



The Effect of SAP Implementation, System Integration, and User Competence on Project Performance Through Procurement Efficiency and Information Completeness at PT ADHI KARYA

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Abstract

Background: Construction firms increasingly rely on integrated digital systems to coordinate procurement and project delivery. At PT ADHI KARYA (Persero) Tbk, however, the procurement workflow remains only partially integrated, even though SAP Materials Management (MM), SAP Project System (PS), and *e-Procurement* are already in use.

Objective: This study examines the relationships of SAP Implementation, SAP-*e-Procurement* Integration, and User Competence with Project Performance, with Procurement Efficiency and Information Completeness specified as intervening mechanisms.

Methods: Data were obtained from 100 purposively selected SAP users through an explanatory quantitative survey. The proposed measurement and structural models were evaluated using partial least squares structural equation modeling (PLS-SEM) with SmartPLS 4.

Results: Procurement Efficiency was positively associated with SAP Implementation ($\beta = 0.319$; $p = 0.007$), SAP-*e-Procurement* Integration ($\beta = 0.321$; $p = 0.002$), and User Competence ($\beta = 0.241$; $p = 0.014$). Procurement Efficiency was also positively associated with Information Completeness ($\beta = 0.500$; $p < 0.001$) and Project Performance ($\beta = 0.494$; $p < 0.001$). Information Completeness showed an additional positive association with Project Performance ($\beta = 0.530$; $p < 0.001$). Bootstrap estimates of the indirect effects further supported the mediating roles of Procurement Efficiency and Information Completeness.

Conclusion: Project performance is strengthened when SAP and *e-Procurement* operate as a more integrated workflow, procurement activities are executed efficiently, information is complete and reliable, and users possess the competence required to operate the systems effectively.

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INTRODUCTION

The proposed framework investigates whether the quality of SAP implementation, the integration between SAP and e-Procurement, and users' operational competence shape procurement efficiency and the completeness of information available for project management. It then traces how these two process-level outcomes relate to project performance. By separating technology use, intersystem connectivity, and user capability, the model makes the hypothesized indirect pathways explicit rather than treating digitalization as a single, undifferentiated factor.

Construction procurement operates within a network of materials, vendors, and

organizational functions that must remain synchronized throughout project execution. Engineering, procurement, project control, and finance depend on one another, so interruptions in the acquisition of materials, equipment, or services can quickly affect site activities. Slow or poorly coordinated procurement can disrupt work schedules, increase costs, and place pressure on quality. For that reason, the way procurement is managed is closely tied to the overall performance of a construction project.

Digital platforms are increasingly used by construction companies to coordinate activities that were previously handled through separate procedures. Enterprise Resource Planning (ERP) is central to this shift because it allows information from different functions to be managed within a common environment. In SAP, Materials Management (MM) supports activities related to purchasing and material management, whereas Project System (PS) is used for planning, cost oversight, progress tracking, and project control (More, 2024). PT ADHI KARYA (Persero) Tbk combines these modules with an e-Procurement platform that supports electronic tender activities such as e-Auction and bid evaluation. When these applications operate as a connected process, they are expected to shorten processing times, improve traceability, and provide decision-makers with more reliable procurement information.

The current operating process does not yet achieve that level of connectivity. Some procurement stages remain dependent on manual intervention, particularly bid evaluation, material approval, and the administration of contractual documents. This means that information does not move seamlessly between SAP and e-Procurement from the beginning to the end of the procurement cycle. Figure 1 illustrates where these manual steps remain concentrated. Re-entry of information and disconnected document handling can create duplicated effort, interrupt the flow of data, and increase the possibility of administrative errors, with downstream consequences for the availability of project inputs and the timing of fieldwork.

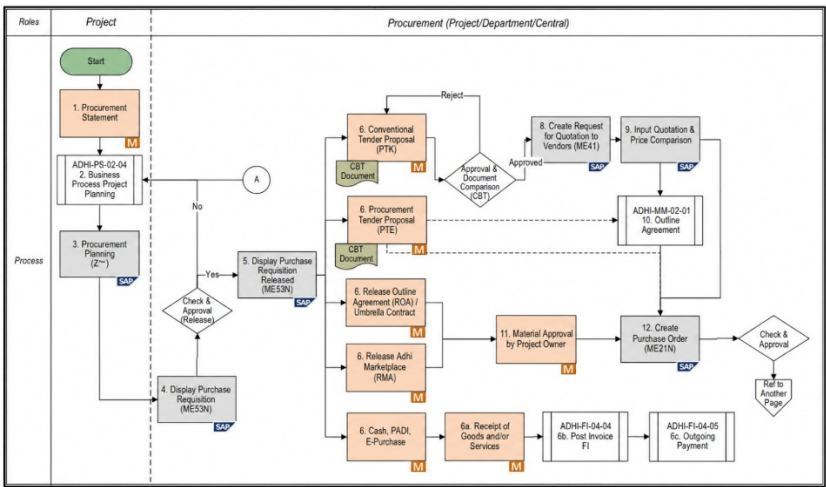


Figure 1. Procurement Flow of Goods and Services at PT ADHI KARYA (Persero) Tbk
Source: PT ADHI KARYA (Persero) Tbk

Internal procurement records from 2025 illustrate the practical consequences of this fragmented workflow. As shown in Figure 2, the elapsed time between e-Auction and contract issuance ranged from 2 to 24 calendar days, averaging 12.6 days, while several packages required more than 20 days. The variation in completion time indicates that digitization at the tender stage has not been accompanied by the same degree of integration in later administrative stages, especially contract preparation and purchase-order issuance. Delays at these points can defer material orders and supplier mobilization, alter execution plans, and increase overhead, labor, equipment, or acceleration expenditures. They can also impair managerial decision-making when

the information needed for action is incomplete, inconsistent, or received too late.

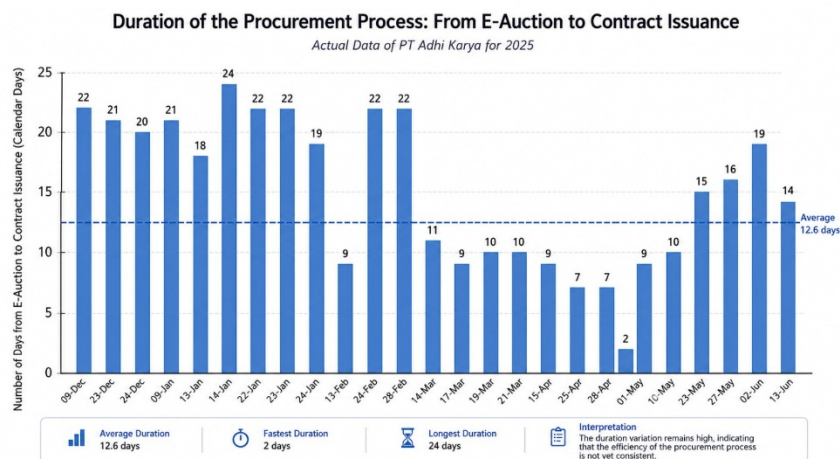


Figure 2. Duration of the Procurement Process of E-Auction until the Issuance of the Contract
Source: Data Procurement PT ADHI KARYA (Persero) Tbk

The value generated by an ERP system is also contingent on the people who operate it. Employees with a strong working knowledge of SAP MM and PS are more likely to enter transactions correctly, resolve operational issues efficiently, and use available functions appropriately (Alsharari, 2021; More, 2024). Limited proficiency, by contrast, can produce incorrect entries, inconsistent records, and avoidable delays even when the technical system itself is available. In procurement, therefore, system connectivity and user capability are expected to work together: better execution of the process should improve efficiency and produce information that is more complete, accurate, and timely. This is particularly important for data on specifications, historical prices, contract progress, and supplier performance because deficiencies in these records may slow approvals or lead to less effective operational decisions.

Previous research largely reports operational gains from ERP-supported procurement, but the evidence also leaves several questions unresolved. Tanjung (2021) reported faster procurement and stronger material control following the use of SAP MM in EPC settings, while Siregar and Hasibuan (2020) and Ahmed et al. (2023) observed a decline in procurement duration from 26 to 14 working days. More (2024) likewise associated digital ERP and supply-chain integration with improved operations. At PT ADHI KARYA (Persero) Tbk, however, procurement lead times still differ markedly between work packages, indicating that the presence of SAP alone does not explain process efficiency. Much of the earlier literature also treats ERP implementation as a single construct, gives less attention to the distinction between module use, system-to-system integration, and user capability, and only rarely tests information quality as an intervening mechanism. Empirical work based on actual procurement conditions in Indonesian construction firms is also limited. This study addresses these gaps by separating SAP MM/PS implementation, SAP-e-Procurement integration, and SAP user competence, and by examining how procurement efficiency and information completeness carry their effects to project performance. The resulting model is intended to contribute to ERP and Supply Chain Management scholarship while providing a process-focused basis for improvement at PT ADHI KARYA (Persero) Tbk and similar construction organizations.

METHOD

The empirical analysis applied one consistent set of construct names: SAP Implementation, System Integration, User Competence, Procurement Efficiency, Information Completeness, and Project Performance. PLS-SEM was used as the common label for the estimation method. The same numerical convention was maintained across descriptive results, measurement-model assessment, structural-model analysis, mediation testing, and predictive assessment.

A quantitative explanatory survey was used because the study sought to explain why procurement duration continued to vary at PT ADHI KARYA (Persero) Tbk despite the operation of SAP MM, SAP PS, and e-Procurement. The analysis therefore went beyond describing the

observed condition and specified a causal structure. SAP MM/PS Implementation, SAP-e-Procurement Integration, and User Competence were treated as antecedent factors; Procurement Efficiency and Information Completeness were positioned as intervening mechanisms; and Project Performance was specified as the final outcome (Sugiyono, 2023). Ten hypotheses followed from this framework, comprising six direct paths and four indirect paths, so the analysis evaluated both the presence of SAP-related benefits and the routes through which those benefits could reach project performance (Hair et al., 2022).

Fieldwork covered PT ADHI KARYA (Persero) Tbk units at the head office and construction-project locations where SAP MM and PS were used for the procurement of goods and services. The company was selected deliberately because it is a state-owned contractor that operates SAP together with e-Procurement while still exhibiting partially connected procurement activities, making it an appropriate setting for the problem under study (Tanjung, 2021; Teetzmann & Quost, 2023). Responses and operational records referred to the 2025 period, allowing survey perceptions to be interpreted against procurement conditions from the same timeframe (APQC, 2019; Gabriel Awuah et al., 2022).

Table 1 summarizes the operationalization of the six constructs. SAP MM and PS Implementation (X1) was represented by system use, perceived ease of operation, and training support (Dospinescu & Buraga, 2025; Ifinedo, 2011; Patare & Minde, 2016). SAP-e-Procurement Integration (X2) reflected automation, consistency of records, and data exchange between systems (APQC, 2019; Gabriel Awuah et al., 2022; Puschmann & Alt, 2005; Walker et al., 2007). User Competence (X3) covered technical understanding, operational skills, and the ability to resolve problems (Archana et al., 2022; Maddi et al., 2020; Ruivo et al., 2014). Procurement Efficiency (Y1) was represented by processing speed and reduced dependence on manual work (Dhuhadmya Anggiya Kirana et al., 2024; Kirana, 2021; Siregar & Hasibuan, 2020). Information Completeness (Y2) addressed the accuracy, coverage, and timeliness of information DeLone & McLean (2003) and Alduaij et al. (2024), while Project Performance (Z) was assessed in relation to cost, time, and quality (Institute, 2021; Project Management Institute, 2025; Van Weele, 2018). The empirical scope was restricted to procurement activities for construction projects and excluded other SAP modules.

The study population comprised employees of PT ADHI KARYA (Persero) Tbk who used SAP MM and PS and were directly involved in construction procurement, including personnel from Supply Chain Management, procurement, engineering, project control, and associated functions. Participants were selected purposively. Eligibility required permanent or contract employment, at least one year of direct experience with the procurement of goods and services, routine use of SAP for procurement activities, a minimum bachelor's degree, and completion of the questionnaire. One hundred eligible respondents were included. For PLS-SEM, sample-size adequacy was assessed in relation to model complexity, the number of structural paths, anticipated effect magnitude, and statistical power rather than against a single universal cutoff (Hair et al., 2022). The individual SAP user was therefore treated as the unit of analysis so that responses reflected direct operational experience (Dospinescu & Buraga, 2025; Ifinedo, 2011; Ruivo et al., 2014).

Measurement relied on a structured questionnaire containing closed-response items derived from the indicators assigned to each construct. Respondents rated each statement on a seven-point Likert scale, where 1 represented “strongly disagree” and 7 represented “strongly agree” (Cheah et al., 2026; Ghazali & Latan, 2015). Items adapted from earlier instruments were rewritten to fit the company's procurement practices so that respondents evaluated situations they encountered when using SAP (Alduaij et al., 2024; DeLone & McLean, 2003; Ifinedo, 2011; Ruivo et al., 2014). The constructs were modeled reflectively. Their measurement properties were assessed before estimates of the structural relationships were interpreted (Hair et al., 2022).

Two forms of evidence were combined. Primary data came from a Google Forms questionnaire completed by respondents who met the sampling requirements. Secondary material consisted of relevant literature, internal procurement documents, process-flow records, measurements of elapsed time from e-Auction to contract issuance, and observations of procurement and SAP use (APQC, 2019; Gabriel Awuah et al., 2022; Korolev, 2009). Using both sources allowed the survey responses to be interpreted alongside actual operating conditions rather than in isolation from the procurement problem that motivated the study.

SmartPLS was used to estimate the PLS-SEM model. The analytical sequence covered descriptive summaries, assessment of the measurement model, evaluation of the structural model, testing of the proposed paths, mediation analysis, and predictive assessment. Convergent validity was assessed using indicator loadings and AVE, with 0.70 and 0.50 used as the respective reference values. Discriminant validity was examined through cross-loadings, Fornell & Larcker, (1981) and Goretzko et al. (2024), and the HTMT ratio (Henseler et al., 2015; Panzeri et al., 2024). Internal consistency was assessed using Cronbach’s alpha and composite reliability, with 0.70 used as the minimum benchmark (Hair et al., 2022). For the structural model, R² values of approximately 0.75, 0.50, and 0.25 were interpreted as strong, moderate, and weak explanatory levels, respectively, while f² values of 0.02, 0.15, and 0.35 were treated as small, medium, and large effect sizes, respectively (Cohen, 1988; Uehata & Rein, 2025). Predictive relevance was examined using PLSpredict (Sharma et al., 2023; Shmueli et al., 2019). The significance of direct and indirect paths was assessed using bootstrapping, with t > 1.96 and p < 0.05 used as the decision criteria (Hair et al., 2022). This analytical sequence permitted comparison of the relative contributions of the constructs and the process pathways associated with project performance (More, 2024).

RESULTS AND DISCUSSION

Results

Descriptive Statistics

The descriptive analysis summarizes the distribution of respondent ratings for each construct. Mean scores are used to describe the general position of the responses, while standard deviations indicate the degree to which individual ratings vary around those averages.

Table 1
Results of Descriptive Statistical Analysis of Research Variables

Variable	Mean	Standard Deviation
SAP Implementation (X1)	5,93	0,85
SAP integration with e-Procurement (X2)	6,02	0,74
User Competencies (X3)	5,94	0,88
Procurement Efficiency (Y1)	6,12	0,83
Completeness of Information Data (Y2)	5,96	0,88
Project Performance (Z)	5,89	0,81

Source: Primary data processed using SmartPLS 4 (2026)

Across the six constructs, mean ratings on the seven-point scale range from 5.89 to 6.12, indicating generally positive evaluations by respondents. Procurement Efficiency records the highest average (6.12), whereas Project Performance has the lowest (5.89). Every standard deviation is below 1.00, showing that responses cluster relatively closely around their respective means.

Evaluation of Measurement Model (Outer Model)

The measurement model was reviewed before interpreting relationships among the latent variables. This stage examined whether the observed indicators represented their intended constructs with sufficient quality by assessing convergent validity, discriminant validity, and reliability within the PLS-SEM analysis.

Convergent Validity

Convergence was first inspected at the indicator level by reviewing the estimated outer loadings. The resulting measurement specification is displayed in Figure 3.

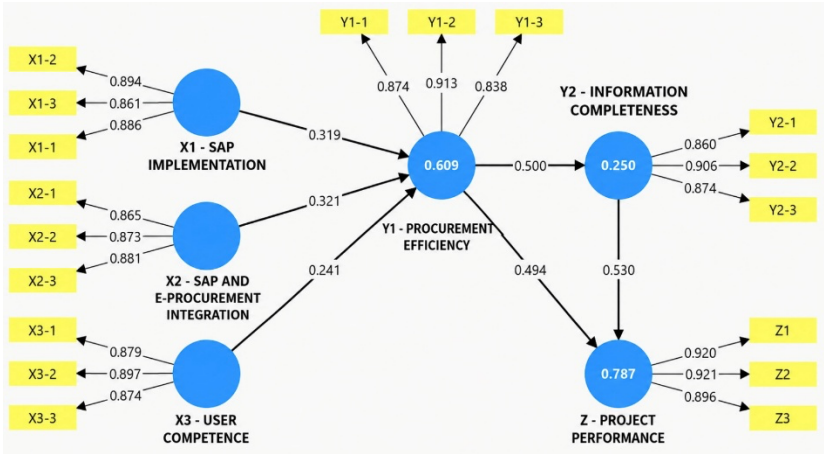


Figure 3. Outer Model Research Model
Source: Primary data processed using SmartPLS 4 (2026)

All indicators in Figure 3 have loadings greater than 0.70 on the constructs to which they were assigned. Because Hair et al. (2022) regard values at or above this level as adequate evidence of indicator convergence, no indicator was excluded. Table 2 provides the corresponding loading estimates in numerical form.

Table 2
Outer Loading Value

Variable	Indicator	Outer Loading	Remarks
SAP Implementation (X1)	X1-1	0,886	Valid
	X1-2	0,894	Valid
	X1-3	0,861	Valid
SAP integration with <i>e-Procurement</i> (X2)	X2-1	0,865	Valid
	X2-2	0,873	Valid
	X2-3	0,881	Valid
User Competencies (X3)	X3-1	0,879	Valid
	X3-2	0,897	Valid
	X3-3	0,874	Valid
Procurement Efficiency (Y1)	Y1-1	0,874	Valid
	Y1-2	0,913	Valid
	Y1-3	0,838	Valid
Completeness of Information Data (Y2)	Y2-1	0,860	Valid
	Y2-2	0,906	Valid
	Y2-3	0,874	Valid
Project Performance (Z)	Z1	0,920	Valid
	Z2	0,921	Valid
	Z3	0,896	Valid

Source: Primary data processed using SmartPLS 4 (2026)

The loading estimates in Table 2 are all above the adopted 0.70 benchmark. Their ranges are 0.861–0.894 for SAP Implementation, 0.865–0.881 for SAP–e-Procurement Integration, 0.874–0.897 for User Competence, 0.838–0.913 for Procurement Efficiency, 0.860–0.906 for Information Completeness, and 0.896–0.921 for Project Performance.

Based on the criterion specified by Hair et al. (2022), these estimates provide adequate evidence of convergent validity at the indicator level. All measurement items were consequently retained for the next stages of the analysis.

Convergent Validity Based on Average Variance Extracted (AVE)

Convergent validity was also considered at the construct level using Average Variance Extracted (AVE). AVE indicates how much of the variance in a construct's indicators is captured by the underlying latent variable. A value of 0.50 or higher was used as the reference point following Hair et al. (2022). The AVE and reliability estimates are reported together in Table 3.

Table 3*Construct Validity and Reliability Test Results*

SAP Implementation (X1)	Cronbach's Alpha	Composite Reliability (ρ_c)	Average Variance Extracted (AVE)	Remarks
SAP integration with e-Procurement (X2)	0,855	0,912	0,775	Valid and Reliable
User Competencies (X3)	0,844	0,906	0,762	Valid and Reliable
Procurement Efficiency (Y1)	0,860	0,914	0,781	Valid and Reliable
Completeness of Information Data (Y2)	0,847	0,908	0,767	Valid and Reliable
Project Performance (Z)	0,855	0,912	0,775	Valid and Reliable
Project Performance (Z)	0,899	0,937	0,832	Valid and Reliable

Source: Primary data processed using SmartPLS 4 (2026)

Every AVE in Table 3 is greater than 0.50. The estimates span 0.762–0.832, with Project Performance producing the highest value (0.832) and SAP–e-Procurement Integration the lowest (0.762).

Thus, each latent variable captures more than half of the variance represented by its indicators. This result provides construct-level support for convergent validity and permits the analysis to proceed to the remaining measurement checks.

Discriminant Validity (HTMT)

HTMT was used as one test of whether the constructs are sufficiently different from one another. Following Henseler et al. (2015) and Panzeri et al. (2024), values below 0.90 were treated as evidence that two constructs are empirically distinguishable. Table 4 contains the pairwise HTMT estimates.

Table 4*HTMT Test Results*

Variable	X1	X2	X3	Y1	Y2	Z
X1	-					
X2	0,789	-				
X3	0,745	0,828	-			
Y1	0,808	0,834	0,786	-		
Y2	0,561	0,681	0,728	0,585	-	
Z	0,716	0,802	0,818	0,870	0,885	-

Source: Primary data processed using SmartPLS 4 (2026)

None of the HTMT values reaches 0.90. The highest coefficient is 0.885 between Information Completeness and Project Performance, whereas the lowest is 0.561 between SAP Implementation and Information Completeness. Based on the adopted criterion, the constructs remain adequately separated.

Discriminatory Validity (Fornell-Larcker Criteria)

A second discriminant-validity check used the Fornell–Larcker approach. Under this procedure, the square root of a construct's AVE is compared with its correlations with the other latent variables; discriminant validity is supported when the diagonal value is larger than the corresponding interconstruct correlations (Fornell & Larcker, 1981; Goretzko et al., 2024). Table 5 presents that comparison.

Table 5*Fornell-Larcker Criteria Test Results*

Variable	X1	X2	X3	Y1	Y2	Z
X1	0,88					
X2	0,673	0,873				
X3	0,64	0,707	0,884			
Y1	0,69	0,707	0,673	0,876		
Y2	0,482	0,58	0,624	0,5	0,88	
Z	0,631	0,701	0,721	0,759	0,777	0,912

Source: Primary data processed using SmartPLS 4 (2026)

The diagonal entries are higher than the corresponding correlations outside the diagonal. In other words, each construct is more strongly associated with its own indicators than with the other constructs in the model. The Fornell–Larcker check therefore provides additional support for discriminant validity.

Discriminating Validity (Cross Loading)

Cross-loadings were inspected as a third assessment of construct separation. The expected pattern is that an indicator shows its strongest loading on the construct it is intended to measure rather than on another latent variable (Hair et al., 2022). The full matrix is reported in Table 6.

Table 6*Cross Loading Test Results*

Indicator	X1 SAP Implementation	X2 SAP and E- Procurement Integration	X3 User Competency	Y1 Procurement Efficiency	Y2 Information Data Completeness	Z Project Performance
X1-1	0.886	0.561	0.501	0.599	0.397	0.550
X1-2	0.894	0.618	0.622	0.662	0.500	0.607
X1-3	0.861	0.598	0.562	0.552	0.365	0.501
X2-1	0.532	0.865	0.585	0.579	0.438	0.567
X2-2	0.593	0.873	0.602	0.621	0.534	0.606
X2-3	0.632	0.881	0.661	0.647	0.541	0.658
X3-1	0.557	0.617	0.879	0.581	0.507	0.595
X3-2	0.551	0.647	0.897	0.627	0.583	0.683
X3-3	0.590	0.609	0.874	0.573	0.561	0.629
Y1-1	0.647	0.593	0.620	0.874	0.414	0.645
Y1-2	0.571	0.635	0.628	0.913	0.491	0.695
Y1-3	0.596	0.629	0.516	0.838	0.405	0.653
Y2-1	0.457	0.510	0.542	0.422	0.860	0.643
Y2-2	0.398	0.500	0.548	0.475	0.906	0.727
Y2-3	0.424	0.524	0.558	0.420	0.874	0.679
Z1	0.570	0.657	0.681	0.700	0.728	0.920
Z2	0.581	0.637	0.680	0.688	0.719	0.921
Z3	0.575	0.623	0.610	0.690	0.678	0.896

Source: Primary data processed using SmartPLS 4 (2026)

The matrix in Table 6 follows the expected pattern. For example, X1-2 loads 0.894 on SAP Implementation, Y1-2 loads 0.913 on Procurement Efficiency, Y2-2 loads 0.906 on Information Completeness, and Z2 loads 0.921 on Project Performance; each corresponding loading on competing constructs is lower. The same pattern is observed for the remaining indicators.

Evidence from HTMT, the Fornell–Larcker comparison, and the cross-loading matrix points in the same direction: the six constructs are empirically distinguishable. The measurement specification was therefore considered adequate for assessment of the structural paths.

Construct Reliability (Cronbach's Alpha and Composite Reliability)

Internal consistency was evaluated with Cronbach's Alpha and Composite Reliability. These statistics indicate whether the indicators assigned to a construct operate consistently as a set. In

line with Hair et al. (2022), 0.70 was used as the minimum acceptable value. The estimates are summarized in Table 7.

Table 7

Construct Reliability Test Results

Variable	Cronbach's Alpha	Composite Reliability (ρ_c)	Remarks
SAP Implementation (X1)	0,855	0,912	Reliable
SAP integration with e-Procurement (X2)	0,844	0,906	Reliable
User Competencies (X3)	0,860	0,914	Reliable
Procurement Efficiency (Y1)	0,847	0,908	Reliable
Completeness of Information Data (Y2)	0,855	0,912	Reliable
Project Performance (Z)	0,899	0,937	Reliable

Source: Primary data processed using SmartPLS 4 (2026)

Cronbach's Alpha ranges from 0.844 to 0.899, and Composite Reliability ranges from 0.906 to 0.937. Because all estimates exceed the 0.70 reference level, each construct exhibits satisfactory internal consistency and remains in the structural analysis.

Structural Model (Inner Model)

Attention then shifted from measurement quality to the relationships specified among the latent variables. Structural-model assessment considered explanatory power (R^2), local effect magnitude (f^2), and predictive relevance (Q^2_{predict}), followed by tests of direct and mediated paths using the SmartPLS 4 bootstrapping procedure.

Coefficient of Determination (R-Square)

R^2 expresses the share of variation in an endogenous construct that is accounted for by the predictors linked to it in the model. The interpretation follows Hair et al. (2022), with values around 0.75, 0.50, and 0.25 used as reference points for strong, moderate, and weak explanatory power, respectively. Table 8 reports the estimated coefficients.

Table 8

Coefficient of Determination Test Results (R-Square)

Endogenous Variable	R-Square	R-Square Adjusted	Categories
Procurement Efficiency (Y1)	0,609	0,597	Moderate
Completeness of Information Data (Y2)	0,25	0,242	Weak
Project Performance (Z)	0,787	0,783	Strong

Source: Primary data processed using SmartPLS 4 (2026)

Procurement Efficiency has an R^2 of 0.609. Accordingly, SAP Implementation, SAP-e-Procurement Integration, and User Competence together explain 60.9% of the observed variation in this construct; the remaining 39.1% is associated with influences that are not represented in the model.

For Information Completeness, R^2 equals 0.250, so Procurement Efficiency accounts for one quarter of its variance, while 75.0% remains outside the specified relationship. Project Performance has a substantially higher R^2 of 0.787. Procurement Efficiency and Information Completeness together account for 78.7% of its variation, leaving 21.3% unexplained by the two predictors included in the model.

Relative to the reference levels proposed by Hair et al. (2022), explanatory power is strong for Project Performance, moderate for Procurement Efficiency, and weak for Information Completeness. The model nevertheless accounts for a large proportion of variance in the principal outcome variable.

Effect Size (f^2)

The f^2 statistic was used to evaluate the incremental contribution of each predictor to an endogenous construct. It captures the change in explained variance associated with removing a predictor from the structural equation. Cohen (1988) and Uehata & Rein (2025) reference points of 0.02, 0.15, and 0.35 were used to characterize small, medium, and large effects, respectively.

Estimates are provided in Table 9.

Table 9

Effect Size Test Results (f^2)

Influence Path	Value f^2	Categories
SAP (X1) Implementation → Procurement Efficiency (Y1)	0,129	Small
SAP Integration with e-Procurement (X2) → Procurement Efficiency (Y1)	0,11	Small
User Competency (X3) → Procurement Efficiency (Y1)	0,067	Small
Procurement Efficiency (Y1) → Completeness of Information Data (Y2)	0,333	Medium
Procurement Efficiency (Y1) → Project Performance (Z)	0,86	Large
Completeness of Information Data (Y2) → Project Performance (Z)	0,989	Large

Source: Primary data processed using SmartPLS 4 (2026)

For Procurement Efficiency, the f^2 estimates are 0.129 for SAP Implementation, 0.110 for SAP-e-Procurement Integration, and 0.067 for User Competence. Each falls within Cohen (1988) and Uehata and Rein (2025) small-effect range, indicating that the three predictors add explanatory value but none makes a large isolated contribution.

The Procurement Efficiency → Information Completeness path produces an f^2 of 0.333. This coefficient lies in the medium range and indicates a material contribution of procurement-process efficiency to the explained variation in Information Completeness.

The two predictors of Project Performance show much larger local effects. Procurement Efficiency yields $f^2 = 0.860$, and Information Completeness yields $f^2 = 0.989$. Both exceed the 0.35 reference point, indicating that each makes a substantial contribution to explaining Project Performance within this model.

Predictive Relevance (Q^2)

Predictive performance beyond the estimation sample was examined using PLSpredict in SmartPLS 4. Q^2 predict was used as the relevant diagnostic; a positive value indicates that the model contains predictive information for the corresponding endogenous indicator.

Table 10

Results of Predictive Relevance Testing Using PLSpredict

Endogenous Variables	Indicator	Q^2 predict	Information
Procurement Efficiency (Y1)	Y1-1	0,468	Having predictive capabilities
	Y1-2	0,449	Having predictive capabilities
Data and Information Completeness (Y2)	Y1-3	0,415	Having predictive capabilities
	Y2-1	0,262	Having predictive capabilities
Project Performance (Z)	Y2-2	0,248	Having predictive capabilities
Procurement Efficiency (Y1)	Y2-3	0,262	Having predictive capabilities
	Z1	0,472	Having predictive capabilities
	Z2	0,466	Having predictive capabilities
	Z3	0,431	Having predictive capabilities

Source: Primary data processed using SmartPLS 4 (2026)

Q^2 predict is positive for every indicator of Procurement Efficiency, Information Completeness, and Project Performance, with values between 0.248 and 0.472. This satisfies the positive- Q^2 predict condition discussed by Sharma et al. (2023) and Hair et al. (2022). Z1 has the largest estimate (0.472), while Y2-2 has the smallest (0.248). Since no indicator produces a negative value, the model shows predictive relevance for the observed endogenous measures and provides a suitable basis for interpreting the structural tests.

Direct Influence Hypothesis Testing ($H1 - H6$)

The six direct paths were tested using bootstrap estimates generated in SmartPLS 4. A relationship was treated as statistically supported when its t statistic was greater than 1.96 and its p value was below 0.05, corresponding to the 5% significance level (Hair et al., 2022). Table 11

contains the results.

Table 11

Results of Direct Influence Hypothesis Testing

Hypothesis	Pathway	Coefficient (O)	T-Statistic	P-Value	Verdict
H1	SAP (X1) Implementation → Procurement Efficiency (Y1)	0,319	2,711	0,007	Accepted
H2	SAP and <i>e-Procurement</i> (X2) Integration → Procurement Efficiency (Y1)	0,321	3,076	0,002	Accepted
H3	User Competency (X3) → Procurement Efficiency (Y1)	0,241	2,456	0,014	Accepted
H4	Procurement Efficiency (Y1) → Completeness of Information Data (Y2)	0,500	7,444	0,000	Accepted
H5	Procurement Efficiency (Y1) → Project Performance (Z)	0,494	7,075	0,000	Accepted
H6	Completeness of Information Data (Y2) → Project Performance (Z)	0,530	7,720	0,000	Accepted

Source: Primary data processed using SmartPLS 4 (2026)

Each of the six direct paths clears the predefined decision thresholds. The evidence therefore supports H1–H6. The path-specific estimates are interpreted in the following subsections.

- 1) H1. The Effect of SAP Implementation on Procurement Efficiency: For H1, the coefficient linking SAP Implementation (X1) to Procurement Efficiency (Y1) is 0.319 ($t = 2.711$; $p = 0.007$). The estimate is positive and statistically different from zero, indicating that better implementation of SAP is associated with a higher level of procurement efficiency.
- 2) H2. The Effect of SAP–e-Procurement Integration on Procurement Efficiency: The $X2 \rightarrow Y1$ coefficient is 0.321, with $t = 3.076$ and $p = 0.002$. The direction and statistical significance of this estimate support H2 and show that closer integration of SAP with *e-Procurement* is associated with higher procurement efficiency.
- 3) H3. The Effect of User Competence on Procurement Efficiency: User Competence also contributes positively to Procurement Efficiency. The estimated $X3 \rightarrow Y1$ path is 0.241 ($t = 2.456$; $p = 0.014$), supporting H3. This result is consistent with the view that users who can operate SAP effectively are better positioned to execute procurement activities efficiently.
- 4) H4. The Effect of Procurement Efficiency on Information Completeness: The path from Procurement Efficiency to Information Completeness is estimated at 0.500 ($t = 7.444$; $p < 0.001$). H4 is therefore supported. Greater efficiency in carrying out procurement activities is associated with a higher level of completeness in the information produced and maintained by the system.
- 5) H5. The Effect of Procurement Efficiency on Project Performance: For H5, Procurement Efficiency is positively related to Project Performance, with $\beta = 0.494$, $t = 7.075$, and $p < 0.001$. The estimate indicates that higher procurement efficiency is associated with stronger project performance across the cost, time, and quality dimensions represented in the study.
- 6) H6. The Effect of Information Completeness on Project Performance: Information Completeness has the stronger of the two direct paths to Project Performance ($\beta = 0.530$; $t = 7.720$; $p < 0.001$). This statistically significant estimate supports H6 and indicates that more complete and dependable information is associated with stronger project outcomes.

Taken as a set, the direct estimates support the structure proposed in the model: the three antecedent capabilities are positively associated with Procurement Efficiency; Procurement Efficiency is positively associated with both Information Completeness and Project Performance; and Information Completeness contributes an additional positive path to Project Performance.

Mediation Effect Testing (H7 – H10)

Indirect effects were examined to determine whether Procurement Efficiency and Information Completeness act as transmission mechanisms between the antecedent variables and Project Performance. Bootstrap estimates from SmartPLS 4 were evaluated using the same 5% decision rule, namely $t > 1.96$ and $p < 0.05$ (Hair et al., 2022). Table 12 reports these estimates.

Table 12*Mediation Effect Test Results (H7-H10)*

Hypothesis	Mediation Pathway	Coefficient (O)	T-Statistic	P-Value	Verdict
H7	SAP (X1) Implementation → Procurement Efficiency (Y1) → Project Performance (Z)	0,16	2,579	0,01	Accepted
H8	SAP and <i>e-Procurement</i> (X2) Integration → Procurement Efficiency (Y1) → Project Performance (Z)	0,16	2,72	0,007	Accepted
H9	User Competency (X3) → Procurement Efficiency (Y1) → Project Performance (Z)	0,121	2,207	0,027	Accepted
H10	Procurement Efficiency (Y1) → Completeness of Information Data (Y2) → Project Performance (Z)	0,265	5,494	0	Accepted

Source: Primary data processed using SmartPLS 4 (2026)

All four indirect effects meet the statistical decision criteria, so H7–H10 receive empirical support. The results indicate that Procurement Efficiency and Information Completeness function as mediating mechanisms within the proposed sequence of relationships.

- 1) H7. The Effect of SAP Implementation on Project Performance through Procurement Efficiency: SAP Implementation has an indirect effect of 0.160 on Project Performance through Procurement Efficiency ($t = 2.579$; $p = 0.010$). The result supports H7: part of the association between stronger SAP implementation and Project Performance is transmitted through improvements in the efficiency of procurement activities.
- 2) H8. The Effect of SAP–*e-Procurement* Integration on Project Performance through Procurement Efficiency: For SAP–*e-Procurement* Integration, the mediated coefficient through Procurement Efficiency is likewise 0.160 ($t = 2.720$; $p = 0.007$). H8 is supported, indicating that the association between system integration and Project Performance is partly transmitted through Procurement Efficiency.
- 3) H9. The Effect of User Competence on Project Performance through Procurement Efficiency: The indirect path from User Competence to Project Performance through Procurement Efficiency equals 0.121 ($t = 2.207$; $p = 0.027$). This supports H9 and suggests that the association between user capability and project outcomes is partly conveyed through more efficient execution of procurement activities.
- 4) H10. The Effect of Procurement Efficiency on Project Performance through Information Completeness: Procurement Efficiency also reaches Project Performance indirectly through Information Completeness. The mediated coefficient is 0.265 ($t = 5.494$; $p < 0.001$), providing support for H10. The pattern indicates that efficient procurement is associated with better project outcomes in part because it improves the quality and completeness of information available for decision-making and execution.

The mediation evidence therefore adds an important process explanation to the direct effects. Technology implementation, system connectivity, and user capability are not associated with project outcomes only as isolated inputs; part of their contribution is transmitted through Procurement Efficiency, while the association between Procurement Efficiency and Project Performance is further transmitted through Information Completeness.

Summary of Hypothesis Testing Results

Table 13 brings the ten hypothesis tests into a single view by pairing each proposed relationship with the statistical decision obtained from the PLS-SEM estimation.

Table 13*Summary of Hypothesis Testing Results*

Hypothesis	Statement	Verdict
H1	The implementation of SAP (X1) has a positive effect on Procurement Efficiency (Y1).	Accepted
H2	The integration of SAP with <i>e-Procurement</i> (X2) has a positive effect on Procurement Efficiency (Y1).	Accepted
H3	User Competency (X3) has a positive effect on Procurement Efficiency	Accepted

Hypothesis	Statement	Verdict
	(Y1).	
H4	Procurement Efficiency (Y1) has a positive effect on the Completeness of Information Data (Y2).	Accepted
H5	Procurement Efficiency (Y1) has a positive effect on Project Performance (Z).	Accepted
H6	Completeness of Information Data (Y2) has a positive effect on Project Performance (Z).	Accepted
H7	Procurement Efficiency (Y1) mediates the effect of SAP Implementation (X1) on Project Performance (Z).	Accepted
H8	Procurement Efficiency (Y1) mediates the effect of SAP Integration with <i>e-Procurement</i> (X2) on Project Performance (Z).	Accepted
H9	Procurement Efficiency (Y1) mediates the influence of User Competency (X3) on Project Performance (Z).	Accepted
H10	Completeness of Information Data (Y2) mediates the effect of Procurement Efficiency (Y1) on Project Performance (Z).	Accepted

Source: Primary data processed using SmartPLS 4 (2026)

The consolidated results show support for all direct and indirect relationships tested at the 5% significance level. Each estimated coefficient has the hypothesized positive direction and satisfies the relevant significance criterion.

At the first stage of the model, SAP Implementation, SAP-*e-Procurement* Integration, and User Competence are each positively associated with Procurement Efficiency. At the next stage, Procurement Efficiency is positively associated with both Information Completeness and Project Performance, and Information Completeness adds a further positive relationship with Project Performance.

The indirect tests complement this pattern. Procurement Efficiency carries part of the associations of SAP Implementation, system integration, and User Competence with Project Performance, while Information Completeness carries part of the association between Procurement Efficiency and Project Performance.

Together, the estimates provide empirical support for the proposed sequence of technological capability, operational process quality, information quality, and project performance, including both the direct and mediated routes specified in the model.

Discussion

The Effects of SAP Implementation, SAP-e-Procurement Integration, and User Competence on Procurement Efficiency

The three antecedent variables are each significantly related to Procurement Efficiency at PT ADHI KARYA (Persero) Tbk. Among them, SAP-*e-Procurement* Integration has the largest standardized path coefficient. This suggests that interoperability between the two systems is particularly relevant to procurement-process improvement, although the quality of SAP implementation and user competence also make statistically significant contributions.

This result can be interpreted through Davenport (1998) and Rachmaniah et al. (2022) view of ERP as an infrastructure for linking activities that would otherwise remain fragmented across business functions. It is also compatible with the Technology–Organization–Environment perspective, in which the benefits of technology adoption depend not only on the technology itself but also on organizational readiness and the ability of people to use it effectively.

The empirical pattern is also in line with Khairnar and Desai (2019) and More (2024), who connect ERP-enabled procurement and system integration with gains arising from automation, better data quality, and faster information exchange. The present findings add that technical capability alone is insufficient: users must be able to execute transactions correctly if those system features are to translate into operational efficiency.

In the operational setting of PT ADHI KARYA (Persero) Tbk, a closer connection between SAP and *e-Procurement* can reduce breaks in the sequence from material planning and purchasing to inventory administration. The practical implication is that integration work should be accompanied by continuing support and training tailored to user roles. This combination is more likely to convert technical improvements into sustained procurement-process gains.

The Effect of Procurement Efficiency on Information Completeness and Project Performance

Procurement Efficiency is significantly associated with both Information Completeness and Project Performance. Its contribution therefore extends beyond shorter processing times. A more orderly and efficient procurement process can also improve the recording, availability, and accuracy of information that managers rely on while projects are being delivered.

From a Resource-Based View perspective, this result is consistent with the argument that performance advantages depend on how well organizational resources and routines are coordinated and used. In procurement, efficient routines can improve both the flow of project inputs and the information base used for planning, control, and day-to-day operational decisions.

Siregar and Hasibuan (2020) and Rahwani (2026) similarly connect procurement efficiency with improvements in information quality and project execution, while Tanjung (2021) reports that ERP-supported procurement can shorten processing cycles, reduce delays, and improve the timeliness of material supply. The present findings are compatible with those mechanisms: smoother procurement can affect project performance through both the physical availability of inputs and better information for coordination.

For PT ADHI KARYA (Persero) Tbk, an efficient procurement process helps align the arrival of materials and services with project needs while ensuring that transactions are captured in SAP. More complete records strengthen monitoring and allow managers to follow schedule, cost, and quality conditions using a more reliable information base.

The Effect of Information Completeness on Project Performance

A significant positive path is also observed from Information Completeness to Project Performance. The finding indicates that project decision-making can be better supported when the system provides a sufficiently complete and accurate record of procurement-related conditions.

Information Quality theory offers a direct explanation for this relationship. Managers can respond to emerging project conditions more effectively when relevant information is available on time, is accurate, and covers the issues needed for monitoring and control. Better information can therefore shorten the gap between identifying a problem and taking corrective action.

The result also corresponds with DeLone and McLean (2003) and Alduaij et al. (2024) information-systems-success framework, which places information quality among the central determinants of system value. In this case, complete procurement records generated through SAP can support material control, project monitoring, and performance review, thereby strengthening the information foundation for project management.

The Role of Procurement Efficiency and Information Completeness as Mediators of Project Performance

The indirect-effect results clarify how the antecedent capabilities are associated with project outcomes. Procurement Efficiency carries part of the associations of SAP Implementation, SAP-*e-Procurement* Integration, and User Competence with Project Performance, while Information Completeness carries part of the association between Procurement Efficiency and Project Performance. Project benefits therefore arise not simply from installing technology or having capable users, but from the operational improvements and better information that these capabilities enable.

This sequence is consistent with the Technology–Organization–Environment perspective, under which technological resources create value when they are embedded in suitable organizational processes and supported by capable users. In the present model, SAP implementation and its integration with *e-Procurement* improve the way procurement is executed; a more efficient process then contributes to better information for project decisions.

The same process logic is reflected in earlier work by Khairnar and Desai (2019), who relate SAP use to organizational results through operating efficiency, and by More (2024), who emphasize that digital procurement produces stronger outcomes when process integration and information quality are developed together.

For PT ADHI KARYA (Persero) Tbk, the implication is that continued investment in SAP and *e-Procurement* should not be treated as an end in itself. The value of the technology depends on whether it reduces friction in procurement and improves the integrity of the information

produced. Management attention should therefore include process redesign, data governance, and continuing improvement in user practices alongside technical integration.

CONCLUSION

The evidence shows that the managerial value of SAP-related capabilities is realized through the procurement process rather than through technology alone. SAP Implementation, SAP-*e-Procurement* Integration, and User Competence are associated with Project Performance through Procurement Efficiency and Information Completeness. By bringing technological capability, operating-process quality, human capability, and information quality into one PLS-SEM framework, the study provides a more explicit explanation of how digital procurement can contribute to construction-project outcomes. For PT ADHI KARYA (Persero) Tbk, the findings point to three practical priorities: completing the connection between SAP and *e-Procurement* across the full workflow, strengthening governance of procurement data, and providing role-specific support for SAP users. Because the study is cross-sectional and confined to one organization, the results should be interpreted within that setting. Future research across multiple firms, projects, and time periods would be useful for assessing the stability of the relationships observed here.

The structural estimates support all relationships proposed in the model. SAP Implementation, SAP-*e-Procurement* Integration, and User Competence each contribute to Procurement Efficiency; Procurement Efficiency contributes directly to Information Completeness and Project Performance; and Information Completeness contributes further to Project Performance. The indirect estimates show an additional mechanism: Procurement Efficiency carries the effects of the three antecedent capabilities to Project Performance, while Information Completeness carries part of the effect of Procurement Efficiency. These results address the study objective by showing a sequence in which digital capability and user capability first influence the procurement process, after which process efficiency and information quality become the immediate channels associated with project outcomes. For the company, this means that system integration, user development, workflow simplification, and information-quality controls should be managed as a connected improvement agenda. The findings should not be generalized without caution because organization-specific processes, culture, and information-system maturity may shape the estimated relationships. The study nevertheless extends ERP research in construction by treating Procurement Efficiency and Information Completeness as explicit explanatory mechanisms between SAP-related capabilities and Project Performance.

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AUTHOR CONTRIBUTION STATEMENT

Ivan Dwi Rahmadhan contributed to the conceptualization, research design, data collection, investigation, data analysis, interpretation of the findings, and preparation of the original manuscript. Melia Eka Lestiani contributed to the conceptual framework, methodology development, validation, supervision, interpretation of the results, and critical review of the manuscript. Erna Mulyati contributed to research supervision, methodological review, validation of the analysis, discussion development, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for the accuracy and integrity of the work.

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