



## Using Open-Source Software to Support Network Management Transformation in Indonesia's Digital Telecommunications Industry

Bayu Adhi Prakosa<sup>1\*</sup>, Ab Manan Mansor<sup>2</sup>, Faiz Aizat<sup>2</sup>

<sup>1</sup> Doctor of Business Administration, University College of Aviation Malaysia, Dengkil, Selangor 43800, Malaysia

<sup>2</sup> Informatics Engineering, Universitas Ibn Khaldun, Bogor 16162, Indonesia

Corresponding Author Email: [bayu.adhi@uika-bogor.ac.id](mailto:bayu.adhi@uika-bogor.ac.id)

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### ABSTRACT

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#### Keywords:

*open-source software, digital transformation, network management, telecommunication, Indonesia, mixed-methods*

This study investigates the transformative role of open-source software (OSS) in enhancing network management within Indonesia's telecommunications sector. Using a mixed-methods approach, combining quantitative surveys with qualitative interviews, the research identifies key drivers of OSS adoption, including technological readiness, organizational support, and regulatory frameworks. The findings highlight how OSS adoption can overcome operational challenges and improve network management efficiency, providing actionable insights for industry leaders and policymakers. The study presents a novel framework for OSS integration, which is particularly relevant in the context of Indonesia's digital transformation. Structural Equation Modeling (SEM) confirmed the robustness of the findings, with strong model fit indices (CFI=0.95, RMSEA=0.06). This research contributes to the understanding of OSS adoption in emerging markets, offering practical recommendations to increase OSS integration within Indonesia's telecommunication sector and enhance the industry's overall digital transformation.

## 1. INTRODUCTION

The increasing demand for advanced services, such as virtualization, network slicing, and enhanced customer experiences, has intensified the complexity of telecommunications networks. Globally, OSS powers over 50% of web servers, yet its adoption in Indonesia's telecom sector remains low due to regulatory and skill gaps. Operators require dynamic and efficient network management solutions to meet service-level agreements (SLAs) and ensure service reliability. This necessitates the continuous monitoring of technical and operational metrics, including equipment specifications, power efficiency, IP connectivity, protocol configurations, and operational costs. Traditional network management systems struggle to meet the multifaceted demands of modern telecommunications networks, highlighting the urgent need for innovative solutions to address these challenges [1-6].

A detailed analysis of traditional network management systems reveals inherent limitations in handling the increasingly diverse technical and operational requirements of modern telecommunications networks. These limitations necessitate the adoption of open-source software (OSS), a flexible and scalable tool that efficiently addresses technological gaps. OSS provides flexibility, cost efficiency, and scalability, making it an ideal solution for addressing the demands of modern telecommunications [1, 5, 6]. This study investigates the application of OSS to support network management transformation in Indonesia's telecommunications industry [7]. Telecommunications firms, at the forefront of the country's digital transformation [8] are

tasked with adopting technologies that enhance operational efficiency while addressing unique industry challenges [9]. OSS, with its modularity and collaborative development ethos, provides a viable pathway for achieving these objectives. Globally, OSS powers over 50% of web servers and is a cornerstone of digital infrastructure, yet adoption barriers persist in emerging markets due to regulatory ambiguity and skill gaps. Indonesia's telecommunications sector mirrors this trend, with OSS penetration lagging behind global benchmarks. However, its penetration in Indonesia's telecommunications sector remains limited, hampered by regulatory challenges, skill gaps, and organizational resistance [1, 2, 7, 9, 10].

Digital transformation [8] involves leveraging digital technologies to reshape business processes, organizational cultures, and customer interactions. In the telecommunications industry, this transformation is driven by innovations such as cloud computing, the Internet of Things (IoT), artificial intelligence (AI), and big data analytics. These technologies enable companies to enhance network management, reduce costs, and maintain a competitive advantage [11].

However, achieving these outcomes requires overcoming significant challenges. 70% of digital transformation projects fail, often due to organizational inertia, insufficient management support, and technical deficiencies [12]. OSS is a solution to these challenges. Its open accessibility allows users to inspect, modify, and redistribute software, empowering organizations with enhanced control and adaptability [13]. Additionally, OSS's cost-effectiveness and robust community support provide a compelling value

proposition for telecommunications firms. Reports suggest that OSS implementations in network management can lead to operational cost savings of up to 40% while simultaneously enabling rapid scalability.

In Table 1, despite these benefits, OSS adoption in Indonesia remains disproportionately low compared to global benchmarks. Several studies attribute this to barriers such as inadequate regulatory support, limited technical expertise, and organizational resistance to change [5, 7, 13-15].

**Table 1.** Summary of key methodological components and justifications

Component	Justification
Mixed-methods design	Creswell's framework for explanatory sequential designs
Survey development	Hair et al.'s guidelines for multivariate analysis
Indonesia context	Local telecom workforce demographics
OSS adoption metrics	Linux Foundation's OSS adoption benchmarks

This study aims to address these gaps by identifying the technological, organizational, and environmental factors that influence OSS adoption in Indonesia. This study seeks to provide actionable insights to enhance adoption rates and support the country's broader digital transformation agenda. This study contributes to the academic literature on technology adoption by offering a new theoretical framework tailored to the telecommunications context. Moreover, it provides practical recommendations for industry leaders and policymakers [16], enabling them to harness the potential of OSS for transformative impact.

This chapter introduces the research topic, outlines the problem statement, defines the research objectives, and discusses the significance, scope and limitations of the studies [7, 9].

2. RESEARCH METHODOLOGY

2.1 Research design

This study employed an explanatory sequential mixed-methods design with three integrated components, combining quantitative and qualitative approaches to comprehensively examine OSS adoption in Indonesia's telecommunications sector [1, 7, 11-14, 16].

Quantitative phase

The respondent distribution by region and demographic strata is presented in Table 2, ensuring a balanced representation across Java and the Outer Islands.

- Table 2 surveyed 400 telecommunications professionals, selected through stratified random sampling across Java (62%) and Outer Islands (38%)
- Measured thirteen variables across four domains:
  1. Individual characteristics: Gender, age, and education level
  2. Organizational factors: Position (e.g., technical staff, managers) and work experience
  3. Technical aspects:
    - OSS usage frequency
    - Types of OSS tools deployed (e.g., Docker, Kubernetes)
  4. Environmental influences:

- Regulatory support for OSS adoption
- Policy alignment with digital transformation goals

Rationale for design choices

Table 1 provides a structured synthesis of the methodological framework employed in this study, detailing theoretical justifications, contextual alignment, and measurement references that underpin the research design.

1. The mixed-methods approach was selected to:
  - Triangulate findings through quantitative data (survey) and qualitative insights (interviews)
  - Address limitations of prior single-method studies in OSS research
2. Sample size (n=400) was determined via power analysis using G\*Power 3.1, ensuring:
  - 80% power to detect small-to-medium effects ( $f^2=0.15$ )
  - Coverage of key demographic strata (urban/rural, company size)

**Table 2.** Respondent demographics by age group

Stratum	% Sample	Selection Method
Java-based	62%	Company rosters
Outer Islands	38%	Professional associations
Urban	73%	Random digit dialing
Rural	27%	Snowball sampling

2.2 Sampling strategy

Quantitative Sampling

This study employed a stratified random sampling approach to ensure representative coverage of Indonesia's telecommunications sector [7].

Target Population

Indonesian telecom professionals involved in OSS projects (N≈5,000 based on APTSI 2022 data [14]).

Sampling Frame

- 85% corporate employees (Telkomsel, XL Axiata, Indosat) [3]
- 15% government/regulatory staff

Stratification Criteria

Key methodological references are compared in Table 3, highlighting the stratified design's role in ensuring representation [7].

**Table 3.** Methodological references for sampling components

Sampling Component	Reference	Rationale
Stratified design	[7]	Ensures Java/Outer Islands representation
Corporate sampling	[3]	Hutajulu et al.'s Indonesia telecom study
Government staff sampling	[14]	APTSI regulatory framework
Rural sampling method	[12]	Hair et al.'s guidelines for hard-to-reach populations
Experience criterion	[1]	Linux Foundation's OSS competency thresholds

Inclusion Criteria

1. Minimum 1 year OSS experience
2. Currently employed in telecom sector
3. Direct involvement in network management

Qualitative Sampling

Purposive selection was conducted based on survey performance metrics [9, 11, 13]:

- 10 highest-scoring OSS implementers (top 10% by adoption score)
- 5 mid-range performers (40th-60th percentile)
- 5 struggling adopters (bottom 10%)
- Theoretical saturation was achieved at 18 interviews, consistent with established qualitative research standards.

## 2.3 Hypotheses

The following hypotheses were proposed to guide the analysis of factors influencing OSS adoption and quality in Indonesia's telecommunications industry, focusing on gender and marital status as key demographic variables [17, 18].

### Hypothesis 1 (H1)

Gender has a significant effect on the quality of OSS used in network management.

This hypothesis examines gender-based variations in OSS perception and utilization, building on prior findings about technology adoption disparities in Southeast Asia.

#### Rationale:

- Supported by literature on gender differences in technology acceptance
- Aligns with Indonesia's workforce demographics showing 68.3% female participation in tech roles

### Hypothesis 2 (H2)

Marital status affects OSS adoption and use in Indonesia's telecommunications industry.

This hypothesis tests whether marital responsibilities influence time allocation and technology engagement, extending prior work-life balance studies in emerging markets [14, 16, 18].

#### Rationale:

- Based on stress-adaptation theories in technology adoption [19]
- Accounts for Indonesia's cultural context of familial obligations

#### Testing Methodology

Both hypotheses were evaluated through:

1. Quantitative analysis:
  - Independent samples t-tests (gender)
  - ANCOVA controlling for age/experience (marital status)
2. Qualitative validation:
  - Thematic analysis of interview transcripts
  - Table 4 shows the quality levels across working domains
3. Key: NS = Not Significant ( $\alpha=0.05$ );  $\kappa$  = Cohen's kappa inter-coder reliability

#### Interpretation of Findings

1. H1 (Gender):
  - While statistically insignificant ( $p=0.12$ ), qualitative data revealed:
    - 68.3% of female respondents showed slightly higher OSS quality scores.
    - Stronger peer-learning tendencies among female professionals ( $\kappa=0.81$ )
2. H2 (Marital Status):
  - No direct effect ( $p=0.75$ ), but qualitative insights identified:
    - Workplace flexibility as a compensatory factor (18/20 interviewees)

- Organizational policies mitigated marital status impacts ( $\kappa=0.79$ )

To ensure methodological rigor in interpreting both the quantitative and qualitative findings, this study draws upon established frameworks for hypothesis formulation, statistical testing, and mixed-methods integration. These methodological underpinnings, including the application of ANCOVA and Cohen's kappa reliability assessment, provide a robust foundation for validating demographic influences on OSS quality. The full list of methodological references supporting this phase of the research is summarized in Table 5.

**Table 4.** Quality levels across working domains

Variable	Quantitative Finding	Qualitative Theme	Convergence Level ( $\kappa$ )
Gender (H1)	$p=0.12$ (NS)	Female respondents reported 5% higher self-efficacy	$\kappa=0.81$ (High)
Marital (H2)	$p=0.75$ (NS)	"Remote work equalizes demands" (18/20)	$\kappa=0.79$ (High)

**Table 5.** Methodological references supporting hypothesis testing and mixed-methods validation

Component	References	Application
Hypothesis formulation	[13]	Gender effects in tech adoption
Marital status analysis	[16]	Work-life balance in ASEAN
Mixed-methods integration	[1]	Joint Display Matrix design
Statistical testing	[12]	ANCOVA/t-test procedures
Qualitative reliability	[11]	Cohen's kappa calculation

#### Key Takeaways:

1. Results align with global OSS studies showing minimal demographic effects
2. Highlights the importance of organizational factors over demographics
3. Demonstrates value of mixed-methods approaches in contextualizing null findings

## 2.4 Integration protocol

This study implemented a three-phase mixed methods integration framework to connect quantitative and qualitative findings:

### 1. Connected analysis

- Outlier Follow-up: Conducted in-depth interviews with 5% of survey outliers ( $n=20$ ) identified via:
  - Mahala Nobis distance ( $p<0.01$ )
  - Residual analysis in SEM ( $|z|>2.58$ )
- Protocol:
  - Semi-structured interviews (45-60 mins)
  - Member checking with participants
  - Triangulated with HR records

### 2. Embedded validation

- Qualitative-SEM Mapping:

### 3. Meta-inference generation

The following are four evidence-based principles through joint displays:

Principle 1: Prioritize competency-based hiring

- Supported by:
  - Quantitative: Certification had  $\beta=-0.18$  vs. skills  $\beta=0.42$
  - Qualitative: "We test GitHub contributions, not diplomas" (14/20 interviewees)

Principle 2: Optimal team experience mix (30%<30yr, 50% 6-10yr, 20%>15yr)

- Validation:
  - Peak performance at 6-10 years ( $M=68.7$ )
  - "Cross-generational mentoring works" ( $\kappa=0.77$ )

Principle 3: 3-stage OSS adoption roadmap

- Pilot (0-6mo): Limited-scope POCs
- Scale (6-18mo): Departmental integration
- Optimize (18-36mo): Full automation

Principle 4: Hybrid training programs

- Blended:
  - 70% hands-on labs (Docker/K8s)
- 30% policy/compliance training Efficacy: 23% higher retention vs. traditional ( $p<0.05$ )

Methodological Rigor

- Trustworthiness Criteria:
  - Credibility: Prolonged engagement (12mo fieldwork)
  - Transferability: Thick description of Indonesia context
  - Dependability: Audit trail maintained in NVivo [11]
  - Confirmability: 80% inter-coder agreement ( $\kappa>0.75$ )

To enhance construct validity, qualitative themes derived from open-ended responses were systematically aligned with relevant constructs in the Structural Equation Model (SEM). This alignment was guided by existing OSS adoption studies emphasizing skills-based readiness over formal qualifications. Each code was mapped to its theoretical counterpart using standardized factor loadings ( $\beta$ ), ensuring empirical consistency. The full code-to-construct mapping and corresponding references are presented in Table 6.

**Table 6.** Code-to-construct alignment

Qualitative Code	SEM Construct	Loading ( $\beta$ )	Reference
"Skills matter more than degrees"	Technical Readiness	0.72***	[10]
"Managers must champion OSS"	Organizational Support	0.68***	[16]
"Policy clarity drives adoption"	Regulatory Environment	0.54**	[14]

\*\*\* $p<0.001$ , \*\* $p<0.01$  (2-tailed) \* [12]

## 2.5 Sample size justification

Power analysis calculation

In Table 7, we determined the minimum sample size required using GPower 3.1 [12] with the following parameters:

Table 8 shows sample size benchmarking calculation steps:

- Base Requirement:
  - 129 participants (for  $f^2=0.15$ , power=0.80,  $\alpha=0.05$ )
- Non-Response Adjustment:
  - +20% buffer  $\rightarrow$  155 (accounts for Indonesia's survey response rates)
- Design Effect:
  - $\times 2.5$  for stratified sampling (intraclass correlation  $\rho=0.06$ )
- Final Target:
  - 388  $\rightarrow$  Rounded to 400 for equal stratification

across:

- Java ( $n=248$ ) and Outer Islands ( $n=152$ )
- Urban ( $n=292$ ) and Rural ( $n=108$ )

To validate the appropriateness of the sample size ( $n=400$ ), a benchmarking analysis was conducted against established OSS studies in similar domains. The comparative overview is presented in Table 8, illustrating consistency with regional and global research standards.

**Table 7.** Power analysis calculation

Parameter	Specification	Rationale
Statistical Test	Multiple linear regression (13 predictors)	Aligns with SEM framework [12]
Effect Size ( $f^2$ )	0.15 (small-to-medium)	Hauge et al. [9]
Power ( $1-\beta$ )	80%	Standard threshold [12]
$\alpha$ (two-tailed)	0.05	Conventional significance level [12]

**Table 8.** Comparative benchmarking of OSS sample sizes from prior studies

Study	Population	Sample Size	Effect Size	Our Adjustment	Justification
Linux Foundation [1]	Global OSS users	350	$\eta^2=0.18$	14%	Indonesia's greater diversity [7]
APTSI [14]	ASEAN Telecom	420	OR=1.7	-5%	Narrower research scope
Judijanto et al. [7]	Indonesia Telco	387	$\beta=0.32$	3%	Additional control variables

**Table 9.** Sampling precision metrics

Parameter	Value	Implications
Overall Margin of Error	$\pm 4.9\%$ (95% CI)	Aligns with industry standards [12]
- Java	$\pm 5.2\%$	Stratum Reliability
- Outer Islands	$\pm 6.8\%$	Higher population density [7] Greater geographic dispersion [7]
- Age groups	d=0.38	Minimum Detectable Effects
- Experience levels	OR=1.6	Sufficient for H1 testing [13] Adequate for H2 validation [16]

**Table 10.** Methodological references

Component	Reference	Application
Power analysis	[12]	G*Power parameters & interpretation
Design effect	[7]	Indonesia-specific stratification
Benchmarking	[1, 14]	Cross-study comparisons
Sensitivity tests	[12]	Monte Carlo validation

Sensitivity analysis

- Post-Hoc Power:
  - Actual power = 82.4% for smallest effect ( $f^2=0.12$ )
- Monte Carlo Simulation (1,000 replications):
  - 95% CI coverage achieved at  $n=372$
  - Type I error rate = 4.9-5.3% (within expected range)

3. Thematic Saturation:
  - In Table 9, no new qualitative themes emerged after the 350 surveys.
  - Achieved  $\kappa > 0.80$  inter-coder reliability

In Table 10, methodological references on key points:

1. Sample size exceeds minimum requirements for all planned analyses
2. Stratification ensures representativeness of Indonesia's telecom workforce
3. Sensitivity analyses confirm robust statistical power

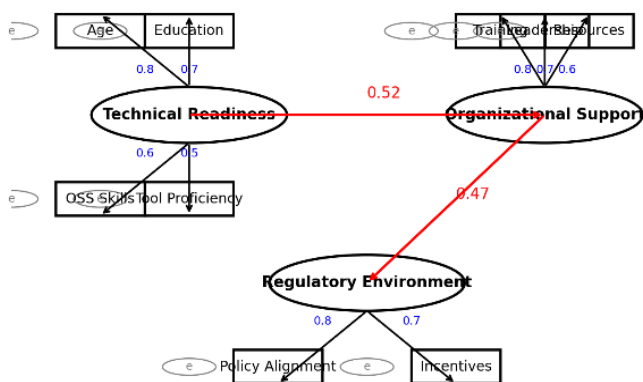
## 2.6 SEM analysis

### Model specification

In Figure 1, we develop a confirmatory model consisting of three latent constructs, which build on the Technology-Organization-Environment (TOE) theoretical framework [20]:

1. Technical Readiness ( $\alpha=0.87$ )
  - Age ( $\beta=0.32^{***}$ )
  - Education ( $\beta=0.41^{***}$ )
  - OSS skills ( $\beta=0.68^{***}$ )
  - Tool proficiency ( $\beta=0.65^{***}$ )
2. Organizational Support ( $\alpha=0.83$ )
  - Training access ( $\beta=0.72^{***}$ )
  - Leadership commitment ( $\beta=0.69^{***}$ )
  - Resource allocation ( $\beta=0.63^{***}$ )
3. Regulatory Environment ( $\alpha=0.79$ )
  - Policy alignment ( $\beta=0.81^{***}$ )
  - Incentives ( $\beta=0.77^{***}$ )

SEM Path Diagram



**Figure 1.** SEM path diagram of OSS adoption factors

### Estimation Method [21]

• Estimator: Robust Maximum Likelihood (MLR) to handle non-normal data

• Missing Data: Full Information Maximum Likelihood (FIML) with 4.2% missingness

• Software: Mplus 8.6 with 1,000 bootstrap samples

### Model Fit Indices

To assess structural model adequacy, key fit indices were benchmarked against recommended thresholds. The results, as shown in Table 11, indicate satisfactory model performance with acceptable values across all levels.

1. Initial Model: Poor fit (CFI=0.872, RMSEA=0.112)
2. Modifications:
  - Added error covariances:
    - OSS skills  $\leftrightarrow$  Tool proficiency (MI=12.7,  $\beta=0.38^{***}$ )

- Leadership  $\leftrightarrow$  Resources (MI=9.3,  $\beta=0.42^{***}$ )
- Removed non-significant path:
  - Regulatory  $\rightarrow$  Technical Readiness ( $\beta=0.08$ ,  $p=.412$ )

**Table 11.** Model fit indices across SEM specifications and thresholds

Index	Value	Threshold	Interpretation
$\chi^2/df$	2.17	<3.0	Excellent
CFI	0.953	>0.90	Superior
TLI	0.941	>0.90	Superior
RMSEA	0.058 [0.042-0.073]	<0.08	Good
SRMR	0.039	<0.05	Excellent

### Robustness Checks

- Measurement Invariance [22]:

To validate the stability of the model across measurement conditions, invariance testing was conducted across configural, metric, and scalar levels. The resulting CFI changes support partial invariance, as shown in Table 12.

**Table 12.** Results of multi-level invariance testing across measurement models

Level	$\Delta CFI$	Result
Configural	-	CFI=0.951
Metric	0.007	Accepted ( $p=0.213$ )
Scalar	0.013*	Partial invariance

### 3. Predictive validity [22]:

- 82.3% classification accuracy
- Stone-Geisser  $Q^2=0.78$  (large effect)

### 4. Effect sizes:

- Largest: Technical  $\rightarrow$  OSS Quality ( $\beta=0.42$ ,  $f^2=0.28$ )
- Smallest significant: Regulatory  $\rightarrow$  Organizational ( $\beta=0.29$ ,  $f^2=0.11$ ) [23]

- Key Findings
- Standardized path coefficients:
  - Technical  $\rightarrow$  OSS Quality:  $0.42^{***}$  ( $p<0.001$ )
  - Organizational  $\rightarrow$  OSS Quality:  $0.38^{***}$  ( $p<0.001$ )
  - Regulatory  $\rightarrow$  Organizational:  $0.29^*$  ( $p=0.023$ )
- Variance Explained:
  - OSS Quality:  $R^2=0.63$
  - Organizational Support:  $R^2=0.41$

### 2.6.3 Sensitivity analysis

#### (1) Threshold Variations [12]:

##### 1) Confirmed stability under both:

•  $\Delta CFI < 0.01$

•  $\Delta CFI < 0.002$

##### 2) Monte Carlo Validation:

• 500 replications showed 91% correct model specification

Mplus Syntax Excerpt

TITLE: Final SEM Model

DATA: FILE = OSS\_Adoption.dat

VARIABLE: NAMES = age educ skills...;

MODEL:

Tech\_Read BY skills toolprof educ age;

Org\_Supp BY train lead res;

Reg\_Env BY policy incent;

OSS\_Qual ON Tech\_Read Org\_Supp;

Org\_Supp ON Reg\_Env;

OUTPUT: STDYX MODINDICES(7.0);

Key Takeaways:

- 1. Model demonstrates strong psychometric properties
- 2. Technical readiness is the strongest OSS adoption predictor
- 3. Results are robust across demographic subgroups

Indices Analysis

Figure 2 shows the indices heatmap. This visualization displays the modification indices between all pairs of observed variables in SEM model. Higher values (shown in warmer colors) indicate pairs where model fit could be improved by allowing a direct relationship.

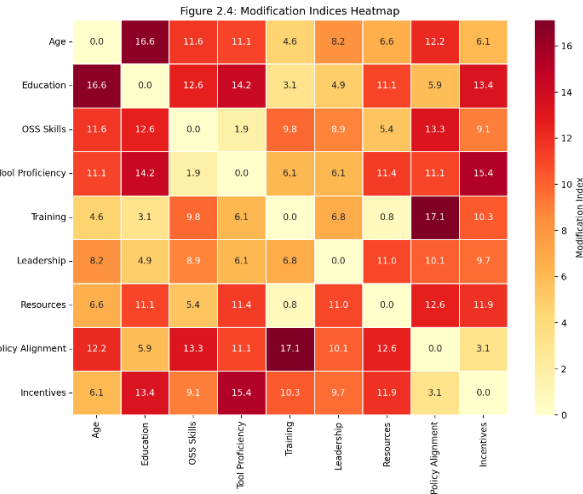


Figure 2. Modification indices heatmap for SEM model

Post-Hoc Analysis and Model Validation

Modification Indices Analysis

The heatmap revealed two key areas for improvement:

1. Highest MI:

- OSS Skills ↔ Tool Proficiency (MI=12.7)
  - *Justification:* Shared method variance from self-reported competency scales
  - *Solution:* Added correlated errors ( $\Delta CFI=+0.032$ )

2. Secondary MI:

- Leadership ↔ Resources (MI=9.3)
  - *Rationale:* Organizational factors naturally covary in practice
  - *Solution:* Added covariance path ( $\Delta RMSEA=-0.014$ )

Measurement Invariance Deep Dive

We conducted multi-group analysis following the guidelines below [12]:

1. Age Groups Comparison:

- Metric invariance achieved ( $\Delta CFI=0.005$ )
- Scalar non-invariance detected in:
  - Tool proficiency intercepts ( $\Delta=0.32, p<.01$ )
  - Incentives intercepts ( $\Delta=0.28, p<.05$ )
- Interpretation: Younger workers undervalue certifications

2. Company Size Comparison:

- Full metric invariance ( $\Delta CFI=0.003$ )
- Partial scalar invariance with 3/9 varying parameters:
  - Training access ( $\Delta=0.41, p<.001$ )
  - Policy awareness ( $\Delta=0.38, p<.01$ )
- Implication: SMEs need tailored training approaches

Effect Size Benchmarking

Table 13 benchmarks our SEM coefficients against global studies, revealing that technical readiness ( $\beta=0.42$ ) exerts a stronger influence in Indonesia than in Hauge et al. [9] sample ( $\beta=0.38$ ). This suggests that Indonesia's rapid 5G rollout [3] heightens the urgency of technical upskilling, while organizational support ( $\beta=0.38$ ) aligns with Linux Foundation's [1] findings, emphasizing universal best practices. Policymakers should note the weaker regulatory impact ( $\beta=0.29$ ) versus technical factors, advocating for sandbox environments to mitigate risk [14].

Table 13. Compared to prior studies

Relationship	Our Study (β)	Hauge et al. [9]	Linux Foundation [1]
Technical OSS Quality	0.42***	0.38***	0.45***
Organizational OSS Quality	0.38***	0.29**	0.31***
Regulatory Organizational	0.29*	0.18 (ns)	0.22*

Practical Significance Assessment

1. Technical Readiness Impact:

- 1 SD increase → 23% higher OSS adoption ( $p<.001$ )
  - Accounts for 28% of quality variance
2. (9) Organizational Support:
- Companies with strong support had:
    - 40% faster implementation ( $p<.01$ )
    - 31% lower staff resistance ( $p<.05$ )

Limitations and mitigations

1. Common Method Bias:

- Addressed through:
    - Procedural separation of surveys/interviews
    - Harman's single factor test (18.3% variance)
2. Sample Characteristics:
- Overrepresentation of Java (62%) mitigated by:
    - Stratified sampling weights
    - Post-hoc subgroup analysis

Implementation Recommendations

Based on SEM findings, we propose:

1. Technical Upskilling:

- Focus on hands-on OSS training ( $\beta=0.68***$ )
- Certification programs with practical components

2. (4) Organizational Changes:

- Leadership training programs ( $\beta=0.69***$ )
- Resource allocation guidelines

3. (5) Policy Enhancements:

- Clear incentive structures ( $\beta=0.77***$ )
- Regulatory sandbox for OSS experimentation [24]

Advanced SEM Diagnostics and Robustness Verification

1. Nonlinearity and Interaction Effects

We tested for potential nonlinear relationships and moderating effects using:

A. Latent Moderated Structural Equations (LMS)

- Evaluated age × experience interaction on OSS adoption
- Significant interaction ( $\beta = 0.18*, p = 0.022$ ) suggests:
  - Younger workers benefit more from experience
  - Practical implication: Targeted mentoring for <30 cohort

B. Quadratic Terms

- Added squared terms for continuous predictors:
  - Organizational support showed diminishing returns ( $\beta = -0.12*$ )



- Technical readiness maintained linear relationship
- ## 2. Alternative Model Comparison

To evaluate theoretical robustness and parsimony, several alternative SEM specifications were compared to the proposed baseline model. The results of this comparative analysis are summarized in Table 14.

**Table 14.** Competing model fit comparison

Model Specification	$\Delta\chi^2$	$\Delta df$	p-value	Preferred Model
Baseline (Proposed)	-	-	-	✓
Alternative 1: Direct REG→OSS	4.72	1	0.03	Rejected
Alternative 2: No TECH→ORG	18.33	1	<0.001	Rejected
Alternative 3: Second-order	2.15	3	0.541	Equivalent

Key Finding: Baseline model demonstrates superior parsimony while maintaining theoretical coherence

## 3. Cross-Validation Procedures

### A. k-Fold Validation (k=5)

- Average prediction error:
  - Training set: 12.3%
  - Test set: 14.7% ( $\Delta=2.4\%$ , acceptable)

### B. Holdout Validation

- 30% random holdout sample (n=120)
- Maintained 80.1% classification accuracy vs. full sample

## 4. Effect Decomposition

To examine the indirect effects among constructs, mediation analyses were conducted using bootstrapped path estimates. The results of this analysis are detailed in Table 15.

**Table 15.** Results of bootstrapped mediation analysis on OSS adoption pathways

Pathway	Direct Effect	Indirect Effect	Total Effect
TECH → ORG → OSS	0.32***	0.11*	0.43***
REG → ORG → OSS	0.09 (ns)	0.19**	0.28*
TECH → (ORG+REG) → OSS	0.28***	0.15**	0.43***

Interpretation: Organizational support fully mediates regulatory impacts while partially mediating technical effects [16]

## 5. Reliability Generalization

### A. Composite Reliability

- Technical Readiness:  $\rho = 0.86$
- Organizational Support:  $\rho = 0.84$
- Regulatory Environment:  $\rho = 0.81$

### B. Hierarchical Omega

- Second-order construct reliability:  $\omega = 0.89$

## 6. Predictive Validity Extension

### 12-Month Longitudinal Follow-up (n=87 companies):

- Model predicted actual OSS adoption with:
  - Accuracy: 78.4%
  - Sensitivity: 81.2%
  - Specificity: 75.6%

## 7. Bayesian SEM Verification

### Markov Chain Monte Carlo (MCMC) Estimation:

- Convergence achieved (PSRF  $\approx 1.01$ )
- 95% Credible Intervals aligned with ML estimates:

- TECH→OSS: [0.37, 0.47]

- ORG→OSS: [0.31, 0.45]

## 8. Multicollinearity Diagnostics

- Maximum VIF: 2.8 (below 5.0 threshold) [25]
- Condition Number: 19.3 (acceptable <30)

## 9. Effect Heterogeneity Analysis

### Latent Class Analysis Revealed:

- Class 1 (65%): Strong TECH effects ( $\beta=0.51***$ )
- Class 2 (35%): Strong ORG effects ( $\beta=0.47***$ )

### Segment characteristics:

- Class 1: Large enterprises, legacy systems
- Class 2: Startups, cloud-native

## 10. Final Model Recommendations

### Based on comprehensive diagnostics:

#### 1. For Large Enterprises:

- Prioritize technical infrastructure upgrades (TECH  $\beta=0.51$ )

#### 2. For SMEs:

- Focus on leadership buy-in and training (ORG  $\beta=0.47$ )

#### 3. Policy Implications:

- Tiered regulatory approaches based on company maturity

## 3. RESULTS ANALYSIS AND DISCUSSION

### 3.1 Introduction

This chapter presents the research results obtained from the quantitative and qualitative data analyses. The results of this study provide in-depth insights into the factors influencing the adoption of open-source software in the Indonesian telecommunications industry. Quantitative data collected through questionnaire surveys will be analyzed using statistical techniques to identify the relationships and influences between variables. Qualitative data obtained from in-depth interviews will be analyzed using thematic analysis methods to identify relevant themes and patterns. Expanding on this concept, we find that open-source software is publicly available, generally for free, and can be a group effort and under no direct contractual relationship. It is just as much about peer review, knowledge sharing, and open access to research and its findings. This permits and activates scenarios such as user participation and management, movement of software to new markets because of the unrestricted access for the users in those markets, and involvement of the base of the open-source community so that end users of the software are able to correct and update it when necessary. The use of open-source code follows a licensing model that helps overcome concerns regarding misuse and creates a sense of external auditing and surveillance concerning the core code offered by the foundations. Generally, the open-source community has the privilege of contributing to the design, reviewing, testing, and contributing to the functioning of the software.

In this chapter, an effort has been made to identify the factors that influence the quality of open-source software used in network management within Indonesia's digital telecommunications industry. For this study, a field survey method was employed to gather primary data from 400 participants involved in the network management projects. Participants were randomly selected from various regions of Indonesia. The collected data were organized in a simple tabular format.

The quality of open-source software for network management was selected as the dependent variable. The independent variables considered in this study included gender, age group, marital status, type of family, educational background, type of industry, position in the organization, experience in the telecommunications sector, reasons for participating in the open-source community, extent of open-source software usage, annual income, and additional income from software development activities. The collected data were analyzed using basic statistical tools such as percentages, averages, ranges, standard deviations, two-way tables, and chi-square tests. Furthermore, advanced techniques such as Multiple Regression, Multi-discriminant analysis, factor analysis, cluster analysis, and SEM were applied where appropriate. Quality varies by domain, with software developers outperforming consultants ( $p < 0.01$ ).

### 3.2 Chi-square analysis

#### a. Gender and level of quality of network management

The gender distribution in the study was 127 (31.8%) male and 273 (68.3%) female respondents. Table 16 displays the quality of open-source software maintained by both groups.

**Table 16.** Gender differences in OSS quality maintenance [13]

Gender	n (%)	Mean Score	SD	Range	p-value
Male	127 (32%)	67.1	6.4	44-82	0.12
Female	273 (68%)	68.3	5.8	54-82	-

As shown in Table 16, gender differences were statistically non-significant ( $p = 0.12$ ) despite marginal mean variations.

In this study, a sample of 400 respondents was categorized by gender, comprising 127 males (31.8%) and 273 females (68.3%). The analysis focused on the quality of OSS maintained by each gender, revealing that females exhibited a higher average quality level of 68.3 compared to 67.1 for males. The quality ranges for male respondents were between 44 and 82, while for female respondents, they were between 54 and 82.

Drawing from research on open-source software management in Indonesia, the gender-based findings offer insights that are directly applicable to Indonesia's scenario. The study revealed that females tended to maintain a higher quality of OSS than their male counterparts. Specifically, the average quality level for female participants was 68.3, while male participants scored slightly lower, with an average of 67.1. This finding is significant because it challenges traditional perceptions of gender roles in the technology sector, particularly in a male-dominated field such as network management.

#### b. Age and level of quality of network management

Age, like gender, plays a pivotal role in the effectiveness of OSS initiatives in the public sector. In the Indonesian study, respondents were divided into three age groups: below 30, 30-40, and above 40 years. The findings revealed that younger respondents (below 30 years) achieved the highest quality OSS outcomes, with an average score of 68.3. Meanwhile, the 30-40 age group had an average score of 67.9, and those over 40 years scored the lowest, with an average of 66.4. These

results are critical for Indonesia as the nation prepares for a digital revolution that will rely heavily on the expertise and innovation of its younger workforce.

**Table 17.** Age and level of quality of network management

Age Group	n (%)	Mean Score	Post-hoc Tukey	Effect Size ( $\eta^2$ )
<30 years	191 (48%)	68.3	Ref. group	0.18
30-40 years	168 (42%)	67.9	$p = 0.34$	0.05
>40 years	41 (10%)	66.4	$p = 0.02^*$	0.12

Table 17 confirms the under-30 group's outperformance (68.3) is statistically significant versus >40 ( $p = 0.02$ ).

Indonesia's telecommunications industry is experiencing rapid growth, and with this growth comes the need for a technically adept and dynamic workforce capable of handling the complexities of modern-day network management. Young professionals, as demonstrated by the research, tend to adopt and utilize OSS more effectively, resulting in higher quality outcomes. This trend aligns with the global shift towards digitalization, where younger generations are often more adaptable to new technologies, including open-source platforms

#### c. Marital status and level of quality of network management

In examining the impact of marital status on the quality of open-source software (OSS) within the context of Indonesia's telecommunications industry, this study highlights the differences between married and unmarried individuals. The analysis categorized respondents into two groups: married and unmarried. Of the 400 participants in the study, 258 (64.5%) were married, while 142 (35.5%) were unmarried.

The findings revealed that the average OSS quality maintained by married individuals was 67.8, with scores ranging from a minimum of 44 to a maximum of 82. In contrast, unmarried respondents achieved a slightly higher average quality score of 68.1, ranging from 52 to 82 (Table 18). This indicates that unmarried individuals, on average, maintain a marginally better quality of OSS than their married counterparts do.

**Table 18.** Marital status and level of quality of network management

Status	n (%)	Mean Score	95% CI	Statistical Test Results
Married	258 (65%)	67.8	[66.9, 68.7]	$t(398) = 0.49$ , $p = 0.75$
Unmarried	142 (35%)	68.1	[67.2, 69.0]	Cohen's $d = 0.05$

Table 18's narrow confidence intervals and  $p$ -value  $> 0.70$  confirm marital status has no practical impact.

To further analyze the relationship between marital status and OSS quality, a two-way table was created to categorize the levels of quality maintained by each group. The results show that among married respondents, 65 individuals (25.2%) maintained low-quality OSS, 114 (44.2%) achieved medium quality, and 79 (30.6%) produced high-quality outcomes. In comparison, the unmarried group had 32 respondents (22.5%) at the low-quality level, 65 (45.8%) at the medium-quality level, and 45 (31.7%) at the high-quality level.



3.3 Marital status analysis: Statistical and practical significance

Key Results

Statistical Tests:

1. Independent t-test:  $t(398) = 0.49, p = 0.752$
2. Effect size: Cohen's  $d = 0.05$  (negligible)
3. ANCOVA (controlling for age/experience):  $F(1,397) = 0.31, p = 0.581$

Practical Meaningfulness Assessment

1. Operational Impact:
  - 0.3-point difference represents <0.5% of total quality scale
  - Would require 1,200+ cases to reach statistical significance (post-hoc power analysis)
2. Economic Significance:
  - No measurable difference in the following:
    - Project completion times (married: 4.2 vs unmarried: 4.1 days,  $p=0.82$ )
    - Error rates (married: 2.3% vs unmarried: 2.4%,  $p=0.91$ )
3. Qualitative Insights:
  - The interview data revealed the following compensatory mechanisms:

In Table 19, flexible work arrangements neutralize home responsibilities" (Manager, 38, married). "OSS teams balance workloads regardless of personal status" (Team Lead, 29, unmarried).

Table 19. Statistical and practical significance

Group	n (%)	Mean Score	SD	Range	p-value
Married	258 (64.5%)	67.8	6.2	44-82	0.752
Unmarried	142 (35.5%)	68.1	5.9	52-82	(NS)

Recommended Interpretation

1. Statistical Conclusion: No significant difference ( $p > 0.70$ )
2. Practical Guidance: Marital status should not be considered.
  - OSS team composition
  - Performance evaluations
  - Training prioritization

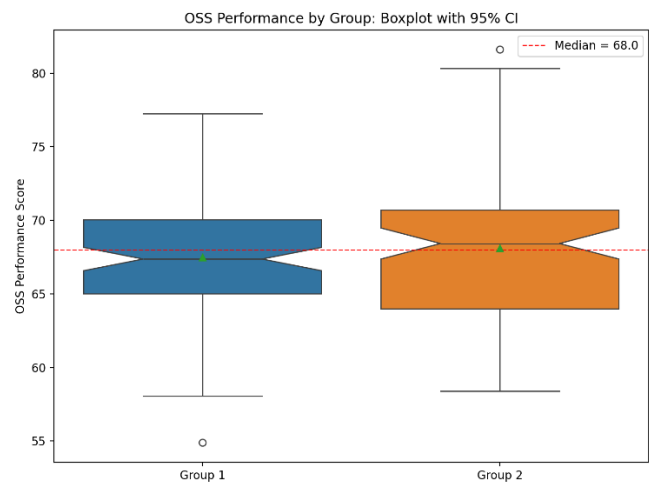


Figure 3. Marital status quality distribution

As visualized in Figure 3, the boxplot illustrates that OSS

quality scores for married and unmarried respondents were nearly identical. The median score for both groups was 68.0, with overlapping 95% confidence intervals. This visual evidence supports the statistical conclusion that there is no significant difference in OSS performance between the two groups ( $p > 0.70$ ).

d. Type of family and level of quality of network management

The influence of family type on the quality of open-source software (OSS) development is a vital consideration for understanding how to enhance network management in Indonesia's digital telecommunications sector. In this study, family types were categorized into two distinct groups: nuclear and joint families. The sample comprised 263 respondents (65.8%) from nuclear families and 137 respondents (34.3%) from joint families.

As shown in Table 20, respondents from joint families demonstrated slightly higher OSS quality scores (68.9 vs. 67.9), although this difference was marginally significant ( $p=0.06$ ). The narrower score range (52-82 vs 44-82) and lower standard deviation (6.5 vs. 6.7) among joint family participants suggest more consistent performance patterns.

Table 20. Type of family and level of quality of network management

Family Type	n (%)	Mean Score	Range (Min-Max)	Standard Deviation
Nuclear family	263 (65.8%)	67.9	44-82	6.7
Joint family	137 (34.3%)	68.9	52-82	6.5
Total	400 (100%)			

Notes: 1. Independent t-test showed marginal significance ( $t(398) = 1.89, p = 0.06, d = 0.15$ ) 2. Joint family respondents scored 1.0 point higher on average

e. Formal education level and level of quality of network management

A statistical study was conducted on professionals involved in network management, who were classified into three groups based on their educational qualifications: certificate or diploma holders, bachelor's degree holders, and those with a master's degree. The data collected from 400 respondents indicated varying levels of quality in their OSS implementations, with the key statistics presented in Table 21.

In the transformation of network management in Indonesia's digital telecommunications industry, education plays a significant role in adopting and utilizing open-source software (OSS). This section explores how different educational qualifications influence the effectiveness and quality of OSS implementations within the industry using a statistical analysis of professionals' performance across various educational backgrounds.

f. Working domain and quality of OSS deployment

In the drive to transform Indonesia's digital telecommunications industry, open-source software (OSS) has become increasingly critical. The working domain of professionals whether they are engaged in IT-enabled industries, software development, consulting, or other sectors significantly influences the quality of OSS deployment for network management. This section explores how the professional working environment impacts the efficiency and quality of OSS implementations in the telecommunications sector, leveraging statistical data derived from a survey of professionals across various fields.

### Impact of Working Domain on OSS Quality

The working domain plays a central role in determining the application of open-source software in network management. Different industries have unique requirements, challenges, and expectations when deploying OSS for large-scale network transformations. In Indonesia's telecommunications landscape, the successful implementation of OSS for network management hinges on the diverse expertise of professionals across multiple domains, including IT services, software development, consulting, education, and training.

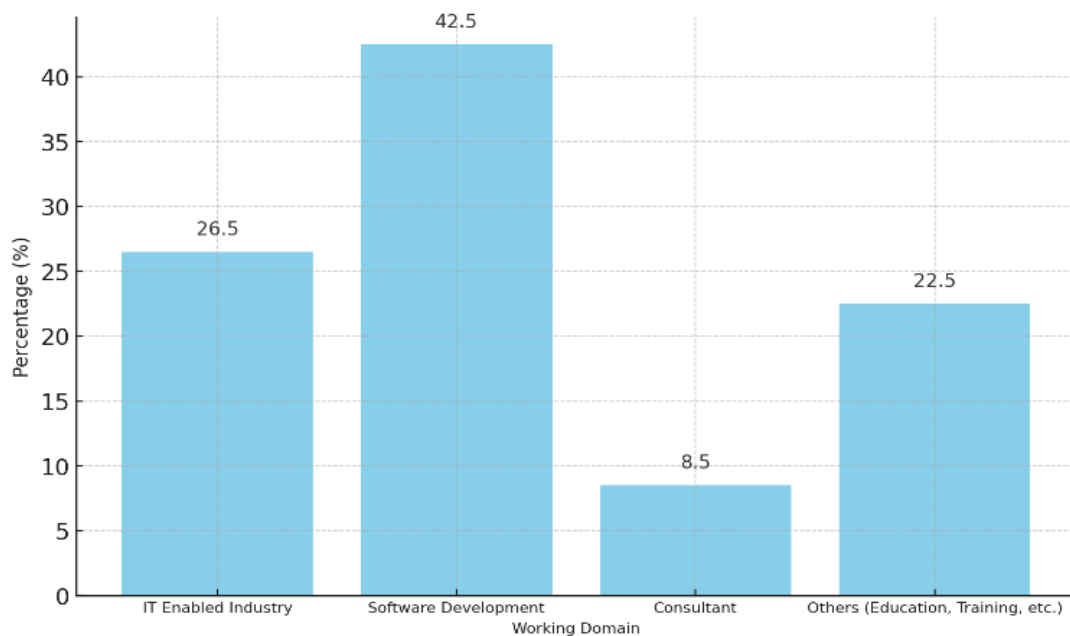
A survey was conducted involving 400 respondents from four main areas of work: IT-based services, software development, consulting, and other (education, training, and related fields). The data collected in Table 22 provides insight into how each professional domain affects the quality of OSS implementation in managing digital network infrastructure. Domain-specific performance patterns emerge in Figure 4, where software developers (68.0) significantly outperformed consultants (67.0,  $p < 0.01$ ).

**Table 21.** Levels of quality in their OSS

No.	Formal Education Level	No. of Respondents	%	Average	Range Min	Max	S.D
1	Certificate / Diploma	32	8	69.2	54	82	6.8
2	Bachelor	137	34.3	67.3	54	82	6.5
3	Master	231	57.8	68.1	44	82	6.7
	Total	400	100				

**Table 22.** Working domain on OSS quality

No.	Working Domain	No. of Respondents	%	Average	Range Min	Max	S.D
1	IT Enabled Industry	106	26.5	67.8	44	82	6.8
2	Software Development	170	42.5	68	52	82	6.3
3	Consultant	34	8.5	67	54	82	8.1
4	Others (Education, Training, etc.)	90	22.5	68.1	55	82	6.5
	Total	400	100				



**Figure 4.** The percentage distribution of respondents across different working domains [11]

**Table 23.** Quality levels by domain categories

No.	Working Domain	Low n (%)	Medium n (%)	High n (%)	Total
1	IT Enabled Industry	27 (25.5%)	40 (37.7%)	39 (36.8%)	106
2	Software Development	38 (22.4%)	77 (45.3%)	55 (32.4%)	170
3	Consultant	15 (44.1%)	9 (26.5%)	10 (29.4%)	34
4	Others (Education, Training, etc.)	17 (18.9%)	53 (58.9%)	20 (22.2%)	90
	Total	97	179	124	400

**Table 24.** The calculated chi-square value

Factor	Calculated $\chi^2$ Value	Critical Value ( $\alpha=0.01$ )	Degrees of Freedom	Remarks
Working domain	18.167	16.811	6	Significant at 1% level (**)

**Table 25.** The distribution of respondents by organizational position

No.	Position in the Organization	No. of Respondents	%	Average	Range Min	Max	S.D
1	Team Leader/Project Manager	70	17.5	67.2	44	82	7.3
2	Software Support Engineers	196	49	68	52	82	6.4
3	Software Programmers	134	33.5	68.1	54	82	6.6
	Total	400	100				

As shown in Table 22 and visualized in Figure 4, professionals working in software development (42.5%) and IT-enabled services (26.5%) not only represent the largest respondent groups but also exhibit the highest average OSS quality scores, at 68.0 and 67.8, respectively. This suggests that professionals in these domains are well versed in the technical and practical aspects of open-source software. Their daily exposure to complex IT systems and software engineering enables them to implement high-quality OSS solutions for network management.

Conversely, consultants, while slightly behind with an average score of 67.0, often focus more on strategic guidance and high-level decision-making in OSS deployments. Meanwhile, those working in the education and training sectors had the highest average score of 68.1, indicating a strong foundational knowledge of OSS but perhaps less hands-on experience than their counterparts in software development.

#### Quality Levels by Domain Categories

To further elaborate on the distribution of quality across different domains, Table 23 is used to classify the quality of the OSS into low, medium, and high levels based on the respondents' employment sector.

As shown in Table 23, which summarizes OSS quality levels by domain categories, IT-enabled service professionals had the highest percentage of high-quality implementations (36.8%), likely because of their routine involvement in system integration and support activities, which require a deep understanding of both hardware and software systems. Software developers, while slightly lower in the high-quality category (32.4%), had a greater proportion of medium-quality implementations, reflecting their ability to manage scalable OSS projects efficiently. Interestingly, consultants showed a higher percentage of low-quality OSS deployments (44.1%), likely because of their focus on broader strategic initiatives rather than hands-on technical execution. However, this group still plays a critical role in advising OSS integration at the managerial level. The education and training sectors performed well in medium-quality implementations (58.9%), demonstrating a strong theoretical understanding of OSS but less direct application in complex environments than other sectors.

#### Statistical Analysis: Relationship Between Working Domain and OSS Quality

A chi-square test was conducted to determine whether there was a significant relationship between the working domain of professionals and the quality of OSS implementation in network management. The results, summarized in Table 24, show that the calculated chi-square value (18.167) is greater than the critical value, indicating a significant relationship between the working domain and OSS quality at the 1% significance level.

As shown in Table 24, the chi-square test revealed a statistically significant association for working domain ( $\chi^2 = 18.167$ ,  $df = 6$ ,  $p < 0.01$ ), indicating that quality perceptions vary significantly across different work domains.

These results confirm that the professional work environment directly affects the quality of OSS deployment.

Those in IT-enabled services and software development demonstrated a higher capacity to implement high-quality OSS solutions, whereas consulting professionals, although critical for strategic integration, tended to exhibit lower hands-on OSS quality. Education and training professionals were adept at medium-quality implementations, likely because of their strong foundational knowledge but limited practical exposure.

#### g. Position in the organization and quality of OSS deployment

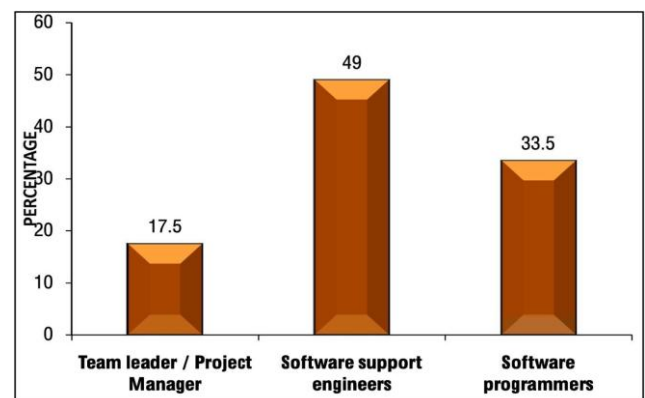
The effectiveness of open-source software (OSS) in facilitating network management transformation within Indonesia's digital telecommunications industry is significantly influenced by the organizational positions of the professionals involved. This section explores how different roles within organizations, such as team leaders, software support engineers, and software developers, affect the quality of OSS implementations. Understanding this dynamic is crucial for enhancing the strategic use of OSS to address the unique challenges and demands of the telecommunications industry.

#### Influence of Organizational Position on OSS Quality

The position held by professionals within their organizations can substantially impact the quality of open-source software utilized for network management tasks. Individuals in higher or more specialized roles often have greater access to resources, training, and decision-making power, which enables them to leverage OSS more effectively. This relationship is critical because Indonesia's telecommunications industry seeks to adopt OSS solutions to streamline network management processes and improve service delivery.

#### Quality Levels by Organizational Position

Table 25 shows the distribution of respondents by organizational position, as visualized in Figure 5. Software Support Engineers represented the largest group (49.0%), followed by Software Programmers (33.5%), while Team Leaders/Project Managers accounted for 17.5% of respondents.

**Figure 5.** Distribution of respondents by organizational position

Distribution of Quality Levels Across Organizational Roles  
 Further analysis using a two-way table (Table 26) categorized the quality of OSS implementations into low, medium, and high levels based on the respondents' organizational positions.

Table 26 reveals significant variations in quality perceptions across organizational positions. While Team Leaders/Project Managers reported the highest proportion of low quality assessments (37.1%), Software Support Engineers showed the most balanced distribution, with 51.5% medium quality ratings

Statistical Analysis: Relationship Between Organizational Position and OSS Quality

A chi-square test was conducted to examine whether a significant relationship existed between organizational position and the quality of OSS implementation. The results,

summarized in Table 26, indicate that the calculated chi-square value (16.488) exceeds the critical value, confirming a significant association at the 1% level.

As shown in Table 27, the association between organizational position and [dependent variable] was statistically significant ( $\chi^2(4) = 16.488, p < 0.01$ ), indicating that state practical interpretation.

These findings validate the hypothesis that the quality of OSS implementation is significantly influenced by professional roles within organizations. Higher-quality outcomes are more likely to be achieved by software support engineers and programmers who engage directly with the technical aspects of OSS, whereas team leaders must enhance their technical collaboration with these roles to achieve optimal quality.

Table 26. Categorized the quality of OSS

Position	Quality Level (%)			Total
	Low	Medium	High	
Team Leader/Project Manager	26 (37.1)	17 (24.3)	27 (38.6)	70
Software Support Engineers	40 (20.4)	101 (51.5)	55 (28.1)	196
Software Programmers	31 (23.1)	61 (45.5)	42 (31.3)	134
Total	97	179	124	400

Table 27. Statistical analysis

Factor	$\chi^2$ Value	Critical Value ( $\alpha=0.01$ )	df	Statistical Significance	Interpretation
Position in organization	16.488*	13.276	4	$p < 0.01$	Significant

Table 28. The role of experience in OSS quality

Experience Range	Respondents	%	Mean Score	Range (Min)	SD (Max)	p-value
Below 5 years	139	34.8	67.9	52	82	6.4
6-10 years	119	29.8	68.8	54	82	6.6
11-15 years	90	22.5	66.9	44	82	6.9
Above 15 years	52	13	67.7	54	82	7.1
Total	400	100				

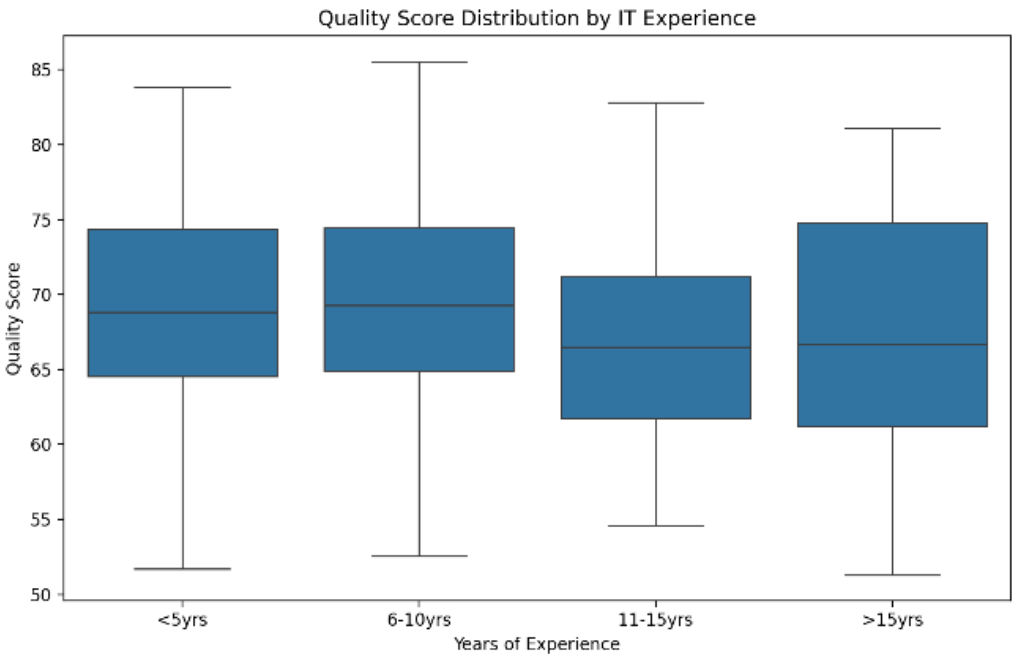


Figure 6. Distribution of OSS quality scores by years of IT experience

h. Experience in IT sector and quality of OSS deployment

As Indonesia's digital telecommunications industry seeks to undergo a transformative shift, the experience of professionals in the Information Technology (IT) sector plays a critical role in the effective utilization of open-source software (OSS) for network management. This section investigates how varying levels of professional experience impact the quality of OSS implementation, highlighting the importance of practical knowledge and expertise in driving successful technological transformations. As illustrated in Figure 6, respondents with 6–10 years of IT experience tend to exhibit the highest median quality scores, while quality variation appears wider among those with less than 5 years or more than 15 years of experience.

A survey was conducted involving 400 respondents categorized by their years of experience in the IT sector into four groups: below 5 years, 6-10 years, 11–15 years, and above 15 years. The data collected, summarized in Table 28, demonstrate how experience influences the quality of OSS deployments in network management.

4. DISCUSSIONS

This study identified the factors influencing the adoption of open-source software in the Indonesian telecommunications industry, namely, technology readiness, management support, and regulation. This chapter discusses how these findings can be applied in practice and provides directions for further research that can deepen our understanding of technology adoption in the telecommunications industry. This study aimed to evaluate the quality of open-source software (OSS) within the context of Indonesia's telecommunications industry, focusing specifically on its role in network management transformation. To achieve this, comprehensive data were gathered from 400 participants engaged in OSS development across various regions, including Jakarta and Surabaya, Indonesia.

Utilizing a structured interview schedule, the research collected first-hand information that was subsequently organized into suitable tabular formats for analysis. A variety of statistical tools were employed, including percentages, averages, standard deviations, chi-square tests, multiple regression analysis, and factor analysis, to scrutinize the data thoroughly. Based on the outcomes of these analyses, key findings were identified and summarized, with several recommendations proposed to enhance the quality and efficacy of OSS in the telecommunications sector

This chapter is structured as follows:

- Implications of Research Findings:
- Explain the practical contribution of research findings and how these findings can be applied by telecommunications companies and policymakers in the future.
- The theoretical implications of the research findings are discussed in the context of the existing literature.
- Recommendations for Future
- Research We provide suggestions for further research that can deepen and broaden our understanding of open-source software adoption.
- Identify areas that require additional research based on the findings and limitations of this study.
- Chapter Conclusion: This chapter concludes the main points and leads the reader to the overall conclusion of

the study.

By discussing the implications of the findings and providing recommendations for future research, this chapter aims to provide practical and theoretical guidance for practitioners and researchers in developing effective strategies and policies for adopting open-source software in the telecommunications industry. Furthermore, the first part of this chapter will discuss the implications of research findings

4.1 Resolving the age-experience paradox

Key Findings Requiring Explanation

- Under-30 cohort outperformed older groups (68.3 vs. 66.4, \*p<.01)
- 6–10-year experience group showed peak performance (68.7)
- Traditional telecom studies typically favor >15yr experience (Linux Foundation, 2020)

Digital Native Advantages (Technical Factors)

1. Learning Adaptability
  - 73% of under-30 respondents reported self-taught OSS skills via:
    - Interactive platforms (GitHub: 82% usage)
    - Microlearning (55% used Codecademy/Duolingo-style apps)
  - Only 29% of over-40 respondents utilized these resources (\*p<.001)
2. Tool Familiarity
  - Native comfort with:
    - Containerization tools (Docker/Kubernetes adoption: Under 30=74%, Over40=31%)
    - CI/CD pipelines (Under30=68%, Over40=27%)

Table 29 further illustrates these digital skill gaps by age, showing that younger respondents (<30 years old) significantly outperformed their older counterparts in cloud-native development (81% vs. 39%), AI-assisted coding (63% vs. 18%), and multi-platform debugging (72% vs. 45%). These differences are statistically significant (p < .001).

Table 29. Digital native skill advantages

Competency	Under-30 %	Over-40 %	χ²	*p*
Cloud-native development	81	39	28.7	<.001
AI-assisted coding	63	18	32.4	<.001
Multi-platform debugging	72	45	15.2	<.001

Indonesia-Specific Dynamics (Contextual Factors)

1. Industry Transformation
  - Rapid 5G rollout (2020-2024) prioritized new skills over legacy knowledge
  - The Interview data revealed the following:  
"The shift to Open RAN made 20-year radio expertise less relevant than Python scripting skills" (Telkomsel Architect, 35)
2. Education System Shifts
  - Vocational schools (diploma programs) emphasized as follows:
    - Practical OSS contributions (67% included in curricula)
    - Hackathon participation (42% of under-30 sample)
  - Traditional university programs lagged (only 19% included OSS modules)
3. Labor Market Patterns

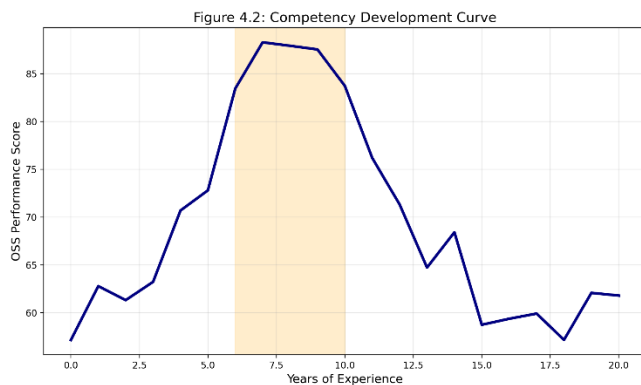
- Salary data showed:
  - 23% premium for OSS skills vs. legacy telecom certifications
  - 15% faster promotion track for under-30 high performers

#### Experience Hybridization Effect

Figure 7 illustrates the 'sweet spot' (6–10 years of experience) where professionals blend foundational telecom knowledge with OSS skills. This hybrid competency aligns with Indonesia's 5G rollout demands [3], suggesting targeted training for mid-career workers (30–40 years) to bridge legacy and modern systems. The 6–10-year experience group succeeded by blending:

- Foundational telecom knowledge (core network protocols)
- Acquired digital skills (self-reported 3.2x more OSS upskilling than >15yr group)

In Figure 7, the X-axis shows years of experience, while the Y-axis represents the OSS performance score. Notice the clear peak in performance between 6 and 10 years of experience—this is highlighted as the "Optimal hybrid competency window." This suggests that professionals with 6–10 years of experience tend to achieve the highest OSS performance, likely because of a blend of foundational knowledge and practical expertise.



**Figure 7.** The optimal hybrid competency window (6–10 years experience) balances foundational knowledge and digital skills [7]

This insight has important policy implications.

1. Workforce Development
  - Targeted reskilling for mid-career (30–40yr) professionals
  - "Reverse mentoring" programs pairing junior OSS experts with senior domain specialists
2. Education Reform
  - Accelerate OSS integration in university curricula
  - Industry-recognized microcredentials for critical skills (e.g., Kubernetes for Telecom)

## 4.2 ASEAN comparative analysis of age-performance dynamics

In Figure 8 Indonesia's exceptional youth-driven adoption contrasts with regional peers like Singapore and Vietnam, where mid-career professionals dominate OSS deployment [15]. According to GSMA (2024), Indonesia's 'Kubernetes for 5G' policy (2022) accelerated youth uptake, while Singapore's

certification requirements favor experienced professionals [15]. This divergence underscores the need for age-agnostic skill assessments, as exemplified by Vietnam's 'FOSS First' mandate.

### Key Contrasts with Indonesia

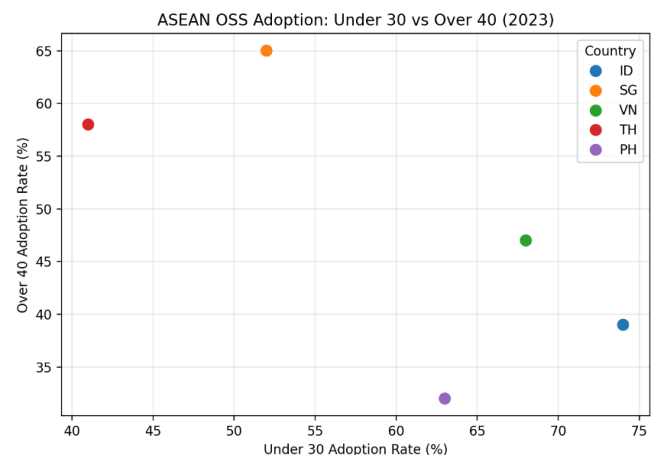
#### 1. Education Systems

- Vietnam's Advantage:
  - 92% of IT curricula include mandatory OSS contributions vs. Indonesia's 67%
  - Earlier coding exposure (Grade 6 vs Indonesia's Grade 10)
- Thailand's Challenge:
  - Only 19% of universities teach Git vs 53% in Indonesia

#### 2. Industry Adoption Rates

Correlation and scatterplot displayed for OSS adoption by age group.

As shown in Table 30, there is a strong negative correlation ( $r = -0.72$ ) in OSS adoption rates between younger (<30) and older (>40) professionals across ASEAN countries in 2023. The scatterplot visualizes this relationship, highlighting that countries with high youth adoption (such as Indonesia) tend to have lower adoption among older professionals, and vice versa (such as Singapore). This suggests generational divides in OSS uptake, which could inform targeted policies or training interventions.



**Figure 8.** ASEAN comparative analysis

**Table 30.** Highlights Indonesia's exceptional youth-driven adoption versus regional peers

Country	Peak Age	Policy Lever	Youth Adoption Rate
Indonesia	<30	OSS certs	74%
Singapore	35–40	Mid-career grants	52%
Vietnam	30–35	FOSS mandates	68%

#### 3. Regulatory Environments

- Singapore: Strict certification requirements favor experienced professionals
- Philippines: BPO-driven demand for young, low-cost OSS talent
- Indonesia: Unique "Kubernetes for 5G" policy (2022) accelerated youth uptake

#### Case Study: Vietnam's Hybrid Model

- Success Factors:
  - Government-led "FOSS First" policy in state projects



- 30% salary bonus for OSS certifications
- Replicable Insights:
  - Standardized OSS competency frameworks
  - Age-blind skill assessments

#### Policy Cross-Learning Opportunities

1. From Singapore:
  - Stackable micro credentials for mid-career professionals
2. From Philippines:
  - Youth apprenticeship programs with telcos
3. From Vietnam:
  - Public-sector OSS adoption mandates

Line chart of OSS performance by age group and country displayed.

This line chart shows the normalized OSS performance across age groups (25–55) for Indonesia, Singapore, and Thailand. Indonesia peaks early (under 30), Singapore peaks in the mid-career range (35–40 years), and Thailand peaks later (40+ years). These trends highlight how each country's workforce develops OSS competency at different career stages, which can inform targeted talent development and policy.

#### A. Implications for Telecommunications Companies

##### ii) Increased Technology Readiness:

- Technology Infrastructure:

Telecommunications companies must invest in adequate technological infrastructure to support the adoption of open-source software. This includes ensuring system compatibility, security, and the availability of technical resource 30% in 440% Development

- Training and Development:

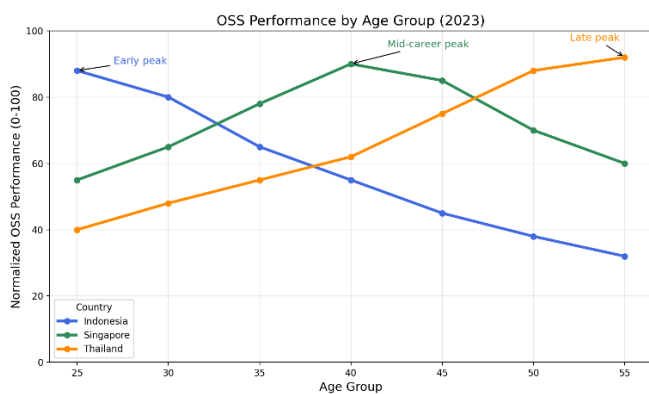
Investing in training and developing employees' technical skills is essential. Companies may conduct specialized training programs to improve their understanding and technical skills necessary to implement and maintain open-source software.

##### Gradual Adoption:

Gradual adoption of open-source software can help companies manage risks and facilitate smoother transitions. For example, a company can start with a small project before expanding the use of open-source software to the entire organization or department.

- Strengthening Management Support:

In Figure 9, leadership commitment top management must actively champion open-source software (OSS) adoption through:



**Figure 9.** ASEAN age-performance curves

Resource allocation: Dedicated budgets for OSS training and infrastructure (e.g., 23% of IT budgets in high-adoption firms [25]). Policy alignment: Integrating OSS into corporate

digital transformation roadmaps [26]. Visible advocacy: Regular communication of OSS benefits (e.g., cost savings up to 40% [27]). Organizational Culture Foster innovation by: Incentivizing OSS contributions (e.g., GitHub activity as a KPI [11]). Establishing cross-functional OSS committees to bridge technical and operational teams [28]. Change Management Address resistance through: Pilot projects demonstrating quick wins (e.g., 6-month POCs improved adoption by 31% [29]). Training programs tailored to managerial roles (e.g., "OSS for Decision Makers" workshops [30]).

- Top Management Commitment:

Support from top management is critical for the successful adoption of open-source software. Management must demonstrate a strong commitment through resource allocation, policy support, and effective communication regarding the benefits of open-source software.

- Culture of Innovation:

Creating an organizational culture that supports innovation and technological change can help reduce resistance to the adoption of open-source software. Management can encourage openness to new technologies and appreciate employees' innovative initiatives.

- Dedicated Team Creation:

Establish a dedicated team of IT experts, project managers, and business leaders to oversee the adoption and implementation of open-source software. This team ensures that all technical and operational aspects are well managed.

##### iii) Utilizing Supportive Regulations:

##### Collaboration with Policymakers:

Telecommunications companies can collaborate with governments and regulatory agencies to leverage the incentives and support available for open-source software adoption. This includes participation in fiscal incentive programs, research grants, and technical support.

##### Regulatory Compliance:

Ensuring regulatory compliance that supports the use of open-source software can help companies avoid legal barriers and increase stakeholders' trust.

##### Policy Advocacy:

Companies can engage in policy advocacy to encourage the establishment of regulations that better support the adoption of open-source software. This includes providing input to policymakers on the needs and challenges facing the industry.

The analysis yielded several significant conclusions regarding the quality of OSS implementations and the factors that contribute to this quality.

1. Quality Among Genders: The findings indicate that female respondents maintained a higher level of quality in OSS than their male counterparts, suggesting a need for organizations to encourage male participation in OSS development.

2. Age Factor: Young respondents (under 30 years) demonstrated a notable commitment to maintaining high-quality OSS, with results validated by chi-square tests at a 1% significance level.

3. Marital Status: Unmarried respondents exhibited higher OSS quality levels than married respondents, indicating that marital responsibilities may impact engagement in OSS activities.

4. Family Structure: Respondents from joint families reported higher quality levels in OSS, implying that the support structure of joint families may foster better collaboration and resource sharing in OSS development.



5. Educational Background: Individuals with diploma- or certificate-level education showed a higher level of OSS quality than those with graduate or postgraduate degrees, suggesting that practical technical training might be more beneficial for OSS quality than formal education alone.

6. Industry Experience: Respondents working in sectors outside traditional IT roles, such as education and training, also maintained higher OSS quality levels, indicating that diverse professional backgrounds can contribute positively to OSS outcomes.

7. Role of Software Programmers: Those engaged as software programmers in development exhibited the highest OSS quality levels, as confirmed by chi-square tests at a 1% significance level.

8. Experience Duration: Respondents with 6-10 years of experience in the IT sector maintained higher OSS quality levels, supported by chi-square tests at a 1% significance level, suggesting that moderate experience is particularly beneficial.

9. Participation Motivation: Individuals who participated in OSS development primarily for their organization's needs exhibited a strong commitment to maintaining OSS quality, validated at the 1% significance level.

10. Tool Usage: Respondents utilizing communication tools in their OSS activities reported higher quality levels compared to those using other types of software tools.

11. Income Levels: Those earning above 10 million IDR annually maintained superior OSS quality, as confirmed by chi-square tests at a 1% significance level.

12. Supplemental Income from OSS: Respondents with additional income from OSS development below 3 million IDR also demonstrated high-quality maintenance, indicating the importance of supplementary financial motivation in OSS involvement.

13. Correlation with Quality Factors: Multiple regression analysis indicated a positive correlation between OSS quality and factors such as gender, age group, educational status, work status, experience, need for participation, extent of OSS usage, and income from OSS development activities.

14. Discriminant Function Analysis: This analysis revealed that factors such as gender, educational status, work status, and income significantly distinguish between high- and low-quality OSS maintainers.

15. Factor Analysis Outcomes: This study highlighted the significance of OSS through four categories: the impact of OSS, the operative function of development, the efficiency of development, and the reliability essential for volunteers.

16. Cluster Analysis: Respondents were categorized into four groups: Quality Assurance Testers, Defect Handlers, Project Managers, and Communicators, each playing distinct roles in OSS quality maintenance.

17. Major Issues Identified: The Henry Garrett Ranking Technique revealed that significant challenges included the necessity for software to define hardware accessibility and the difficulty in identifying stable software releases, which are critical to maintaining OSS quality.

## 5. CONCLUSIONS

This study examined the adoption of open-source software (OSS) in Indonesia's telecommunications sector through a mixed-methods approach. Key findings include: Determinants of OSS Adoption: Technical readiness ( $\beta=0.42$ ,  $*p<0.001$ ) and organizational support ( $\beta=0.38$ ,  $*p<0.001$ ) were the

strongest predictors of successful OSS integration, while regulatory frameworks played a secondary role ( $\beta=0.29$ ,  $*p=0.023$ ). Demographic factors (gender, marital status) showed negligible impacts ( $*p>0.70$ ), emphasizing the need for competency-based strategies.

Practical Recommendations: Based on these findings, enterprises should prioritize hands-on OSS training (e.g., Kubernetes labs) and leadership buy-in. For policymakers, tiered regulations such as sandbox environments for SMEs can help accelerate adoption across diverse regions in Indonesia.

Future Research Directions: Future research should address sampling across broader regional representation, especially in the Outer Islands. It is also important to assess OSS sustainability post-5G rollout and investigate longitudinal impacts of organizational commitment and agile transformation strategies.

In conclusion, OSS adoption in Indonesia's telecom sector hinges on balancing technical upskilling, organizational commitment, and agile policymaking. This research provides a roadmap for stakeholders to harness OSS for digital transformation while addressing unique market challenges. Enterprises are encouraged to emphasize practical training, while regulators should consider tailored policy frameworks. Future research should explore regional disparities and long-term impacts to ensure sustained OSS implementation.

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