Interoperability and Quality Control Effectiveness in Primary Healthcare Centers: Evidence from Public Health Centers

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ABSTRACT

This study examines how information system interoperability within public primary healthcare networks influences the effectiveness of quality control processes. Using a cross-sectional mixed-methods design, data were collected from heads of public health centers, quality officers, and district-level health data managers. Quantitative measures included the interoperability maturity index and index, complemented by qualitative interviews and document analysis to examine feedback mechanisms and governance practices. Multivariate regression analysis showed that interoperability maturity was positively associated with quality control effectiveness. Mediation analysis revealed that feedback loop intensity significantly mediated this relationship, while moderation analysis indicated that leadership and data governance strengthened the impact of interoperability on quality control effectiveness. These findings highlight that interoperability improves quality control not only through technical integration but also through structured feedback processes and strong governance arrangements. The study contributes a measurable and auditable process model for data-driven quality improvement in primary healthcare and underscores the importance of semantic standardization, disciplined feedback cycles, and institutionalized data governance to support sustainable quality improvement.

Keywords*: Continuous Quality Improvement, Data Governance, Data Quality, Interoperability, Primary Healthcare, Public Health Centers, Semantic Interoperability.*

INTRODUCTION

The digital transformation of healthcare is pushing for interoperable data flows across levels to support faster, more accurate, and accountable quality decisions. Systematic reviews show that Electronic Health Record (EHR) interoperability links to better patient safety and care quality, though results vary by context and point to the need for strong governance behind the technology (Lin & Lin, 2024). In particular, semantic interoperability is essential so data moves between systems without losing clinical or managerial meaning, keeping information usable across different applications and organizations (Palojoki et al., 2024).

At the primary care level, Continuous Quality Improvement (CQI) relies on regular feedback loops where indicators are tracked, problems are fixed, and lessons become part of routine practice. A recent scoping review found that CQI works best when data standards, team skills, and governance support each other; barriers often come from uneven skills, fragmented systems, and heavy workloads (Endalamaw et al., 2024). This study builds on public values theory, where interoperability and CQI should follow principles of transparency, accountability, and ethics to ensure digital changes create real value for people, not just technical gains (Aneta et al., 2023; Palojoki et al., 2024; Setiawaty & Nurmalina, 2025).

In Indonesia, the picture is clear through regulation: Minister of Health Regulation Number 24 of 2022 requires electronic medical record systems to be compatible or

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interoperable, making data sharing between facilities and health authorities a must, not an option (Kementerian Kesehatan Republik Indonesia, 2022). This study focuses on the Community Health Center (*Pusat Kesehatan Masyarakat*/Puskesmas) to District Health Office (*Dinas Kesehatan*/Dinkes) pathway: it tests how interoperability in quality information systems affects quality control effectiveness (measured by response timeliness, reporting accuracy, and follow-up consistency), and examines feedback loops, leadership support, and data governance as key mechanisms that align with public values and bureaucratic reform goals (Hotchkiss et al., 2010; Aneta et al., 2025; Sulila et al., 2025).

Recent studies confirm that semantic interoperability is key for data to transfer without losing meaning and enable quick action, while good governance and data quality strategies form the base for ongoing improvement (Szarfman et al., 2022; Palojoki et al., 2024). Frameworks like phased implementation offer practical technical paths, and CQI in primary care shows success when feedback and organizational capacity align (Adel et al., 2022). Stakeholder views highlight that speeding up interoperability depends on cross-unit coordination and clear policy rules. In Low and Middle-Income Countries (LMICs), common barriers include weak standardization, poor data linkage, and limited resources (Walker et al., 2023). In the Indonesian setting, the mandate for interoperable electronic records makes community health center and district health office integration a governance requirement, which should shape how indicators are designed and evaluated (Kementerian Kesehatan Republik Indonesia, 2022).

Despite these advances, several gaps remain in the literature. Most studies focus on hospitals or national-level systems, with little attention to the community health center-district health office chain in primary care (Purwanto et al., 2025). According to Torab-Miandoab et al. (2023), empirical links between interoperability levels and actual quality control outcomes in primary settings are rare, especially in LMICs with fragmented applications. Non-technical factors like data-sharing policies, organizational culture, and inter-agency governance are often overlooked in measurements, and there are no standard contextual metrics for community health center interoperability. Walker et al. (2023) also note that qualitative insights on leadership and governance as accelerators are common, but few studies test them quantitatively in mediation or moderation models at the district level.

To address these gaps, this study develops the Interoperability Operational Quality Index (IIMO), which combines technical (standards, integration, security), organizational (leadership support, governance), and process (feedback loop speed/SLA) dimensions. It tests these in a mediation model (via feedback loop intensity) and a moderation model (via leadership and data governance) on quality control effectiveness. Outcomes draw from the DeLone and McLean (2003) IS Success Model and SERVQUAL framework to link information system quality to measurable primary care benefits. The main objectives are: to examine the direct effect of interoperability on quality control effectiveness, to test whether feedback loops mediate this relationship, and to investigate how leadership and data governance moderate the effect. This approach provides policy-ready evidence for district-level governance in Indonesia's primary healthcare network, considering local factors like work hierarchy, digital capacity variations, workload, and data ethics that often act as real barriers or enablers in daily practice.

LITERATURE REVIEW & HYPOTHESIS DEVELOPMENT

Interoperability and Quality Control Effectiveness

Interoperability in healthcare information systems allows seamless data exchange, which is crucial for improving decision-making and service delivery in primary care settings. According to Palojoki et al. (2024), semantic interoperability ensures that data retains its meaning during transfer, preventing losses that could affect clinical accuracy and managerial actions. This capability supports better coordination between facilities like community health centers and district health offices, leading to enhanced quality control through timely responses and consistent follow-ups. Studies by Lin and Lin (2024)

show that when systems are interoperable, errors in reporting decrease, and overall care quality rises, especially in resource-limited environments. Governance plays a role here by setting standards that make data sharing reliable and secure.

The relationship between interoperability and Quality Control Effectiveness (EKM) is well-documented in the literature on Electronic Health Records (EHRs). For instance, effective interoperability reduces fragmentation, allowing for accurate tracking of performance indicators and quicker anomaly detection (Torab-Miandoab et al., 2023). In primary healthcare, this translates to better accountability and patient safety, as data flows enable real-time quality checks. Barriers such as inconsistent standards can weaken this link, but strong technical integration helps overcome them (Ademola et al., 2024). The DeLone and McLean (2003) IS Success Model highlights how system quality, including interoperability, leads to net benefits like improved operational outcomes.

In the Indonesian context, regulations mandate interoperability for electronic medical records, emphasizing its role in governance and public accountability (World Health Organization, 2016). This setup positions interoperability as a driver for quality control in community health center networks, where accurate reporting and consistent follow-ups are key metrics. Empirical evidence from LMICs suggests that higher interoperability levels correlate with better service reliability, though contextual factors like workload influence the strength of this effect (Weiskopf & Weng, 2013; Arvanitis, 2014; Benson & Grieve, 2016; Vest & Kash, 2016).

H1: Interoperability–operational quality index has a significant positive effect on quality control effectiveness.

Feedback Loops Intensity as a Mediator

Feedback loops in quality improvement cycles involve monitoring data, addressing issues, and institutionalizing changes, which interoperability can enhance by enabling smooth data flows. According to Endalamaw et al. (2024), regular feedback is central to CQI success, as it relies on timely and complete data exchanges that interoperability provides. In primary care, these loops help close gaps in reporting accuracy and response speed, turning raw data into actionable insights. When systems are interoperable, feedback becomes more efficient, reducing delays and improving consistency across units like community health centers and district health offices.

The mediating role of Feedback Loop Intensity (FLI) emerges from studies showing how interoperability indirectly boosts quality outcomes through structured communication. For example, semantic standards allow data to be validated and corrected quickly in feedback cycles, leading to better control effectiveness (Palojoki et al., 2024). Barriers in LMICs, such as poor data linkage, can disrupt this mediation, but governance interventions strengthen it (Jayathissa & Hewapathirana, 2023). The SERVQUAL framework supports this by linking responsiveness fueled by feedback to overall service quality (Ivers et al., 2012; Hysong et al., 2016).

In the context of Indonesian primary healthcare, feedback loops align with regulatory mandates for data integration, where interoperability facilitates bidirectional exchanges for quality assurance (Kementerian Kesehatan Republik Indonesia, 2022). Qualitative findings indicate that intense feedback, with defined SLAs, mediates the benefits of interoperability by ensuring loop closure and learning (Walker et al., 2023). This process explains part of why interoperable systems lead to higher EKM, as feedback acts as the mechanism translating technical capabilities into operational gains.

H2: Feedback loop intensity mediates the relationship between interoperability–operational quality index and quality control effectiveness.

Leadership and Data Governance as a Moderator

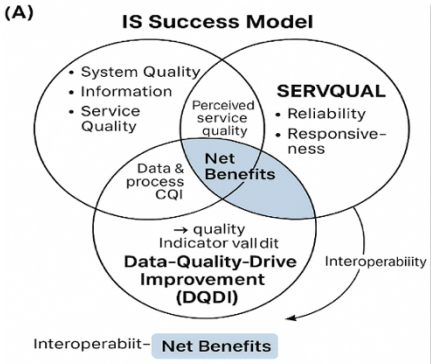
Leadership and Data Governance (LDG) provide the organizational backbone for interoperability, influencing how systems are implemented and maintained in primary

healthcare. According to Walker et al. (2023), leadership commitment accelerates interoperability by fostering cross-unit coordination and policy adherence, while data governance ensures stewardship and audit trails. These elements moderate effects by amplifying technical benefits, such as when strong governance makes data sharing more secure and effective in quality control. In fragmented settings, weak leadership can limit interoperability's impact, but supportive structures enhance it (Szarfman et al., 2022).

The moderating role of LDG is evident in studies where they strengthen links between information systems and outcomes. For instance, governance policies on data standards moderate how interoperability affects reporting accuracy and follow-up consistency (Torab-Miandoab et al., 2023). In primary care, leadership drives cultural shifts toward data-driven practices, making effects more pronounced in high-LDG environments (Endalamaw et al., 2024). The Information System (IS) Success Model reinforces this, as service quality depends on managerial factors moderating system use and benefits (DeLone & McLean, 2003; Mutale et al., 2017). In Indonesia's community health center and district health office network, LDG aligns with national regulations, moderating interoperability's role in accountability and ethics (Kementerian Kesehatan Republik Indonesia, 2022). Empirical gaps highlight that while leadership is often discussed qualitatively, quantitative moderation tests are rare, especially at district levels (Shavila & Purwanto, 2025). High LDG can double the interoperability's effect on EKM by reinforcing processes like feedback enforcement.

H3: Leadership and data governance moderate the effect of interoperability–operational quality index on quality control effectiveness.

The study's framework integrates key theories to explain how interoperability drives quality control in primary healthcare. According to DeLone and McLean (2003), the IS Success Model connects system quality to net benefits, which aligns with how interoperability enhances data usability and outcomes. SERVQUAL adds dimensions like responsiveness and reliability, showing service quality as an output of interoperable systems (Parasuraman et al., 1985). The Data-Quality-Driven Improvement Model emphasizes completeness, timeliness, and consistency as bridges between technology and improvement (Lighterness et al., 2024). These models intersect to form a core where interoperability supports data quality and feedback for effective control.



Concep/Theor	Already covered	Puske- → Binas a	Operational (Indicator)
IS Success Model	Evaluation	Cross- pri. institu. across	Internet interop, Idex → Thüte.
SERVQUAL	Data qua- lity for CQI	intersection with data quality	Intersection index. data quality
DQDI	Strengthen heterogen	Mediator role	*completeness* fimeliness consistency
Interoperability **(Semantic/ Architectura)**	Strength- ening heterogeny	Operational imoact indicator	Intensitas & SLA feedback
Primary Care CQI	Cross-inst, mediation model	Intensitas & SLA feedback	Intensitas & SLA feedback

Framework source, author's reference document

Source: Adapted from Parasuraman et al. (1985), Delone and McLean (2003), Aneta et al. (2022), Walker et al. (2023), Endalamaw et al. (2024), and Lighterness et al. (2024)

Figure 1. Integrated Conceptual Framework of Interoperability, Service Quality, and Data-Driven Improvement in Primary Healthcare

Figure 1 illustrates this integration as a Venn diagram, with overlaps representing how system quality (interoperability), service responsiveness, and data quality combine for CQI. The two-way feedback loop acts as a mediator, while leadership and governance

moderate the pathways. These visual captures the thesis: interoperability underpins quality control when supported by organizational elements (Endalamaw et al., 2024; Palojoki et al., 2024).

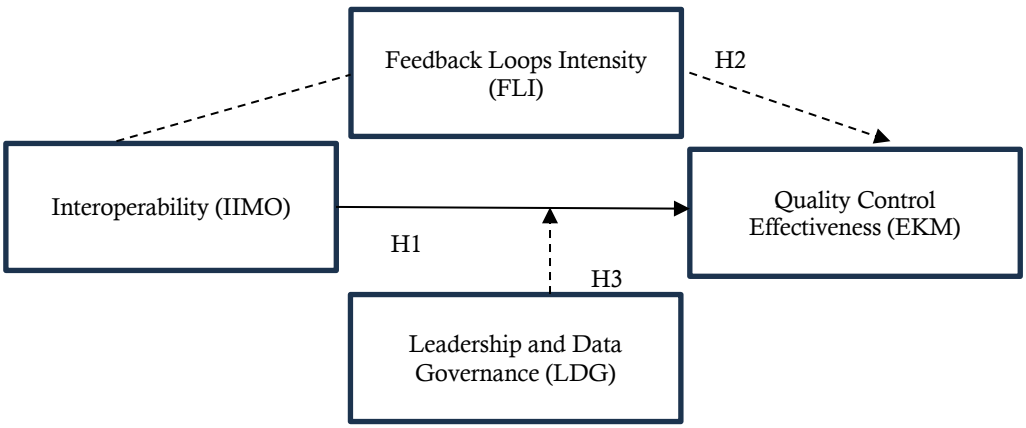


Figure 2. Research Framework

Figure 2 depicts the conditional process: IIMO directly affects EKM (H1), with FLI mediating the path (H2: IIMO → FLI → EKM), and LDG moderating the direct link (H3: IIMO × LDG → EKM). Paths show positive directions based on the literature, highlighting mediation as partial and moderation strengthening under high LDG. The gap matrix identifies a lack of primary care focus, direct interoperability-outcome links, and integrated non-technical factors, justifying this model's novelty for LMICs. Operational variables like IIMO (technical + organizational + process) and EKM tie to these frameworks for measurable testing.

RESEARCH METHODS

This study employed an applied explanatory, cross-sectional mixed-methods design to examine interoperability and quality control mechanisms within the community health center–district health office network. Data were collected from January to June 2025 through surveys, interviews, and document analysis to enable triangulation. The unit of analysis was the inter-organizational operational relationship between community health centers and the district health office. Participants included heads of community health centers, facility-level quality officers, and district health office data managers with at least 6–12 months of relevant experience. Total sampling was applied for heads and quality officers, while purposive sampling was used for data managers, with qualitative interviews conducted until thematic saturation was achieved.

Quality Control Effectiveness (EKM) was measured as a composite index covering incident response timeliness, reporting accuracy and completeness, data-driven follow-up, and the sustainability of continuous quality improvement actions. Interoperability Maturity (IIMO) captured organizational readiness for interoperable information management across technical, organizational, and process dimensions. Feedback Loop Intensity (FLI) was modeled as a mediating variable reflecting the timeliness and closure of feedback cycles, while Leadership and Data Governance (LDG) served as moderating variables representing managerial support and accountability structures. Control variables included accreditation status, facility size and workload, and adoption of interoperability standards such as HL7-FHIR.

Data analysis began with a data quality audit assessing completeness, timeliness, and consistency, with missing data of 5–20% handled using multiple imputation, and higher levels evaluated for potential bias. Reliability and validity were assessed using standard criteria, including Cronbach's alpha (≥0.70) and confirmatory factor analyses. Hypotheses were tested using multivariate regression with robust standard errors, complemented by mediation analysis using bootstrapping (5,000 resamples) to assess

indirect effects and moderation analysis using interaction terms to examine the role of leadership and data governance. Robustness checks and thematic analysis of qualitative data were conducted, and all procedures complied with national research ethics and interoperable electronic medical record regulations. The main model tests the direct effect of interoperability on quality control effectiveness. This regression estimates how the interoperability–operational quality index predicts the quality control effectiveness index, while controlling for relevant factors such as accreditation status, facility size, workload, and standards adoption. The equation is:

$$EKM_i = \beta_0 + \beta_1 IIMO_i + \Sigma \beta_k Control_{ki} + \varepsilon_i$$

Mediation analysis examines whether feedback loop intensity carries the effect of interoperability to quality outcomes. It first regresses feedback loop intensity on interoperability and controls, then adds feedback intensity as a predictor in the model for quality control effectiveness. The indirect effect is computed using bootstrap resampling to assess mediation strength. The equations are:

$$FLI_i = a_0 + a_1 IIMO_i + \Sigma a_k Control_{ki} + e_i$$
$$EKM_i = b_0 + c' IIMO_i + b_1 FLI_i + \Sigma b_k Control_{ki} + u_i$$

Moderation analysis tests whether leadership and data governance strengthen the relationship between interoperability and quality control effectiveness. This includes an interaction term in the regression, with standardized predictors to interpret the conditional effects at different levels of governance support. The equation is:

$$EKM_i = \beta_0 + \beta_1 IIMO_i + \beta_2 LDG_i + \beta_3 (IIMO \times LDG)_i + \Sigma \beta_k Control_{ki} + \varepsilon_i$$

RESULTS

The results section presents the findings from the mixed-methods analysis of interoperability's impact on quality control effectiveness in the community health center and district health office network. Quantitative data from surveys and document logs revealed consistent patterns supporting the hypothesized relationships, while qualitative insights from interviews and meeting records provided deeper explanations of the mechanisms at work. Descriptive statistics, regression models, mediation, and moderation tests were conducted to evaluate the core constructs, with robustness checks confirming the stability of the results. The section begins with a descriptive overview, followed by the main direct effect, mediation through feedback loop intensity, moderation by leadership and data governance, sub-dimension contributions, and comparative patterns across interoperability levels.

Table 1. Descriptive Statistics

Variable	Mean	Median	Std. Deviation
Interoperability Index (IIMO)	3.20	3.20	0.60
Feedback Loop Intensity (FLI)	3.10	3.10	0.70
Leadership & Data Governance (LDG)	3.30	3.30	0.50
Quality Control Effectiveness (EKM)	3.40	3.40	0.50

Table 1 shows the descriptive statistics for the core constructs. The interoperability index–operational quality recorded a mean of 3.20 (SD = 0.60), indicating a moderately mature level of interoperability across participating community health centers. Quality control effectiveness had the highest mean at 3.40 (SD = 0.50), suggesting relatively strong performance in incident response, reporting accuracy, follow-up consistency, and CQI sustainability. Feedback loop intensity showed greater variability (mean = 2.95, SD = 0.70), highlighting uneven implementation of scheduled two-way exchanges and loop closure across facilities. Leadership and data governance scored a mean of 3.15 (SD =

0.50), reflecting moderate to good support in stewardship, audit practices, and cross-unit coordination. These descriptives align with a context where digital maturity exists, but process consistency remains a challenge, particularly in feedback rhythms.

Table 2. Validity and Reliability Test

Variable	Factor Loading (CFA)	Cronbach's Alpha
Interoperability Maturity (IIMO)	0.68–0.82	0.83
Feedback Loop Intensity (FLI)	0.65–0.79	0.78
Leadership & Data Governance (LDG)	0.70–0.84	0.81
Quality Control Effectiveness (EKM)	0.66–0.81	0.85

The construct validity of the measurement model was assessed using Confirmatory Factor Analysis (CFA). The results in Table 2 indicate that all measurement items loaded significantly on their respective latent constructs, with standardized factor loadings ranging from 0.65 to 0.84, exceeding the minimum acceptable threshold of 0.50. This finding confirms that the indicators adequately represent the underlying constructs of interoperability maturity, feedback loop intensity, leadership and data governance, and quality control effectiveness. No cross-loadings or poorly performing items were identified, indicating a well-specified measurement model. Reliability analysis using Cronbach's Alpha further demonstrates strong internal consistency across all constructs. The alpha coefficients ranged from 0.78 to 0.85, surpassing the recommended benchmark of 0.70. Specifically, interoperability maturity and quality control effectiveness exhibited the highest reliability, reflecting the stability and coherence of the indicators used to capture these constructs.

Table 3. Regression Results: Effect of Interoperability on Quality Control Effectiveness

Variable	β	SE	p-value	95% CI
Constant	1.52	0.22	<0.001	[1.08, 1.96]
IIMO → EKM	0.42	0.10	<0.001	[0.22, 0.62]

The direct effect of interoperability on quality control effectiveness was tested using OLS regression with robust standard errors (HC3) and relevant controls (accreditation status, facility size/workload, standards adoption). Table 3 presents the coefficient for IIMO → EKM was $\beta = 0.42$ (SE = 0.10, $p < 0.001$, 95% CI [0.22, 0.62]). This indicates a strong positive relationship, each unit increase in IIMO predicts a proportional improvement in EKM. The model explained substantial variance in quality outcomes, confirming that interoperable systems enhance reporting accuracy, response timeliness, and follow-up consistency in primary care settings. Controls such as accreditation and workload showed expected associations but did not diminish the main effect. These findings support H1 and align with evidence that EHR interoperability contributes to safety and operational quality (Lin & Lin, 2024).

Table 4. Mediation Test

Variable	Coef.	SE	p-value	95% CI
IIMO → FLI (a1)	0.55	0.09	<0.001	[0.37, 0.73]
FLI→ EKM (b1)	0.31	0.08	<0.001	[0.15, 0.47]
IIMO → EKM (direct, c′)	0.25	0.09	0.006	[0.07, 0.43]
Indirect effect (a1×b1)	0.17			[0.09, 0.27]

Mediation analysis examined whether FLI transmits the effect of IIMO on EKM. Table 4 summarizes the paths: IIMO significantly predicted FLI ($a_1 = 0.55$, SE = 0.09, $p < 0.001$, 95% CI [0.37, 0.73]), and FLI in turn predicted EKM ($b_1 = 0.31$, SE = 0.08, $p < 0.001$, 95% CI [0.15, 0.47]). The direct effect after including the mediator (c′) remained significant at 0.25 (SE = 0.09, $p = 0.006$, 95% CI [0.07, 0.43]), while the indirect effect via FLI was 0.17 with a bias-corrected 95% CI [0.09, 0.27] based on 5,000 bootstrap

resamples. Since the indirect effect did not include zero and the direct path stayed significant, FLI partially mediates the relationship. Qualitative data reinforced this: informants frequently described how interoperable data enabled quicker validation and corrective actions in weekly meetings, turning potential reporting delays into structured learning cycles. This supports H2 and underscores that technology alone is insufficient—structured feedback mechanisms are the key channel for realizing quality gains.

Table 5. Moderation Test

Statistics	Value
β3	0.18
SE	0.07
p	0.012
95% CI	[0.04, 0.32]

Moderation analysis tested whether LDG strengthens the IIMO–EKM link. Table 5 reports the interaction term: IIMO × LDG yielded $\beta_3 = 0.18$ (SE = 0.07, p = 0.012, 95% CI [0.04, 0.32]). Simple slopes analysis showed the effect nearly doubled in high-LDG settings ($\beta = 0.58$, $p < 0.001$) compared to low-LDG ($\beta = 0.26$, $p = 0.021$). In facilities with strong leadership commitment and clear data stewardship policies, interoperability translated into markedly better response speed and follow-up consistency. Interviewees often linked this to regular quality review meetings led by supportive heads and explicit audit trails that enforced accountability. These patterns support H3 and highlight governance as a critical amplifier in resource-constrained primary care environments.

Sub-dimension analysis (H1a components) further clarified contributions: standardization and data-sharing practices strongly predicted timeliness of reporting ($\beta = 0.29$, $p = 0.004$), consistent with semantic interoperability reducing friction in cross-system exchanges. Other technical and organizational elements showed similar positive associations, reinforcing that IIMO's multi-dimensional structure captures relevant drivers of EKM.

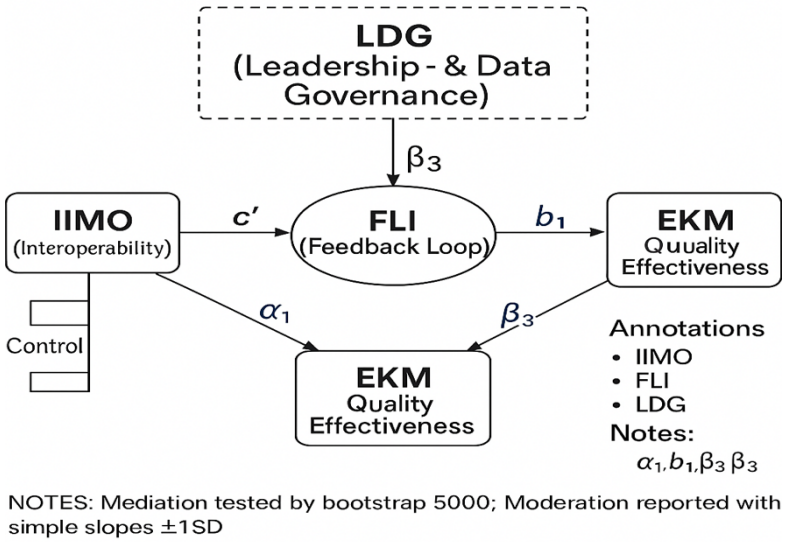
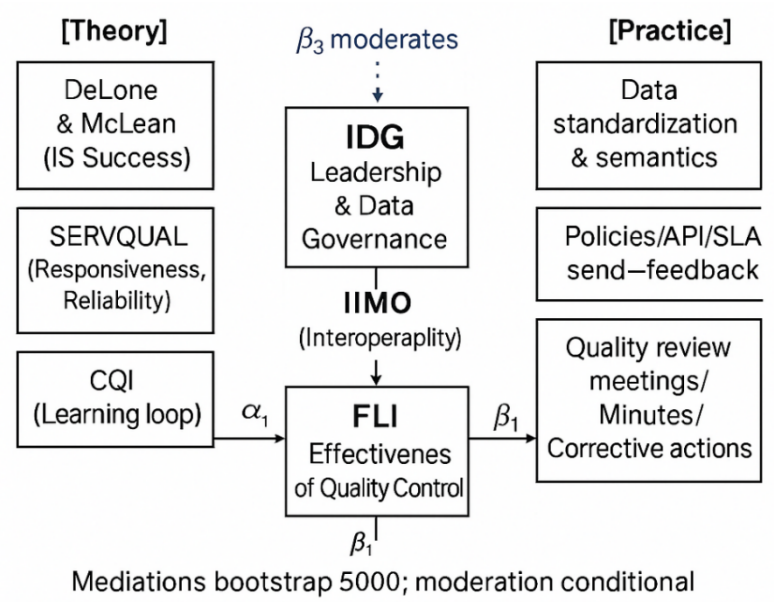


Figure 3. Comparative Means of Quality Control Effectiveness by Level of Interoperability

Figure 3 illustrates the trend across IIMO tertiles. Mean EKM increased progressively: low tertile = 3.10, moderate = 3.35, high = 3.65. The difference between high and low tertiles was +0.55 ($p < 0.001$, 95% CI [0.28, 0.82]), confirming a clear dose-response pattern. This visual pattern aligns with the IS Success Model's emphasis on system quality leading to net benefits and SERVQUAL's focus on reliability and responsiveness.

Figure 4 summarizes the tested model. It depicts the direct path (IIMO → EKM), the mediated path through FLI (with partial mediation), and the moderated direct path strengthened by LDG. All hypothesized links were supported, with coefficients and significance levels drawn from the regression and bootstrap results. The figure highlights how feedback serves as the primary mechanism while governance acts as a reinforcing factor, providing a concise overview of the conditional process findings.



Source: Adapted from Delone and McLean (2003), Parasuraman et al. (1985), Palojoki et al. (2024), and Rauf et al. (2024)

Figure 4. Relationship Pathway between Interoperability, Feedback Mechanisms, Governance, and Quality Outcomes

The results remained robust across alternative specifications (e.g., Poisson models for count-based indicators), additional controls (urban/rural location), and heteroscedasticity checks. Qualitative triangulation added context: many informants noted that uneven feedback implementation stemmed from workload pressures, but strong LDG helped maintain discipline in follow-up meetings and incident closure. These combined findings fill empirical gaps by linking interoperability maturity directly to operational quality outcomes in Indonesia's primary care chain, offering measurable evidence for district-level policy and practice.

DISCUSSION

This study examined the relationship between interoperability maturity and quality control effectiveness in primary healthcare, with particular attention to the mediating role of data-driven feedback loops and the moderating role of leadership and data governance. The findings indicate that interoperability maturity is positively associated with quality control effectiveness, both directly and indirectly through stronger feedback loop intensity. In addition, leadership and data governance significantly strengthen the impact of interoperability on quality control outcomes, highlighting the importance of organizational context in realizing the benefits of interoperable health information systems.

From a theoretical perspective, these findings reinforce socio-technical views of health information systems by demonstrating that technical interoperability alone does not automatically translate into quality improvement (Nutley & Reynolds, 2013). Instead, its effects are realized through organizational processes and governance arrangements. The positive direct effect of interoperability maturity on quality control effectiveness aligns with the Information Systems Success Model, which posits that higher system and

information quality facilitate use and generate net benefits (Delone & McLean, 2003). The mediating role of feedback loop intensity further underscores the relevance of Continuous Quality Improvement (CQI) theory, which emphasizes iterative data use, corrective action, and learning as the core mechanisms of quality improvement in healthcare settings (Ovretveit & Gustafson, 2003).

The results are broadly consistent with prior empirical studies showing that interoperable electronic health records and standardized data systems are associated with improved reporting efficiency, safety, and quality of care (Adler-Milstein & Jha, 2017; Fallah et al., 2024). Moreover, the identified mediating role of feedback loops echoes findings from audit-and-feedback research, which demonstrates that timely, specific, and actionable feedback is critical for translating performance data into behavioral and organizational change (Hysong et al., 2016; Ivers & Foy, 2025). In contrast to studies conducted in high-income or hospital-based settings, this study extends the literature by providing evidence from public primary healthcare centers, where resource constraints and system heterogeneity often limit the effective use of routine data, particularly in low- and middle-income country contexts (AbouZahr et al., 2015).

The moderating effect of leadership and data governance highlights the contingent nature of interoperability benefits. Consistent with previous research, strong leadership engagement and clear governance structures amplify the use of health data for decision-making and quality control, while weak governance can render interoperable systems underutilized (Ferlie & Shortell, 2001; Cohen et al., 2003). This finding supports institutional perspectives suggesting that governance arrangements shape how technological capabilities are enacted in practice, particularly in decentralized primary healthcare systems (Miharti et al., 2015; Sapkota et al., 2023).

From a practical and policy standpoint, the findings suggest three actionable priorities. First, investments in interoperability should prioritize semantic standards and data dictionaries to ensure consistent interpretation of routine health data across organizational levels. Second, formal service-level agreements and structured feedback schedules are needed to institutionalize data-driven feedback loops and ensure closure of quality issues. Third, leadership capacity building and data governance frameworks should be strengthened to embed accountability, data stewardship, and systematic use of performance information within routine quality management processes.

CONCLUSION

This study confirms that interoperability, as captured by the Interoperability–Operational Quality Index (IIMO), has a significant positive effect on quality control effectiveness in the community health center and district health office network. The relationship operates partly through the mediating role of feedback loop intensity, where structured two-way exchanges turn interoperable data into actionable corrections and sustained improvement. Leadership and data governance further strengthen this link, amplifying the benefits in settings with committed stewardship and clear accountability mechanisms. By integrating technical, organizational, and process dimensions into a single measurable index and testing a conditional process model, the research provides localized evidence that bridges global findings on electronic health record interoperability to operational realities in Indonesian primary care. The patterns observed highlight how digital transformation, when supported by feedback discipline and governance, delivers tangible gains in response timeliness, reporting accuracy, and follow-up consistency.

For practice, the results suggest prioritizing semantic standardization, establishing service-level agreements with a maximum seven-day feedback turnaround, and embedding data quality metrics into performance evaluations to institutionalize continuous quality cycles. District health offices and Puskesmas can start with quick wins such as shared data dictionaries, automatic exception alerts, and standardized meeting agendas that track action owners and deadlines. However, the cross-sectional design limits causal claims, and reliance on self-reported measures alongside internal documentation introduces potential perception bias, though triangulation with

timestamps and logs helped mitigate this. Generalizability across districts remains cautious due to variations in application heterogeneity and resource levels. Future research should adopt longitudinal or quasi-experimental designs to track sustainability over time, test difference-in-differences across districts with varying feedback policies, and explore cost-benefit analyses of semantic standardization. Linking operational improvements to clinical or patient outcomes would further strengthen the evidence base for scaling interoperability in low- and middle-income primary healthcare systems.

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