness differs between internal employees and external contractors, potentially revealing different success factor patterns.

Second, the cross-sectional design captures implementation effectiveness at a single point in time, potentially missing temporal dynamics of digital transformation. Longitudinal studies could better understand how effectiveness factors evolve as organizations mature in their digitalization journey and how performance impacts emerge over extended periods.

Third, the study's focus on EPM application in P2TL operations, while providing deep contextual insights, may limit transferability to other digitalization initiatives. Future research should examine similar effectiveness factors across different operational processes and technological implementations to develop more generalizable digital transformation frameworks.

Mathematical Model Representation

The structural equation model employed in this research follows the fundamental PLS-SEM framework, mathematically represented through measurement and structural model equations. For reflective constructs, the relationship between latent variables and their indicators is expressed where each observed indicator is a function of its corresponding latent construct plus measurement error. In the case of Application Stability (X_1), the five indicators (SA_1 through SA_5) are each represented as $SA_1 = \lambda_{11}X_1 + \varepsilon_1$, where λ_{11} represents the factor loading of the first indicator on the first construct, and ε_1 represents the measurement error. This pattern continues for all indicators across all constructs, establishing the measurement model foundation.

The structural model relationships follow the general form $\eta = B\eta + \Gamma\xi + \zeta$, where η represents endogenous variables, ξ represents exogenous variables, B contains path coefficients between endogenous variables, Γ contains path coefficients from exogenous to endogenous variables, and ζ represents structural errors. Specifically for this research model, the equations become: $Y = \gamma_{11}X_1 + \gamma_{12}X_2 + \gamma_{13}X_3 + \gamma_{14}X_4 + \zeta_1$ for EPM Implementation Effectiveness, $Z_1 = \beta_{21}Y + \zeta_2$ for P2TL kWh Realization, and $Z_2 = \beta_{31}Y + \zeta_3$ for Job Satisfaction. The notation system employs λ_{ij} for factor loadings of indicator i on construct j, γ_{ij} for path coefficients from exogenous construct j to endogenous construct i, β_{ij} for path coefficients between endogenous constructs, ε_i for measurement error of indicator i, and ζ_i for structural error of endogenous construct i.

The final model with significant path coefficients demonstrates the relationships as $Y = 0.210X_1 + 0.013X_2 + 0.502X_3 + 0.249X_4 + \zeta_1$, $Z_1 = -0.187Y + \zeta_2$, and $Z_2 = 0.843Y + \zeta_3$. This mathematical representation reveals that Process-Technology Fit (X_3) exerts the strongest influence on EPM Implementation Effectiveness (Y) with a coefficient of 0.502, while Application Stability (X_1) and User-Friendliness (X_4) provide moderate positive influences with coefficients of 0.210 and 0.249 respectively. Management Support (X_2) shows negligible influence with a coefficient of only 0.013. Furthermore, EPM Implementation Effectiveness strongly predicts Job Satisfaction (Z_2) with a coefficient of 0.843, representing the strongest relationship in the model, but demonstrates no significant prediction of P2TL Performance (Z_1) with a negative coefficient of -0.187.

Comprehensive Results Summary

The comprehensive analysis of factors influencing EPM application implementation effectiveness and its impact on P2TL performance at PLN UID KALTIMRA reveals several critical insights:

Primary Findings

Factor Influence on Implementation Effectiveness:

1) Process-Technology Fit emerges as the strongest predictor ($\beta = 0.502$, $p < 0.001$), indicating that alignment between EPM features and P2TL operational requirements serves as the primary driver of digitalization success.
2) User-Friendliness demonstrates significant positive influence ($\beta = 0.249$, $p = 0.019$), confirming that ease of use, intuitive navigation, and interface design substantially affect implementation effectiveness.
3) Application Stability shows significant positive impact ($\beta = 0.210$, $p = 0.015$), validating the importance of technical reliability in digital transformation success.
4) Management Support surprisingly shows no significant influence ($\beta = 0.013$, $p = 0.877$), challenging conventional change management wisdom in third-party contractor contexts.

Implementation Effectiveness Outcomes:

1) Job Satisfaction receives strong positive impact ($\beta = 0.843$, $p < 0.001$), representing the most powerful relationship in the model and confirming digitalization's substantial human benefits.
2) P2TL kWh Realization shows no significant improvement ($\beta = -0.187$, $p = 0.372$), indicating that perceived implementation effectiveness doesn't automatically translate to operational performance gains.

Model Performance Metrics

The structural model demonstrates strong overall performance:

a. EPM Implementation Effectiveness $R^2 = 0.798$ (substantial explanatory power)
b. Job Satisfaction $R^2 = 0.710$ (moderate explanatory power)
c. P2TL kWh Realization $R^2 = 0.035$ (weak explanatory power)

Predictive relevance testing confirms strong model validity:

a. EPM Implementation Effectiveness $Q^2 = 0.556$ (strong predictive relevance)
b. Job Satisfaction $Q^2 = 0.550$ (strong predictive relevance)
c. P2TL kWh Realization $Q^2 = -0.005$ (no predictive relevance)

Strategic Implications

The findings provide actionable insights for digital transformation management:

1) Technical Development Priorities:
    a. Prioritize application stability improvements, focusing on network resilience and error reduction

   b. Ensure strong alignment between application features and operational processes
   c. Invest in user interface design and navigation simplicity
2) Human Resource Management:
   a. Recognize that effective digitalization significantly enhances job satisfaction
   b. Develop training programs that emphasize process alignment rather than just technical skills
   c. Consider differential approaches for internal employees versus third-party contractors
3) Performance Management:
   a. Develop more sophisticated metrics that account for digital transformation maturity
   b. Recognize temporal delays between implementation effectiveness and performance outcomes
   c. Implement complementary initiatives to maximize operational performance gains

Contribution to Digital Transformation Literature

This research contributes to digital transformation literature by:

1) Validating Task-Technology Fit Theory in public utility contexts, demonstrating its continued relevance in contemporary digital transformation initiatives.
2) Challenging Management Support Assumptions in mandatory technology adoption scenarios, particularly involving third-party contractors.
3) Revealing Performance-Satisfaction Divergence in digitalization outcomes, showing that employee benefits may emerge before organizational performance improvements.
4) Providing Empirical Evidence from developing country public utility contexts, addressing literature gaps in sector-specific digital transformation research.

The comprehensive analysis demonstrates that successful digital transformation requires careful attention to technical excellence, operational alignment, and user experience design, while acknowledging that organizational performance benefits may require longer maturation periods and complementary strategic initiatives.

CONCLUSION

This study concludes that application stability, process-technology fit, and user-friendliness positively and significantly influence EPM implementation effectiveness, while management support shows no significant effect. EPM implementation effectiveness significantly affects job satisfaction but does not influence P2TL kWh realization improvement. These findings indicate digitalization success depends not only on technology adoption but also on process alignment and user engagement. For EPM application developers, continuous technical improvements focusing on stability, process alignment, and user interface simplification are recommended. PLN management should enhance support visibility and integrate machine learning for P2TL target analysis. Future research should consider employee respondents for comparison and include mediation-moderation analysis using mixed-method approaches for deeper user experience insights.

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