

The Mediation Effect Of Knowledge Resources In The Relationship Between Project Complexity Management And Project Performance Of SCADA, Yaka And AMR Projects.

Kazibwe Richard¹, Iumba Alex²

1, 2 Metropolitan International University

Abstract

This study examined the mediation effect of knowledge resources in the relationship between project complexity management and project performance in SCADA (Supervisory Control and Data Acquisition), Yaka (prepaid water meter systems), and AMR (Automatic Meter Reading) projects. Using a quantitative research design, data were collected from 247 project managers and team members across 82 completed projects in the utility sector. Structural equation modeling revealed that knowledge resources significantly mediated the relationship between project complexity management and project performance ($\beta = 0.428$, $p < 0.001$). The findings demonstrated that project complexity management had a direct positive effect on project performance ($\beta = 0.362$, $p < 0.001$) and on knowledge resources ($\beta = 0.517$, $p < 0.001$). Knowledge resources positively influenced project performance ($\beta = 0.428$, $p < 0.001$). The indirect effect through knowledge resources was statistically significant ($\beta = 0.221$, $p < 0.001$), indicating partial mediation. The model explained 67.3% of the variance in project performance. Knowledge resources served as a critical mechanism through which project complexity management influenced project performance in technical utility projects. Organizations that effectively managed project complexity through structured approaches were better positioned to develop, capture, and utilize knowledge resources, which subsequently enhanced project outcomes in terms of schedule adherence, budget compliance, quality standards, and stakeholder satisfaction. Project managers should prioritize the establishment of knowledge management systems alongside complexity management frameworks. Organizations implementing SCADA, Yaka, and AMR projects should invest in knowledge repositories, facilitate cross-functional learning, and create communities of practice to maximize the benefits of complexity management initiatives.

Keywords: project complexity management, knowledge resources, project performance, SCADA projects, Yaka systems, AMR projects, mediation analysis, utility projects

1. Background of the study

The contemporary landscape of utility infrastructure projects presented unprecedented challenges characterized by technological sophistication, stakeholder multiplicity, and operational intricacies. SCADA systems, Yaka prepaid water meters, and AMR technologies represented critical components of modern utility management, enabling real-time monitoring, automated billing, and enhanced resource distribution (Kazaara et al., 2024). These projects embodied substantial complexity stemming from technical interdependencies, regulatory requirements, diverse stakeholder expectations, and integration challenges with existing infrastructure systems (Promise et al., 2024).

Project complexity management emerged as a strategic imperative in navigating the multifaceted challenges inherent in utility technology implementations (Akankwasa et al., 2022). Scholars and practitioners recognized that complexity,

when inadequately addressed, precipitated schedule overruns, budget escalations, quality deficiencies, and stakeholder dissatisfaction. The systematic management of complexity required comprehensive approaches encompassing organizational structure optimization, technological integration strategies, stakeholder engagement protocols, and risk mitigation frameworks (Moses & Nancy, 2024). Organizations that successfully managed complexity demonstrated superior project outcomes, operational efficiency, and long-term sustainability (Nancy & Prudence, 2024).

Knowledge resources constituted another critical dimension in project success, encompassing the collective expertise, documented procedures, lessons learned, best practices, and intellectual capital accumulated through organizational experience (Frank et al., 2023). In technical projects such as SCADA, Yaka, and AMR implementations, knowledge resources enabled teams to anticipate challenges, apply proven solutions, avoid repeated mistakes, and accelerate decision-making processes (David et al., 2023). The literature suggested that knowledge resources bridged the gap between complexity management practices and tangible project outcomes, serving as repositories of organizational learning and strategic assets for continuous improvement (A & Ahmed, 2019).

Despite growing recognition of both project complexity management and knowledge resources as determinants of project success, limited empirical evidence existed regarding the mechanisms through which these constructs interacted (Alex & Devis, 2023). Particularly in the context of specialized utility projects, researchers had not adequately explored whether knowledge resources mediated the relationship between complexity management and project performance. This gap in understanding hindered the development of comprehensive frameworks that organizations could employ to optimize project outcomes in increasingly complex technological environments (Alex & Devis, 2023).

The utility sector in developing economies faced particular pressures to modernize infrastructure, improve service delivery, reduce non-revenue water, and enhance operational efficiency. Governments and utility companies invested substantial resources in SCADA systems for centralized control, Yaka meters for prepaid water services, and AMR technologies for automated data collection (Julius & Kaazara, 2025). However, implementation success rates varied considerably, with many projects experiencing delays, cost overruns, and performance shortfalls. Understanding the role of knowledge resources in mediating the complexity-performance relationship offered potential insights for improving project delivery in this critical sector, ultimately contributing to better utility services, resource conservation, and customer satisfaction.

2. Problem Statement

Despite significant investments in SCADA, Yaka, and AMR projects within the utility sector, organizations continued to experience suboptimal project performance characterized by schedule delays, budget overruns, technical deficiencies, and stakeholder dissatisfaction (Ntirandekura & Christopher, 2022). While project complexity management had been identified as a critical factor influencing project outcomes, the mechanisms through which complexity management translated into improved performance remained inadequately understood (Lydia et al., 2023).

Specifically, the potential mediating role of knowledge resources in this relationship had not been empirically examined within the context of technical utility projects.

Practitioners lacked evidence-based guidance on whether investments in knowledge management systems, learning initiatives, and organizational memory would amplify the benefits of complexity management efforts (Nicholas & Nancy, 2024). This knowledge gap resulted in fragmented approaches where organizations implemented complexity management frameworks without corresponding investments in knowledge infrastructure, or conversely, developed knowledge repositories without aligning them with complexity management objectives (Faridah et al., 2023). The absence of empirical evidence regarding the mediation effect prevented organizations from making informed strategic decisions about resource allocation, capability development, and process optimization (Christopher et al., 2022). Furthermore, the unique characteristics of SCADA, Yaka, and AMR projects including technological sophistication, multi-stakeholder environments, and operational criticality suggested that findings from other project contexts might not directly apply, necessitating context-specific research to guide practice in the utility sector.

3. Specific Objective

To determine the mediation effect of knowledge resources on the relationship between project complexity management and project performance of SCADA, Yaka, and AMR projects.

4. Methodology

This study employed a quantitative research design utilizing a cross-sectional survey approach to examine the mediation effect of knowledge resources in the relationship between project complexity management and project performance (Nafiu, 2012). The research focused on SCADA, Yaka, and AMR projects implemented by utility companies and contractors operating within the East African region during the period 2020-2023.

Population and Sampling: The target population comprised project managers, technical leads, and senior team members who had participated in completed SCADA, Yaka, or AMR projects. Using purposive sampling combined with snowball techniques, the study identified 320 potential respondents across 95 projects. The final sample consisted of 247 respondents from 82 projects, representing a response rate of 77.2%. Inclusion criteria required that respondents had been involved in projects for at least six months and that projects had reached substantial completion or closure (Olanrewaju et al., 2021).

Measurement Instruments: Data were collected using a structured questionnaire comprising four main sections. Project complexity management was measured using a 15-item scale adapted from established complexity management frameworks, assessing dimensions including technical complexity management, organizational complexity management, stakeholder complexity management, and environmental complexity management (Julius & Kaazara, 2025). Knowledge resources were measured using a 12-item scale evaluating knowledge acquisition, knowledge documentation, knowledge sharing, and knowledge application practices. Project performance was assessed using a 10-item scale measuring schedule performance, budget performance, quality performance, and

stakeholder satisfaction (Julius, 2024). All items utilized seven-point Likert scales ranging from 1 (strongly disagree) to 7 (strongly agree). The questionnaire also captured demographic and project characteristics for descriptive analysis.

Reliability and Validity: Pilot testing with 35 respondents established instrument reliability and validity. Cronbach's alpha coefficients exceeded 0.85 for all constructs, indicating excellent internal consistency. Content validity was established through expert review by five academics and practitioners in project management. Confirmatory factor analysis demonstrated adequate convergent validity (Average Variance Extracted > 0.50) and discriminant validity (square root of AVE exceeded inter-construct correlations).

Data Analysis: Descriptive statistics characterized the sample and key variables. Correlation analysis examined bivariate relationships between constructs. The mediation hypothesis was tested using structural equation modeling (SEM) with AMOS 24.0 software (Nelson et al., 2022). The analysis followed Baron and Kenny's approach, supplemented by bootstrapping procedures with 5,000 iterations to estimate indirect effects and confidence intervals. Model fit was evaluated using multiple indices including Chi-square/df ratio, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR) (Nelson et al., 2023). Mediation was confirmed if the indirect effect through knowledge resources was statistically significant.

5. Results and Discussion

5.1 Descriptive Statistics

Table 1: Demographic and Project Characteristics

Characteristic	Category	Frequency	Percentage
Respondent Role	Project Manager	89	36.0%
	Technical Lead	76	30.8%
	Senior Team Member	82	33.2%
Project Type	SCADA	94	38.1%
	Yaka	88	35.6%
	AMR	65	26.3%
Project Duration	< 12 months	67	27.1%
	12-24 months	112	45.3%
	> 24 months	68	27.5%
Project Budget	< \$500K	58	23.5%
	\$500K-\$2M	103	41.7%
	> \$2M	86	34.8%
Organization Type	Utility Company	145	58.7%
	Contractor	102	41.3%

Source: Primary Data, 2024

The demographic profile revealed a well-distributed sample across respondent roles, project types, durations, and budget categories. The inclusion of both utility companies and contractors provided comprehensive perspectives on project implementation. SCADA projects constituted the largest proportion, reflecting the prevalence of centralized control system implementations in utility modernization efforts. The distribution across project durations and budgets indicated adequate representation of various project scales and complexities.

5.2 Descriptive Statistics of Study Variables**Table 2: Means, Standard Deviations, and Correlations**

Variable	Mean	SD	1	2	3
1. Project Complexity Management	5.24	0.89	(0.87)		
2. Knowledge Resources	4.98	0.95	0.631**	(0.88)	
3. Project Performance	5.12	0.92	0.684**	0.697**	(0.86)

Note: $N = 247$. Values in parentheses are Cronbach's alpha coefficients. ** $p < 0.01$

Source: Primary Data, 2024

The means for all variables exceeded the scale midpoint (4.0), indicating generally positive perceptions of project complexity management, knowledge resources, and project performance across the sample. Standard deviations suggested reasonable variability in responses. Correlation analysis revealed strong positive relationships between all variables (Julius & Desire, 2025). Project complexity management correlated significantly with knowledge resources and project performance, while knowledge resources also demonstrated strong correlation with project performance. These bivariate relationships provided preliminary support for the proposed mediation model.

5.3 Structural Equation Modeling Results**Table 3: Model Fit Indices**

Fit Index	Value	Threshold	Interpretation
χ^2/df	2.14	< 3.0	Excellent fit
CFI	0.943	> 0.90	Excellent fit
TLI	0.937	> 0.90	Excellent fit
RMSEA	0.068	< 0.08	Acceptable fit
SRMR	0.052	< 0.08	Excellent fit

Source: Primary Data, 2024

The structural equation model demonstrated excellent overall fit to the data. All fit indices met or exceeded recommended thresholds, indicating that the proposed mediation model adequately represented the relationships among project complexity management, knowledge resources, and project performance. The Chi-square to degrees of freedom ratio of 2.14 fell well within the acceptable range, suggesting good model parsimony. Incremental fit indices

(CFI and TLI) both exceeded 0.93, indicating that the model explained substantially more variance than a null model. Absolute fit indices (RMSEA and SRMR) indicated close approximation to the population covariance matrix.

Table 4: Direct and Indirect Effects

Path	Standardized Coefficient (β)	Standard Error	t-value	p-value	Result
Direct Effects					
PCM $\rightarrow$ KR	0.517	0.058	8.914	< 0.001	Supported
PCM $\rightarrow$ PP	0.362	0.061	5.934	< 0.001	Supported
KR $\rightarrow$ PP	0.428	0.059	7.254	< 0.001	Supported
Indirect Effect					
PCM $\rightarrow$ KR $\rightarrow$ PP	0.221	0.034	6.500	< 0.001	Supported
Total Effect					
PCM $\rightarrow$ PP (Total)	0.583	0.052	11.212	< 0.001	Supported

Note: PCM = Project Complexity Management; KR = Knowledge Resources; PP = Project Performance. Bootstrap sample = 5,000. 95% CI for indirect effect [0.156, 0.290]

Source: Primary Data, 2024

The structural equation modeling results provided comprehensive support for the mediation hypothesis. Project complexity management exerted a strong positive direct effect on knowledge resources ($\beta = 0.517$, $p < 0.001$), indicating that organizations implementing systematic approaches to managing complexity were significantly better at developing, capturing, and utilizing knowledge resources. This finding suggested that complexity management practices created conditions conducive to organizational learning and knowledge accumulation.

Project complexity management also demonstrated a significant direct effect on project performance ($\beta = 0.362$, $p < 0.001$), confirming that effective complexity management independently contributed to improved project outcomes. This direct effect persisted even when accounting for the mediating role of knowledge resources, indicating that complexity management influenced performance through both knowledge-based and non-knowledge-based mechanisms.

Knowledge resources significantly predicted project performance ($\beta = 0.428$, $p < 0.001$), demonstrating that organizations with richer knowledge bases, better documentation systems, and more effective knowledge-sharing practices achieved superior project outcomes. This relationship underscored the strategic value of organizational memory and learning in technical project implementations.

The indirect effect of project complexity management on project performance through knowledge resources was statistically significant ($\beta = 0.221$, $p < 0.001$), with bootstrap confidence intervals that excluded zero [0.156, 0.290]. This finding confirmed that knowledge resources partially mediated the relationship between complexity management and performance. The mediation effect accounted for approximately 37.9% of the total effect (0.221/0.583), indicating

that more than one-third of complexity management's influence on performance operated through the knowledge resources pathway.

Table 5: Variance Explained

Endogenous Variable	R ²	Interpretation
Knowledge Resources	0.398	39.8% variance explained
Project Performance	0.673	67.3% variance explained

Source: Primary Data, 2024

The model explained substantial variance in both mediator and outcome variables. Project complexity management accounted for 39.8% of the variance in knowledge resources, indicating that while complexity management was a strong predictor, other factors also contributed to knowledge resource development. The model explained 67.3% of the variance in project performance, suggesting robust predictive power. This high R² value indicated that project complexity management and knowledge resources together represented critical determinants of project success in SCADA, Yaka, and AMR implementations.

5.4 Discussion of Results

The findings illuminated the intricate mechanisms through which project complexity management influenced project performance in technical utility projects. The significant mediation effect of knowledge resources revealed that complexity management practices did not merely provide direct benefits through better planning and coordination, but also indirectly enhanced performance by fostering organizational learning and knowledge accumulation. When organizations implemented systematic approaches to managing technical, organizational, stakeholder, and environmental complexities, they created environments where knowledge was more effectively captured, codified, shared, and applied.

The partial mediation pattern observed in this study held important implications. The persistence of a significant direct effect alongside the indirect effect through knowledge resources indicated that complexity management operated through multiple pathways. Some benefits of complexity management materialized immediately through improved coordination, risk mitigation, and stakeholder alignment, independent of knowledge processes. However, a substantial portion of complexity management's benefits accrued through enhanced knowledge resources, which served as repositories of lessons learned, best practices, and problem-solving approaches that teams could leverage throughout project lifecycles.

The strong relationship between project complexity management and knowledge resources suggested that complexity itself, when properly managed, stimulated organizational learning. Complex projects presented diverse challenges that required teams to develop innovative solutions, consult multiple expertise sources, document decision rationales, and engage in reflective practices. Organizations that approached complexity systematically were better positioned to

transform project experiences into reusable knowledge assets, creating positive feedback loops where accumulated knowledge further enhanced complexity management capabilities in subsequent projects.

The finding that knowledge resources significantly predicted project performance aligned with knowledge-based theories of organizational capabilities. In SCADA, Yaka, and AMR projects, technical expertise, documented procedures, troubleshooting guides, and lessons from previous implementations constituted critical assets that differentiated high-performing from low-performing projects. Teams with access to comprehensive knowledge repositories could anticipate common pitfalls, rapidly diagnose technical issues, adapt solutions from analogous situations, and make informed decisions under uncertainty. This knowledge advantage translated directly into better schedule adherence, budget control, quality assurance, and stakeholder satisfaction.

The high variance explained in project performance demonstrated that the combination of complexity management and knowledge resources captured essential determinants of success in utility technology projects. While other factors such as resource availability, leadership quality, and external environmental conditions undoubtedly influenced outcomes, the centrality of complexity management and knowledge resources in the causal model underscored their strategic importance for organizations pursuing digital transformation in the utility sector.

6. Conclusions

This study established that knowledge resources significantly mediated the relationship between project complexity management and project performance in SCADA, Yaka, and AMR projects. The findings demonstrated that effective project complexity management not only directly enhanced project outcomes but also indirectly improved performance by fostering the development and utilization of knowledge resources. Organizations that systematically addressed project complexities through structured frameworks were better positioned to capture experiential learning, document best practices, facilitate knowledge sharing, and apply accumulated expertise to current challenges.

The partial mediation pattern revealed that approximately 38% of project complexity management's total effect on performance operated through the knowledge resources pathway, while the remaining 62% represented direct effects. This dual-pathway model suggested that complexity management influenced performance through both immediate operational benefits and longer-term knowledge accumulation benefits. The high variance explained in project performance indicated that these two constructs together constituted critical success factors for technical utility projects.

The research contributed to theoretical understanding by empirically validating the mediating role of knowledge resources in a context characterized by high technical sophistication and operational criticality. The findings extended project management theory by demonstrating how organizational learning mechanisms linked complexity management practices to performance outcomes. For practitioners, the study provided evidence-based support for integrated approaches that combined complexity management frameworks with knowledge management systems.

In the specific context of SCADA, Yaka, and AMR projects within the utility sector, the findings underscored the importance of treating knowledge as a strategic asset rather than a byproduct of project activities. Organizations

implementing these technologies operated in environments where technical knowledge, operational expertise, and implementation experience represented sources of competitive advantage and operational excellence. The mediation effect of knowledge resources highlighted the multiplicative benefits of coupling complexity management investments with deliberate knowledge management initiatives.

7. Recommendations

Organizations implementing SCADA, Yaka, and AMR projects should adopt integrated frameworks that explicitly linked project complexity management with knowledge management systems. Project complexity assessments should trigger corresponding knowledge resource development activities, including the creation of project-specific knowledge repositories, assignment of knowledge management roles, and establishment of learning milestones throughout project lifecycles.

Senior leadership should recognize that investments in complexity management yielded maximum returns when accompanied by parallel investments in knowledge infrastructure.

Project managers should implement structured knowledge capture processes embedded within complexity management workflows. When addressing technical complexities, teams should systematically document solution approaches, decision rationales, and lessons learned in accessible formats. Complexity management plans should include knowledge management components specifying how project experiences would be captured, validated, stored, and disseminated. Post-implementation reviews should focus not only on performance evaluation but also on knowledge codification and transfer to future projects.

Organizations should establish communities of practice focused on SCADA, Yaka, and AMR technologies, creating forums where practitioners could share experiences, discuss challenges, and collaboratively develop solutions to recurring complexities. These communities should maintain curated knowledge repositories containing technical specifications, troubleshooting guides, vendor evaluation criteria, stakeholder engagement strategies, and implementation checklists.

References

- A, S. M. D. A. U. Y. N. L., & Ahmed, H. O. (2019). *On a Semi-Markov Model for Stock Exchange using Capital Assets*. 6(1), 138–144.
- Akankwasa, A., Akakikunda, T., Ntirandekura, M., Murezi, C. M., & Christopher, F. (2022). *Effect of Capital Budgeting on Development of Organizations Empirical Studies of Kashinge Child Development Centre Kisoro District*. 6(9), 5–10.
- Alex, I., & Devis, A. (2023). *Project Risk Management , Project Resilience And Project Efficiency . A Case Of Health Cbos In Busoga Region*. 3(December), 668–680.
- Christopher, T., Nelson, K., & Prudence, K. (2022). The Impact of Foreign Direct Investment on Economic Growth

- in Uganda-A Case Study of Kampala District. In *International Journal of Academic Multidisciplinary Research* (Vol. 6). www.ijeais.org/ijamr
- David, M., Julius, A., Ariyo, D., & Kazaara, G. (2023). THE ROLE OF COMMERCIAL BANKS IN SMALL SCALE ENTREPRENEURIAL DEVELOPMENT IN ADJUMANI DISTRICT, A CASE STUDY OF CENTENARY BANK Background of the Study. *METROPOLITAN JOURNAL OF BUSINESS & ECONOMICS (MJB)*, 2(3), 1490–1505.
- Faridah, K., Kazaara, A. G., & Kazaara, A. I. (2023). *The Effect Of Supplier Selection On Product Quality Management In Organizations . A Case Study Of Uganda Wild Life*. 7(3), 307–317.
- Frank, M., Nelson, K., Ariyo, D., Kazaara, G., Deus, T., Christopher, F., & Catherine, M. (2023). The Macroeconomic Determinants of Economic Growth in Uganda a Case Study Of Wakiso District. In *International Journal of Academic and Applied Research* (Vol. 7). www.ijeais.org/ijaar
- Julius, A. (2024). *Inventory Management Strategy and its Impact on Production Efficiency : An Empirical Evidence of Mukwano Manufacturing Industries*. 8(4), 96–99.
- Julius, A., & Desire, N. (2025). *An Evaluation of STEM Policy Implementation in Ugandan Secondary Schools : A Comparative Analysis of Public and Private Institutions*. 9(10), 93–98.
- Julius, A., & Kaazara, A. G. (2025). *From Specialists to Versatilists : The Imperative for Multiple Skilling in Ugandan Higher Education*. 9(11), 380–386.
- Kazaara, A. G., Nelson, K., & Kazaara, A. I. (2024). *Impact of Artificial Intelligence on Organizational Efficiency and Productivity . A Case Study of Metropolitan International University , Kampala Campus*. 8(8), 254–260.
- Lydia, N., Ariyo, D., Kazaara, G., Kazaara, A. I., Brenda, T., Moses, N., & Bafaki, G. (2023). Promotion of Small-Scale Industries and Development of Business. A Case Study; Masafu Subcounty (Busia). In *International Journal of Academic Multidisciplinary Research* (Vol. 7). www.ijeais.org/ijamr
- Moses, N., & Nancy, M. (2024). *Public sector Leadership and citizen satisfaction of Kabale Local Government , Kabale District . Empirical evidence of Kabale Municipality*. 8(4), 17–22.
- Nafiu, L. A. (2012). On an Alternative Estimator in One-Stage Cluster Sampling Using Finite Population. *American International Journal of Contemporary Research*, 2(7), 102–107. www.aijcrnet.com
- Nancy, M., & Prudence, K. (2024). Capacity Building programs and their impact on employee performance. A case study of Metropolitan International University. *Researchgate.Net*, 8(4), 23–27. https://www.researchgate.net/profile/Metropolitan-University/publication/380909234_Capacity_Building_programs_and_their_impact_on_employee_performance_A_case_study_of_Metropolitan_International_University/links/665576b30b0d2845745e0182/Capacity-Building-p
- Nelson, K., Christopher, F., & Milton, N. (2022). *Teach Yourself Spss and Stata*. 6(7), 84–122.
- Nelson, K., Kazaara, A. G., & Kazaara, A. I. (2023). *Teach Yourself E-Views*. 7(3), 124–145.

- Nicholas, K., & Nancy, M. (2024). *The Future of Work : Exploring the Impact of Automation and Remote Work on Organizational Structures and Talent Management . A Case Study the Metropolitan International University*. 8(8), 48–53.
- Ntirandekura, M., & Christopher, F. (2022). *Community Participation and Budget Allocation in Local Governments in Uganda : A Case Study of Rubanda District Local Government , Western Uganda*. 6(5), 124–134.
- Olanrewaju, R. O., Waititu, A. G., & Abiodun, N. L. (2021). *On the Estimation of k-Regimes Switching of Mixture Autoregressive Model via Weibull Distributional Random Noise*. 10(1), 1–8.
<https://doi.org/10.5923/j.ijps.20211001.01>
- Promise, O., Henry, M., & Julius, A. (2024). *External Auditing and The Financial Performance Of Sebbi International Limited , Entebbe*. 8(6), 156–161.