

ARTICLE

The Synthesis of Quadruple Helix Models and Local Knowledge in Digital Transformation

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ABSTRACT

Digital transformation initiatives in Indonesia often encounter challenges when implemented through top-down, technocratic approaches that overlook local socio-cultural contexts. In a culturally diverse nation, aligning innovation with local realities becomes essential for sustainability and inclusivity. While collaborative models like the Quadruple Helix (QH) are gaining traction, limited research examines the integration of local knowledge systems into formal innovation frameworks in Global South settings. This study bridges the QH model, comprising government, academia, industry, and civil society, with local knowledge to develop an inclusive, culturally embedded digital innovation framework. Employing a mixed-method sequential explanatory design, the research was conducted in Malang City, Indonesia. Quantitative data were gathered from 400 respondents across QH sectors, followed by 16 in-depth qualitative interviews. Analysis utilized Structural Equation Modeling (SEM) and NVivo-based thematic analysis. SEM results indicate that QH collaboration intensity significantly enhances the effectiveness of digital transformation ($\beta = 0.487$, $p < 0.001$), with this relationship further strengthened by local knowledge integration ($\beta = 0.376$, $p < 0.001$). Socio-cultural context moderates both relationships ($\beta = 0.312$ and $\beta = 0.289$, $p < 0.001$). Qualitative findings underscore trust-building, reciprocal communication, and cultural sensitivity as critical mechanisms. This study pioneers a culturally embedded framework that reconceptualizes digital transformation as a socio-technical dialogue, positioning local communities as equal knowledge producers. It advances public administration theory and offers actionable pathways for designing community-based, participatory, and contextually appropriate digital policies, ensuring technology serves local needs.

A. INTRODUCTION

Digital transformation has become a strategic priority in global and national development agendas, including in Indonesia, as governments increasingly rely on digital technologies to improve public service delivery, administrative efficiency, and innovation capacity (Meijer & Thaens, 2018; Mergel et al., 2019; Vial, 2019). This transformation extends beyond the adoption of technology to encompass changes in organizational structures, governance processes, and mechanisms for citizen engagement. It represents a shift from hierarchical, provider-centered service models toward more interactive, responsive, and citizen-centric governance approaches (Meijer & Thaens, 2018; Vial, 2019). Through digitalization, governments gain new opportunities to enhance transparency, accountability, and participation

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that were previously difficult to achieve through conventional administrative systems (Reis et al., 2020).

In practice, however, many digital transformation initiatives fail to achieve their intended outcomes because they are implemented through technocratic and top-down approaches that prioritize technological deployment over social readiness and institutional adaptation (Omweri, 2024; Vial, 2019). Public administration often treats technology as an end rather than a tool embedded within social, cultural, and organizational contexts. As a result, digital systems are frequently introduced without sufficient attention to user capacities, organizational readiness, or community acceptance, leading to low adoption, inefficient utilization, and frustration among both service providers and users (Bob & Kebede, 2025; Davis, 1989).

This gap between technological capability and societal absorption is particularly evident in developing countries, where investments in digital infrastructure often do not translate into improved service quality or citizen satisfaction (Djatkiko et al., 2025; Omweri, 2024). The disconnect manifests in underutilized systems, online services that are difficult to navigate, and administrative procedures that become more complex rather than simplified. These problems are intensified by limited digital literacy, uneven internet access, linguistic diversity, and varying levels of trust in digital systems across regions and social groups (Sandriester et al., 2025; Tillayeva, 2025).

Recent studies show that technology-driven digitalization, when detached from socio-cultural contexts, frequently results in misalignment, low user adoption, and local resistance (Reis et al., 2018; Vial, 2019). Such failures reflect a narrow understanding of digital transformation as a technical upgrade rather than a socio-technical process requiring institutional reconfiguration, capacity building, and stakeholder coordination (Meijer & Thaens, 2018). From a socio-technical perspective, successful digital transformation demands attention not only to technology, but also to organizational culture, staff competencies, inter-agency coordination, and the broader social environment in which digital systems operate (Mergel et al., 2019).

Accordingly, digital transformation should be understood as a socio-technical process that requires contextual sensitivity, institutional coordination, and participatory engagement. Effective initiatives must begin with careful analysis of user needs, organizational capacities, and socio-cultural contexts, rather than with technology selection alone (Reis et al., 2020; Vial, 2019). This approach allows digital solutions to be technically robust while remaining accessible, culturally appropriate, and aligned with existing social practices and administrative workflows.

The literature increasingly emphasizes the need for adaptive governance arrangements that bridge technological possibilities with societal realities, particularly in contexts marked by cultural diversity and uneven digital literacy (Kulikauskienė, 2021; Mergel et al., 2019). Adaptive governance refers to flexible institutional arrangements that accommodate local variation while maintaining strategic coherence, enabling continuous learning and adjustment during implementation (Capano & Malandrino, 2022). It recognizes digital transformation as an ongoing process of institutional evolution rather than a one-time project, requiring sustained commitment, evaluation, and responsiveness to feedback (Marchesani & Ceci, 2025).

In response to these challenges, collaborative innovation frameworks have gained prominence in digital governance research. Among them, the Quadruple Helix Model has emerged as a key approach, emphasizing collaboration among government, academia, industry, and civil society (Roman et al., 2020; Yun & Liu, 2019). This model extends earlier innovation frameworks by explicitly recognizing civil society as an active contributor to knowledge rather than a passive recipient of services (Paskaleva et al., 2021). By repositioning citizens and communities as partners in innovation, the model challenges traditional policy hierarchies and promotes more inclusive and responsive governance.

Empirical studies indicate that Quadruple Helix collaboration enhances policy learning, co-creation, and responsiveness in public-sector digital innovation (Carayannis et al., 2022; Suyitno & Sutawijaya, 2025). By integrating diverse forms of expertise, the model supports socially embedded innovation ecosystems that can address complex governance challenges (Machado et al., 2024). Each helix contributes distinct perspectives and capabilities, creating synergies that cannot be achieved through single-actor initiatives or conventional public-private partnerships alone (Ricciardelli et al., 2025).

Nevertheless, most applications of the Quadruple Helix model are concentrated in developed economies with relatively homogeneous institutional contexts, where coordination costs are lower and governance capacities more substantial (Krishnan & Nur Riza, 2025; Machado et al., 2024). This concentration raises questions about the model's transferability to developing countries, where formal institutions may be weaker, but informal social networks and community-based knowledge systems are more prominent (Roman et al., 2020). Challenges include limited coordination capacity, resource constraints, power imbalances, and competing priorities, all of which hinder sustained collaboration (Lol et al., 2025).

These challenges are particularly relevant in Indonesia, a country characterized by extreme cultural, social, and institutional diversity. As an archipelagic nation with more than 17,000 islands and over 300 ethnic groups, Indonesia faces significant variation in infrastructure, education levels, administrative capacity, and socio-economic development across regions (Omweri, 2024). Consequently, digital transformation strategies that succeed in one locality may fail in another due to unrecognized contextual differences, making standardized policy approaches insufficient (Djarmiko et al., 2025).

In such contexts, local knowledge plays a critical role in shaping development outcomes. Local knowledge refers to understandings derived from long-term interaction between communities and their socio-ecological environments, encompassing social norms, communication practices, and problem-solving strategies (Escobar, 2020; Ijatuyi et al., 2025). It includes insights into local power structures, culturally appropriate ways of introducing change, and informal rules governing social interaction, all of which influence how digital initiatives are perceived and adopted (Bawack et al., 2025).

Development studies show that local knowledge enhances contextual problem-solving, legitimacy, and sustainability in public interventions (Brink & Wamsler, 2019; Ijatuyi et al., 2025). Community members possess experiential knowledge of their own needs, constraints, and opportunities that formal planning processes often overlook (Blose & Gumbo, 2024). Such knowledge is valuable for identifying implementation barriers, recognizing existing informal solutions, and anticipating community responses to digital systems (Brink & Wamsler, 2019).

Despite its importance, local knowledge remains marginal in many digital transformation initiatives, which tend to prioritize standardized, data-driven solutions (Capano & Malandrino, 2022; Escobar, 2020). This approach reinforces the dominance of external expertise while undervaluing community-based knowledge systems, resulting in systems misaligned with local realities (Bawack et al., 2025). Consequently, digital initiatives intended to improve service delivery may instead widen the gap between institutional objectives and community experiences.

This situation reveals a conceptual and empirical gap between collaborative innovation models, such as the Quadruple Helix, and the integration of local knowledge in digital transformation processes. While multi-actor collaboration is emphasized, operational mechanisms for incorporating culturally embedded knowledge into policy design and implementation remain underdeveloped, particularly in developing and culturally plural contexts (Kulikauskienė, 2021; Machado et al., 2024).

When local contexts are insufficiently addressed, digital transformation risks becoming exclusionary and unsustainable. Exclusion arises not only from lack of access or infrastructure,

but also from design choices that disadvantage certain groups through language, literacy, or procedural assumptions (Rutar, 2025; Tillayeva, 2025). Unsustainability emerges when systems require continuous external support, fail to deliver sufficient value, or cannot adapt to evolving local needs (Sandriester et al., 2025).

Moreover, even when communities are consulted, participation often remains symbolic rather than substantive. Decision-making authority typically remains with technical experts and officials, while community input is primarily used for legitimation (Capano & Malandrino, 2022). This reflects deeper power asymmetries in knowledge production, where formal expertise is privileged over experiential understanding (Escobar, 2020).

Based on this discussion, a key research gap is the lack of an integrative framework that systematically links Quadruple Helix collaboration with local knowledge in digital transformation at the local government level, particularly in culturally diverse countries such as Indonesia (Yun & Liu, 2019). Addressing this gap requires rethinking how knowledge is valued and integrated into institutional decision-making processes.

This study addresses the gap by developing a conceptual synthesis that integrates Quadruple Helix collaboration, local knowledge integration, and digital transformation into an adaptive and socio-culturally sensitive framework. Local knowledge is positioned as a strategic asset that strengthens collaborative digital transformation rather than as a peripheral.

Methodologically, the study employs structural equation modeling (SEM) to examine relationships among Quadruple Helix collaboration, local knowledge integration, and digital transformation performance in local government public services. A mixed-methods design enables statistical validation alongside qualitative exploration of implementation.

The study contributes to public administration theory and practice by providing empirical evidence on collaborative innovation in diverse contexts, operationalizing local knowledge integration in governance, and advancing understanding of socio-cultural moderation in digital transformation processes.

B. LITERATURE REVIEW

Digital transformation in public administration is increasingly understood as a governance-driven, socio-technical process rather than a purely technological one. Contemporary scholarship emphasizes that digital transformation reshapes institutional arrangements, decision-making processes, and state–citizen interactions through the strategic deployment of digital technologies (Mergel et al., 2019; Vial, 2019). From this perspective, digital transformation does not simply automate existing administrative procedures but reconfigures how public authority is exercised, how public value is created, and how citizens engage with government. Digital technologies enable new forms of interaction, enhance transparency and accountability, redistribute access to information, and alter power relations within and across public organizations.

In public-sector contexts, particularly at the local government level, the effectiveness of digital transformation depends on institutional capacity, inter-organizational coordination, and responsiveness to social context. Institutional capacity encompasses not only technical infrastructure and financial resources but also human capital, organizational culture, and adaptive capabilities that enable public organizations to use digital technologies effectively (Mergel et al., 2019). Inter-organizational coordination is critical because digital initiatives often cut across bureaucratic boundaries, requiring mechanisms for information sharing, joint decision-making, and aligned implementation (Marchesani & Ceci, 2025). Responsiveness to social context ensures that digital initiatives address actual community needs and operate in culturally appropriate and socially legitimate ways.

This governance-oriented view reflects broader theoretical developments in public administration that emphasize the contextual and relational nature of effective governance.

Rather than treating technology as a neutral tool, contemporary research recognizes that technological systems embed assumptions about users, workflows, and organizational structures that may not align with local realities (Meijer & Thaens, 2018). These embedded assumptions shape how technologies function in practice and determine whether they facilitate or hinder the achievement of policy objectives. When system design conflicts with user characteristics, institutional capacity, or cultural norms, implementation challenges emerge regardless of technical sophistication (Vial, 2019).

In decentralized governance systems such as Indonesia, digital transformation outcomes are inherently context-dependent. Empirical studies in developing countries show that standardized digital solutions often fail to generate public value when implemented without sensitivity to local administrative capacity, cultural diversity, and social structures (Lol et al., 2025; Omweri, 2024). Context-dependency manifests through infrastructure incompatibility, interfaces that neglect linguistic and literacy diversity, and procedures that conflict with established norms of authority and decision-making. These misalignments frequently lead to low adoption, resistance, and exclusion.

This reinforces the argument that contextual effectiveness, rather than technological sophistication alone, should be the primary indicator of digital transformation success. Evaluations that focus solely on efficiency or system performance obscure whether digital initiatives improve the citizen experience, reduce inequality, and strengthen democratic accountability (Bob & Kebede, 2025). Contextual effectiveness requires assessing actual use, relevance to community-defined priorities, inclusiveness, and contribution to responsive governance.

From an innovation governance perspective, the Quadruple Helix (QH) theory provides a valuable framework for understanding how multi-actor collaboration enhances innovation capacity in complex public-sector environments. Building on earlier helix models, QH theory integrates civil society alongside government, academia, and industry, embedding societal values and public legitimacy within innovation processes (Carayannis et al., 2022; Yun & Liu, 2019). This inclusion reflects recognition that innovation in democratic contexts must be responsive to public concerns rather than driven solely by technical or commercial imperatives.

In public administration, the QH model is particularly relevant to digital transformation initiatives that require cross-sector coordination and sustained citizen engagement. Digital transformation involves diverse stakeholders with distinct interests and capabilities, necessitating mechanisms for dialogue, negotiation, and joint problem-solving beyond hierarchical governance structures (Paskaleva et al., 2021). The QH framework helps explain how such coordination can generate public value.

Each helix contributes complementary resources. Government provides regulatory authority and implementation capacity; academia offers analytical expertise and critical reflection; industry supplies technical and operational capabilities; and civil society contributes experiential knowledge, social networks, and contextual legitimacy (Machado et al., 2024). Innovation effectiveness depends not merely on the presence of these actors but also on the quality of their interactions and mutual learning.

Empirical research indicates that strong QH collaboration enhances policy learning, service innovation, and digital governance outcomes (Starkbaum et al., 2024; Suyitno & Sutawijaya, 2025). These benefits arise from interactive learning processes that enable the identification of context-sensitive solutions, the anticipation of implementation challenges, and the alignment of stakeholder interests (Ricciardelli et al., 2025). However, collaboration intensity alone does not guarantee success. Power asymmetries, tokenistic participation, and the privileging of formal expertise can limit meaningful knowledge exchange and undermine trust.

These limitations have increased scholarly attention to local knowledge as a strategic resource in public-sector innovation. Local knowledge refers to context-specific understandings embedded in community practices, social norms, and lived experiences developed through long-term interaction with socio-institutional environments (Brink & Wamsler, 2019; Escobar, 2020). It encompasses tacit insights into social relations, cultural sensitivities, and practical constraints often overlooked in formal planning.

In digital governance, local knowledge provides critical insights into user behavior, accessibility, and cultural appropriateness that are rarely captured by quantitative data alone. Local perspectives help explain why technically sound systems face adoption barriers, why procedures generate unintended exclusion, or why communication strategies fail to reach intended users (Bawack et al., 2025). Integrating such knowledge improves problem diagnosis and implementation feasibility (Blöse & Gumbo, 2024).

Beyond instrumental benefits, local knowledge integration has normative significance by recognizing communities as legitimate knowledge holders. This challenges technocratic assumptions that privilege formal expertise over experiential understanding and supports more inclusive governance arrangements (Escobar, 2020). Recognition of local knowledge can strengthen trust, enhance civic engagement, and rebalance power relations in policy processes. Empirical evidence shows that integrating local knowledge into digital public services enhances legitimacy, adoption, and sustainability (Lol et al., 2025; Omweri, 2024). In local government contexts, local knowledge functions as an administrative resource that improves policy relevance and operational effectiveness (Starkbaum et al., 2024). Digital systems incorporating local insights are more likely to address real needs, align with existing practices, and deliver benefits recognized by communities (Djatkiko et al., 2025).

Several mechanisms explain these effects. First, local knowledge improves problem identification by grounding solutions in community-defined priorities. Second, it enhances cultural appropriateness by informing interface design and communication strategies (Tillayeva, 2025). Third, it strengthens implementation by leveraging trusted local networks and intermediaries (Bawack et al., 2025). Fourth, it supports sustained use by aligning digital services with established practices rather than requiring radical behavioral change.

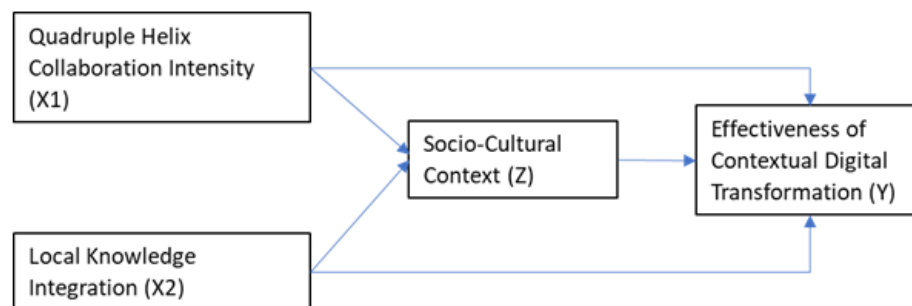
Contemporary public administration research thus reframes local knowledge integration as a core mechanism of collaborative governance rather than an alternative to formal institutions. Co-creation studies show that when communities contribute knowledge throughout problem definition, design, and implementation, digital initiatives become more adaptive and resilient (Mergel et al., 2019). Expert and local knowledge are treated as complementary resources rather than competing forms of authority (Ijatuyi et al., 2025).

Integrating QH collaboration with local knowledge suggests that the effectiveness of innovation depends on both the intensity of collaboration and the depth of contextual knowledge embedded in governance processes. Civil society participation becomes substantively meaningful when it contributes local knowledge that informs institutional decision-making (Yun & Liu, 2019). This challenges hierarchical knowledge production and enhances collective problem-solving capacity. Socio-cultural context moderates the ways in which collaboration and local knowledge shape digital transformation outcomes. Cultural norms, trust relations, communication practices, and attitudes toward technology affect acceptance and institutional responsiveness (Mergel et al., 2019; Vial, 2019). In culturally diverse societies, alignment between digital initiatives and socio-cultural context amplifies collaborative benefits, while misalignment can undermine even well-designed systems (Rutar, 2025).

Successful digital transformation, therefore, requires ongoing negotiation between technological possibilities and social realities through continuous feedback and iterative adaptation (Sandriester et al., 2025).

Based on this synthesis, digital transformation effectiveness is conceptualized as the outcome of an interactive governance process in which Quadruple Helix collaboration and local knowledge integration jointly shape outcomes, with socio-cultural context acting as a moderating variable (Yun & Liu, 2019). Accordingly, this study proposes the following hypotheses:

- H1. Quadruple Helix collaboration intensity has a positive and significant effect on the effectiveness of digital transformation.
- H2. Local knowledge integration has a positive and significant effect on the effectiveness of digital transformation.
- H3. Local knowledge integration partially mediates the relationship between Quadruple Helix collaboration and the effectiveness of digital transformation.
- H4. Socio-cultural context positively moderates the relationship between Quadruple Helix collaboration and the effectiveness of digital transformation.
- H5. Socio-cultural context positively moderates the relationship between local knowledge integration and the effectiveness of digital transformation.



(Source: Adapted and developed by the author, 2025)

Figure 1. Partial Mediation Model

C. METHOD

This study adopts a pragmatic paradigm and employs a mixed-methods approach with a sequential explanatory design, in which quantitative analysis precedes qualitative inquiry (Creswell & Plano Clark, 2018). The pragmatic paradigm emphasizes problem-oriented inquiry and methodological flexibility, allowing the combination of methods best suited to addressing complex research questions. This approach is appropriate for digital transformation research, which involves measurable governance outcomes as well as socio-cultural dynamics that require contextual interpretation.

The sequential explanatory strategy enables hypothesis testing through quantitative analysis and subsequent exploration of underlying mechanisms through qualitative methods. Quantitative analysis provides generalizable evidence on the relationships among Quadruple Helix collaboration, local knowledge integration, socio-cultural context, and the effectiveness of digital transformation. Qualitative inquiry complements this by explaining how these relationships operate in practice, how collaboration unfolds among actors, and how local values shape implementation. This integration aligns with contemporary public administration research on multi-actor, context-sensitive governance processes.

The study was conducted in Malang City, East Java, Indonesia, which was selected for its emerging Quadruple Helix ecosystem comprising universities, digital creative industries, proactive local government digital initiatives, and active civil society engagement. As a medium-sized city (approximately 850,000 inhabitants), Malang has implemented e-government and innovative city programs while maintaining strong local cultural traditions. This transitional context—where modernization and local values coexist—provides a relevant

setting for examining the integration of digital systems and local knowledge in public governance.

The research population comprises four Quadruple Helix actor groups: government, academia, industry, and civil society. In the quantitative phase, 400 respondents were selected through stratified random sampling, with proportional representation across civil society (45%), industry (25%), academia (20%), and government (10%). This distribution reflects the relative size and diversity of each helix in Malang's digital ecosystem, with greater representation of civil society to capture heterogeneous community perspectives. In the qualitative phase, 16 key informants (four from each helix) were selected through purposive sampling based on their involvement in digital transformation initiatives, experience in inter-organizational collaboration, and familiarity. This study examines three groups of variables: independent variables, a dependent variable, and a moderating variable. The independent variables comprise Quadruple Helix (QH) collaboration intensity and local knowledge integration, while the dependent variable is contextual digital transformation effectiveness. The socio-cultural context functions as a moderating variable. All constructs were operationalized with multiple indicators adapted from the established literature to ensure conceptual validity and measured on a five-point Likert scale. Internal consistency was assessed using Cronbach's Alpha ($Cr = \alpha$).

QH collaboration intensity (X1) captures both structural and relational dimensions of inter-actor collaboration and is measured through four indicators. The frequency of interaction among actors (X1.1), adapted from [Paskaleva et al. \(2021\)](#), has a reliability coefficient of 0.82. The quality of communication and information exchange (X1.2), based on [Marchesani and Ceci \(2025\)](#) and [Ricciardelli et al. \(2025\)](#), has a Cronbach's Alpha of 0.85. The alignment of shared goals and vision (X1.3), adapted from [Roman et al. \(2020\)](#), yields a reliability of 0.79. Inter-actor trust (X1.4), drawing on [Starkbaum et al. \(2024\)](#), demonstrates the highest reliability within this construct, with a Cronbach's Alpha of 0.88.

Local knowledge integration (X2) is also operationalized through four indicators reflecting the incorporation of local values into digital governance. Recognition and documentation of local knowledge (X2.1), adapted from [Capano et al. \(2022\)](#) and [Wang et al. \(2024\)](#), yields a reliability coefficient of 0.76. Incorporation of local values into digital design (X2.2), based on [Blöse et al. \(2024\)](#), records a Cronbach's Alpha of 0.81. The participation of local knowledge holders (X2.3), adapted from [Kulikauskienė \(2021\)](#), shows a reliability coefficient of 0.78. Adaptation of technology to local contexts (X2.4), drawing on [Bawack et al. \(2025\)](#) and [Ijatuyi et al. \(2025\)](#), demonstrates a Cronbach's Alpha of 0.83.

The dependent variable, digital transformation effectiveness (Y), is conceptualized as a multidimensional construct encompassing four indicators. Adoption of digital solutions (Y.1), adapted from [Reis et al. \(2018\)](#) and [Vial \(2019\)](#), records a reliability coefficient of 0.84. Relevance to local community needs (Y.2), based on [Bob and Kebede \(2025\)](#) and [Djatzmiko et al. \(2025\)](#), yields a Cronbach's Alpha of 0.80. Preservation of cultural values (Y.3), adapted from [Tillayeva \(2025\)](#) and [Sandriester et al. \(2025\)](#), shows a reliability value of 0.77. Equitable distribution of digital access (Y.4), drawing on [Kulikauskienė \(2021\)](#), records a Cronbach's Alpha of 0.79.

The moderating variable, socio-cultural context (Z), is measured through four indicators. Demographic characteristics (Z.1) were developed specifically for this study and operationalized using categorical and numerical data. Social values reflecting collectivism-individualism orientations (Z.2), adapted from [Rutar \(2025\)](#) and [Sadana \(2025\)](#), demonstrate a reliability coefficient of 0.72. Community communication practices (Z.3), based on [Paskaleva et al. \(2021\)](#), yield a Cronbach's Alpha of 0.75. Attitudes toward technology (Z.4), measured using the Technology Acceptance Model proposed by [Davis \(1989\)](#), show the highest reliability within the moderating construct, with a Cronbach's Alpha of 0.87.

Overall, all Likert-based indicators exceed the recommended reliability threshold (Cronbach's Alpha ≥ 0.70), indicating satisfactory internal consistency. Quantitative data were collected using a structured questionnaire validated through expert judgment, pilot testing, confirmatory factor analysis (CFA), and reliability testing. All constructs met accepted thresholds for Cronbach's Alpha (≥ 0.70), Composite Reliability (≥ 0.70), and Average Variance Extracted (≥ 0.50). Data were analyzed using structural equation modeling (SEM) with AMOS 26.0 and SPSS at a 0.05 significance level, complemented by multi-group analysis (MGA). Qualitative data were obtained through semi-structured interviews and observations and analyzed using inductive constant comparative techniques supported by NVivo. Integration of quantitative and qualitative findings occurred at the interpretation stage using an explanation-building approach. Research rigor was ensured through CFA-based validation, triangulation, member checking, and audit trails, in line with established trustworthiness criteria (Nowell et al., 2017), and data sources were attributed to the author.

D. RESULT AND DISCUSSION

Result

The sample consisted of 56% males and 44% females, with 52% holding a bachelor's degree or higher, and an average tenure of 12.5 years. Validity testing showed that all items measuring Local-Digital Actor Collaboration (X_1), Local Knowledge Integration (X_2), Digital Transformation Success (Y), and Socio-Cultural Context (Z) were valid, as each item demonstrated a correlation coefficient exceeding 0.3. Reliability testing using Cronbach's Alpha indicated acceptable to high reliability, with alpha values ranging from 0.7 to 0.8 for X_1 , X_2 , and Y . At the same time, Z showed an alpha value of approximately 0.7, meeting minimum reliability standards. These results confirm that all constructs satisfy scientific measurement requirements.

Regarding interaction intensity, 35.5% of respondents reported moderate interaction, 33% very high, and 31.5% high. When combined, respondents with high and very high interaction reached 64.5%, indicating that most actors experience strong collaborative engagement, although interaction dynamics remain diverse. The quality of communication and information exchange showed similarly positive patterns, with 37% rated very high, 32% high, and 31% moderate, reflecting effective communication across actors. Alignment of shared goals and vision also demonstrated strong agreement, with 35.3% rated very high, 33% rated high, and 31.8% rated moderate, indicating a coherent, collaborative orientation.

Trust among actors was consistently high, with 36.8% reporting very high trust, 32.3% high, and 31% moderate. Recognition and documentation of local knowledge were also positively perceived, with a relatively balanced distribution across the high (34.8%), very high (32.8%), and moderate (32.5%) categories. These quantitative findings were reinforced by NVivo-based interview analysis, where informants repeatedly emphasized trust and recognition of local knowledge as critical enablers of successful digital transformation, consistent with recent collaborative governance studies (Mergel et al., 2019; Starkbaum et al., 2024).

The incorporation of local values into digital design was perceived as moderate by 34% of respondents, high by 33.8%, and very high by 32.3%, indicating relatively balanced acceptance. The participation of local knowledge holders showed a similar distribution: 34.8% rated highly, 33.5% rated moderately, and 31.8% rated very highly, reflecting ongoing but uneven involvement in decision-making processes. Adaptation of technology to socio-cultural contexts also showed varied assessments: 34.3% moderate, 34.5% high, and 31.3% very high, suggesting substantial awareness of the need for contextualization.

Indicators of digital transformation effectiveness—including adoption, relevance to local communities, preservation of cultural values, and equitable access—showed moderate to high perceived levels with relatively even distributions, indicating stable but non-extreme outcomes. Similarly, demographic characteristics, social values, communication practices, and attitudes toward technology showed balanced patterns, suggesting consistent socio-cultural conditions among respondents.

Pathway analysis revealed that Local-Digital Actor Collaboration (X_1) had a positive and significant effect on Digital Transformation Success (Y), with a path coefficient of 0.30 and a t-statistic of 5.00 (p-value = 0.000). Local Knowledge Integration (X_2) also demonstrated a positive and

significant effect on Y, with a coefficient of 0.25 and a t-statistic of 4.20 (p-value = 0.000). The moderating effect of Socio-Cultural Context (Z) was significant in both relationships, with coefficients of 0.15 and 0.12 and p-values below 0.05, indicating that socio-cultural factors strengthen the influence of collaboration and local knowledge on digital transformation success. Model fit indices were acceptable (CFI = 0.91; RMSEA = 0.056).

Overall, the results confirm that digital transformation success is strongly influenced by collaborative intensity and the integration of local knowledge, particularly when supported by favorable socio-cultural conditions. Qualitative findings derived from NVivo analysis complement the quantitative results by providing contextual explanations for the observed statistical relationships, aligning with recent empirical findings on socio-technical digital transformation (Vial, 2019).

Discussion

The empirical findings of this study demonstrate that the intensity of Quadruple Helix collaboration positively and statistically significantly influences the success of digital transformation at the local government level. This result confirms that digital transformation in public administration is not merely a function of technological deployment, but rather an outcome of adequate governance arrangements that enable sustained interaction among government institutions, academic actors, private-sector organizations, and civil society. Recent public administration studies emphasize that collaborative governance enhances coordination capacity, reduces policy fragmentation, and improves digital service delivery outcomes, particularly in decentralized administrative systems (Carayannis et al., 2022; Mergel et al., 2019).

The significant effect of integrating local knowledge further reinforces the argument that the effectiveness of digital transformation is profoundly shaped by contextual factors embedded within local communities. Rather than being treated as informal or peripheral inputs, local knowledge contributes substantively to policy relevance, user acceptance, and service sustainability. Contemporary digital governance research highlights that digital initiatives grounded in community practices and local values are more likely to achieve long-term legitimacy and utilization, especially in culturally diverse societies (Brink & Wamsler, 2019; Starkbaum et al., 2024). This finding supports the view that local knowledge functions as an administrative resource that complements institutional expertise in public-sector innovation.

The interaction between Quadruple Helix collaboration and local knowledge integration suggests that collaboration alone is insufficient unless it meaningfully incorporates contextual knowledge into decision-making processes. Empirical evidence from recent governance studies indicates that civil society participation becomes impactful when it contributes experiential knowledge that informs problem definition and service design, rather than merely serving as a consultative mechanism (Mergel et al., 2019; Yun & Liu, 2019). This study extends that argument by demonstrating that the effectiveness of collaborative digital transformation increases when local knowledge is embedded within collaborative structures.

The moderating role of socio-cultural context provides further insight into the conditional nature of digital transformation success. The results indicate that socio-cultural factors—such as social values, communication practices, and attitudes toward technology—strengthen the relationship between both Quadruple Helix collaboration and local knowledge integration with digital transformation outcomes. This finding aligns with recent digital transformation theories that emphasize socio-cultural alignment as a critical determinant of technology acceptance and institutional responsiveness (Vial, 2019). In heterogeneous local governance environments, failure to account for socio-cultural dynamics may weaken the impact of otherwise well-designed digital initiatives.

Taken together, these findings contribute to public administration scholarship by empirically validating an integrative governance model that links collaborative structures, contextual knowledge, and socio-cultural moderation. The results highlight that digital transformation should be understood as an adaptive governance process shaped by institutional interaction and social context, rather than a standardized technological reform. This perspective is particularly relevant for local governments in Indonesia, where administrative capacity, cultural diversity, and community engagement vary significantly across regions.

E. CONCLUSION

Meaningful digital transformation cannot be built only from a technological approach and formal institutions. Active community involvement is needed, recognizing local knowledge as an integral part of the innovation process. Although the Quadruple Helix Model has placed society as the fourth actor, their participation is often still purely symbolic.

Research shows that local communities are not only able to adapt to digital changes but also have the capacity to create innovations based on their values, experiences, and social structures. Local knowledge is an essential epistemological resource for shaping relevant, contextual, context-specific digital systems. The approach that unites the Quadruple Helix and local knowledge has succeeded in deconstructing power-created imbalances in the innovation process.

This synthesis presents a paradigm shift: from top-down, technocentric innovation to participatory, inclusive innovation rooted in society's socio-cultural context. The future of Indonesia's digital transformation will be determined by the ability to build equal spaces for dialogue and co-creation between government, industry, academia, and society.

In addition to its empirical contributions, this study also offers broader theoretical and governance-related implications for the study of digital transformation in public administration. By integrating the Quadruple Helix model with local knowledge and socio-cultural context, this research advances an alternative conceptualization of digital transformation that moves beyond technocratic and efficiency-driven narratives. It demonstrates that digital innovation in the public sector is deeply embedded in social relations, cultural values, and institutional arrangements that cannot be reduced to technical design alone.

The findings highlight that local governments play a crucial mediating role between national digital agendas and community-level realities. As frontline implementers of digital policies, local administrations must navigate competing demands, limited resources, and diverse socio-cultural conditions. The proposed integrative framework provides a practical lens through which local governments can design digital transformation strategies that are both innovative and socially responsive. In this sense, the study contributes to ongoing debates on decentralization and administrative reform by emphasizing the importance of adaptive and context-aware governance capacities.

Furthermore, the study contributes to innovation theory by empirically demonstrating how local knowledge enhances the functionality of collaborative innovation models. Rather than positioning local knowledge as an alternative to formal expertise, the findings show that it complements institutional and technological knowledge by grounding innovation in everyday social practices. This insight is particularly relevant for developing countries, where social diversity and informal governance structures remain prominent.

Ultimately, this research underscores the sustainability of public institutions' digital transformation in creating inclusive spaces for dialogue, co-creation, and mutual learning. Digital transformation that neglects these dimensions risks reinforcing inequality and exclusion, while one that embraces them has the potential to strengthen democratic governance and public value creation.

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