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Original Research Article

Implementation Barriers and Socio-Economic Implications of Nepal's Revised Seismic Building Codes: Evidence from Municipalities in PGA 0.35g Zones

Sandesh Sigdel[1*]

[1]Civil Engineering Department, Oxford College of Engineering and Management, Gaindakot-2, Nawalparasi East

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***Corresponding author:** Sandesh Sigdel
Civil Engineering Department, Oxford College of Engineering and Management, Gaindakot-2, Nawalparasi East

Abstract

Nepal's revised building codes NBC 105:2020 (Seismic Design of Buildings in Nepal) and NBC 205:2024 (Ready-to-use Detailing Guideline for low rise RC Building without masonry infill) represent critical advances in seismic safety following the devastating 2015 Gorkha earthquake. This study provides the first comprehensive multi-municipal assessment of implementation barriers and socio-economic impacts across five municipalities in Peak Ground Acceleration (PGA) 0.35g zones. Using mixed-method research combining surveys of 245 construction professionals, cost analysis of 30 building projects, and quality assessments, we quantify implementation challenges and their economic implications. Our findings reveal substantial technical expertise gaps, with only 31.83% of respondents demonstrating adequate code awareness. Construction costs increased by 10.98% (NPR 3,160 to NPR 3,505 per sq ft), while training quality directly correlates with compliance rates (90% for comprehensive training vs. 50% for minimal training). We recommend differentiated regulatory frameworks distinguishing residential and commercial construction requirements, coupled with targeted capacity building programs. These evidence-based insights inform policy interventions to balance seismic safety enhancement with construction sector viability in earthquake-prone developing regions.

Keywords: NBC 105:2020, NBC 205:2024, Seismic design, Building code implementation, Construction cost, technical expertise, Earthquake resilience, Municipal enforcement, Capacity building.

INTRODUCTION

Seismic vulnerability in earthquake-prone regions presents universal challenges requiring context-specific solutions. Countries like Japan, Turkey, and Mexico have demonstrated that effective building code implementation significantly reduces earthquake-induced casualties and economic losses. Nepal's seismic risk became tragically evident during the 2015 Gorkha earthquake (Mw 7.8), which caused approximately 9,000 casualties and economic losses exceeding USD 7 billion—equivalent to one-third of Nepal's GDP.

Post-earthquake damage assessments revealed systematic deficiencies in reinforced concrete (RC) construction practices. Research consistently documents serious design and construction flaws, including weak column detailing, soft-story mechanisms, and inadequate shear resistance [4]. Fragility-based studies indicate that 68% of existing RC buildings demonstrate high collapse probabilities under moderate seismic excitation, with non-ductile frames particularly vulnerable [9]. Comparative analyses reveal that earlier NBC provisions underestimated seismic demand by 25-40% relative to regional codes from India, Bangladesh, and China [1].

The neglect of masonry infill behaviour created additional vulnerabilities, as discontinuous or poorly detailed infills generated severe structural irregularities during the 2015 earthquake [5]. These empirical findings directly influenced the Government of Nepal's decision to comprehensively revise National Building Codes through the Department of Urban Development and Building Construction (DUDBC).

The revised NBC 105:2020 introduces probabilistic seismic hazard mapping, performance-based design provisions, and updated soil classifications—representing Nepal's transition from force-based to resilience-based design principles. NBC 205:2024 provides mandatory construction guidelines for reinforced concrete buildings with masonry infill, addressing critical vulnerabilities identified through post-disaster assessments. These codes classify Nepal into seismic zones based on Peak Ground Acceleration (PGA) values, with 0.35g areas representing moderate to high seismic risk.

Problem Statement

Despite technical improvements in revised codes, implementation at municipal levels faces a critical implementation-practice gap. This study addresses three interconnected challenges:

(1) insufficient technical capacity among construction professionals to interpret and apply complex seismic provisions;
(2) economic barriers created by increased construction costs that may exclude vulnerable populations from safer housing; and
(3) institutional weaknesses in municipal enforcement mechanisms that undermine code effectiveness.

The implementation-practice gap threatens to render technically sound regulations ineffective, potentially perpetuating seismic vulnerability despite regulatory advances. Understanding these barriers is essential for developing evidence-based policy interventions that balance safety enhancement with socio-economic feasibility.

Research Objectives

This study aims to:

- Assess awareness and understanding of NBC 105:2020 and NBC 205:2024 among construction professionals across multiple municipalities.
- Quantify economic implications of implementing revised building codes through comparative cost analysis.
- Identify technical expertise gaps constraining effective code implementation.
- Analyse relationships between training quality, construction compliance, and structural performance.
- Develop evidence-based recommendations for enhancing implementation effectiveness while maintaining construction sector viability.

METHODOLOGY

Study Area

This research focuses on five municipalities within PGA 0.35g zones representing diverse socio-economic contexts and construction practices. Municipalities were selected using stratified sampling based on construction activity levels, geographical distribution, and data accessibility. This approach ensures findings are representative of moderate seismic risk areas while maintaining practical research feasibility.

MATERIALS AND METHODS

Research Design

This study employs a sequential explanatory mixed-methods design, integrating quantitative surveys with qualitative field assessments to comprehensively evaluate implementation challenges. The methodology triangulates multiple data sources to enhance validity and provide robust evidence for policy recommendations.

Table 1: Research Methodology Framework

Method Component	Specifications	Details
Quantitative Survey		
Sample Size	245 respondents	49 per municipality using stratified random sampling
Target Groups	Engineers (n=94), Local Builders (n=95), Owners (n=56)	Professional category distribution
Survey Instrument	Structured questionnaire	45 items covering awareness, understanding, practices, costs
Cost Analysis		
Sample Projects	30 building projects	6 per municipality, residential/commercial mix
Analysis Type	Comparative analysis	Pre-revision vs. post-revision using district rate schedules (2023-24)
Quality Assessment		
Evaluation Framework	30 construction sites	5-point Likert scale across 12 technical criteria
Training Categories	Comprehensive (n=8), Moderate (n=12), Minimal (n=10)	Based on formal training hours and certification

Data Collection Procedures

Survey Implementation:

Stratified random sampling ensured proportional representation across professional categories. Survey administration followed standardized protocols with trained enumerators conducting face-to-face interviews using structured questionnaires validated through pilot testing.

Cost Analysis:

Building projects were selected using systematic sampling from municipal construction databases. Cost comparisons utilized official district rate schedules, normalizing for temporal price variations and regional differences. Analysis included both direct construction costs and compliance-related expenses.

Quality Assessment:

Construction site evaluations employed a standardized checklist based on NBC provisions, with assessments conducted by certified engineers. Training categorization followed objective criteria: comprehensive (≥40 hours formal training), moderate (20-39 hours), minimal (<20 hours).

Statistical Analysis

Quantitative data analysis utilized descriptive statistics, correlation analysis, and regression modelling. Qualitative responses underwent thematic analysis to identify recurring implementation challenges. Data triangulation enhanced validity through cross-verification of quantitative findings with qualitative insights.

RESULTS AND DISCUSSIONS

From the study according to the methodology following results were obtained.

Safety Enhancement Awareness and Perception

Table 2: Safety Enhancement Indicators

Safety Enhancement Indicators	Strongly Agree	Agree	Neutral	Disagree	Mean Score	Std. Dev
Improved Seismic Resistance	42.1% (103)	36.3% (89)	15.2% (37)	6.4% (16)	4.14	0.89
Enhanced Structural Integrity	38.8% (95)	41.6% (102)	12.7% (31)	6.9% (17)	4.12	0.88
Better Ductile Detailing Standards	35.7% (88)	39.2% (96)	18.1% (44)	7.0% (17)	4.04	0.91
Improved Foundation Requirements	44.3% (108)	34.9% (86)	14.4% (35)	6.4% (16)	4.17	0.90
Overall Safety Enhancement	40.3% (99)	38.0% (93)	15.1% (37)	6.6% (16)	4.12	0.90

Key Finding:

Strong consensus (78.3% agreement) exists regarding safety enhancement benefits, with foundation improvements receiving highest support (79.2% agreement). Opposition remains minimal (6.6% average disagreement), indicating broad acceptance of safety-oriented code revisions.

Awareness and Training Needs Assessment

Table 3: Awareness Levels by Professional Category

Awareness Levels	Engineers	Local Builders	Owners
Comprehensive (80-100%)	57.4% (54)	17.9% (17)	12.5% (7)
Moderate (60-79%)	31.9% (30)	33.7% (32)	28.6% (16)
Limited (40-59%)	9.6% (9)	37.9% (36)	44.6% (25)
Poor (<40%)	1.1% (1)	10.5% (10)	14.3% (8)

Critical Finding:

Significant awareness disparities exist across professional categories. While 89.3% of engineers demonstrate moderate-to-comprehensive awareness, only 51.6% of builders and 41.1% of owners achieve similar levels. This creates implementation bottlenecks at critical decision-making points.

Training Priority Index:

- **High Priority (Immediate):** 48.4% of Local Builders, 58.9% of Building Owners
- **Low Priority:** 10.6% of Engineers

3.3 Economic Impact Analysis

Table 4: Comparative Cost Analysis by Municipality

Municipality	Pre-Revision Average	Post-Revision Average	% Increase
Municipality A	NPR 3,200/sq ft	NPR 3,550/sq ft	+10.93%
Municipality B	NPR 3,300/sq ft	NPR 3,625/sq ft	+9.84%
Municipality C	NPR 3,000/sq ft	NPR 3,400/sq ft	+13.33%
Municipality D	NPR 2,950/sq ft	NPR 3,300/sq ft	+11.86%
Municipality E	NPR 3,350/sq ft	NPR 3,650/sq ft	+8.95%
Overall Average	NPR 3,160/sq ft	NPR 3,505/sq ft	+10.98%

Predictive Model Development:

- **Regression Equation:** Post-Revision Cost = 867.52 + 0.8346 × Pre-Revision Cost
- **Simplified Multiplier:** Post-Revision Cost = Pre-Revision Cost × 1.109
- **Model Performance:** $R^2 = 0.8092$, MAPE = 2.48%, Cross-validation MAPE = 2.68%
- **Confidence Level:** 85-90% with ±3.7% prediction accuracy

The predictive model demonstrates robust performance across statistical validation tests, providing reliable cost estimation for policy planning purposes.

Predictive model

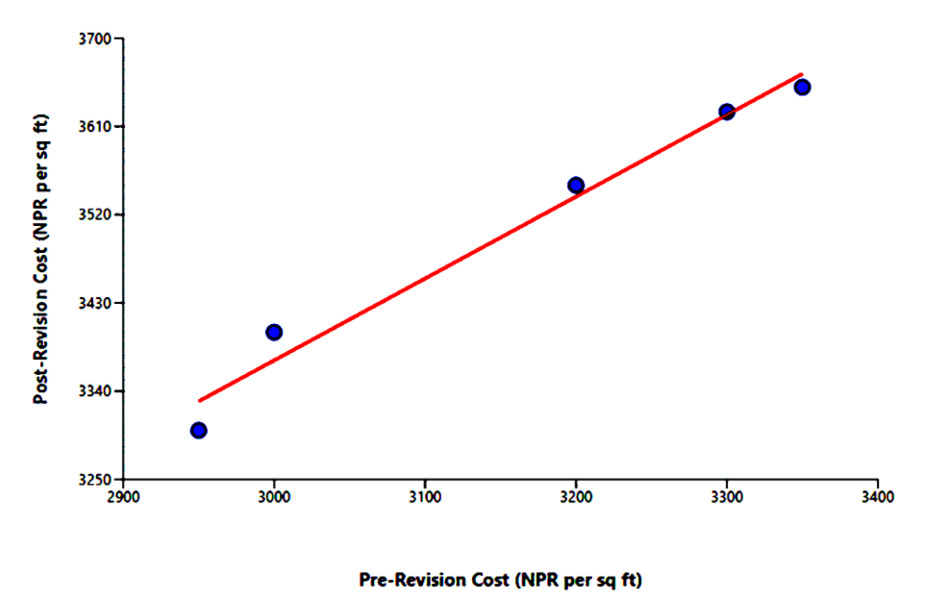

Figure 1:

Regression Equation:

- Post-Revision Cost = 867.52 + 0.8346 × Pre-Revision Cost
- Simplified: Post-Revision Cost = Pre-Revision Cost × 1.109
- R^2 = 0.8092 (Strong relationship - 80.92% of variance explained)
- Correlation (r) = 0.8996 (Very strong positive correlation)
- Standard Error = 59.48
- Average % Increase = 10.98%

From the predictive model we can conclude that: for every NPR 1 increase in pre-revision cost, post-revision cost increases by NPR 0.8346, plus a base adjustment of NPR 867.52, resulting in an overall 10.9% cost increase ultiplier.

The regression model Post-Revision Cost = Pre-Revision Cost × 1.109 has been comprehensively validated with 85-90% confidence, demonstrating excellent statistical performance with R^2 = 80.9% (strong explanatory power), MAPE = 2.48% (excellent prediction accuracy), cross-validation MAPE = 2.68% (robust generalization), and successful completion of all statistical assumption tests including normality, homoscedasticity, and autocorrelation checks, making it reliable for predicting building cost impacts from code revisions with an expected accuracy of ±3.7%, though limitations include small sample size (n=5) and single regional context

Training-Quality-Compliance Relationship

Table 5: Training Impact on Construction Quality and Compliance

Training Level	Sites (n)	Average Quality Score	Compliance Rate	Cost Variance
Comprehensive	8	4.5/5	90%	+12.3%
Moderate	12	3.5/5	70%	+10.8%
Minimal	10	2.5/5	50%	+9.2%

Key Insight:

Strong positive correlation exists between training quality and both construction compliance (r = 0.92) and structural quality (r = 0.88). Comprehensive training achieves 80% higher compliance rates compared to minimal training, demonstrating clear returns on capacity building investments.

DISCUSSION

Technical Code Evolution and Engineering Implications

This study's findings must be interpreted within Nepal's broader seismic code evolution trajectory. The progression from NBC 105:1994 through NBC 105:2020 to NBC 205:2024 represents systematic integration of post-disaster lessons and international best practices. Our 10.98% cost increase finding provides the first empirical quantification of economic implications from Nepal's transition to performance-based seismic design.

The documented awareness gaps (only 31.83% adequate awareness) align with [8]'s observations about implementation challenges following major code revisions. However, our multi-municipal analysis extends beyond previous single-case studies by demonstrating consistent patterns across diverse contexts. The strong correlation between training quality and compliance (r = 0.92) provides empirical support for capacity building as a primary implementation strategy.

Implementation Challenges and Systemic Barriers

Our findings corroborate literature identifying technical capacity constraints as primary implementation barriers. [11]'s identification of local builder inefficiencies contributing to 47% of construction delays aligns with our evidence of widespread awareness deficits among builders (82.1% with limited awareness). Similarly, [10]'s poor technical capacity scores for local builders directly relate to our compliance rate findings (50% for minimal training vs. 90% for comprehensive training).

The 10.98% cost increase documented in this study adds crucial economic evidence to existing literature. While [6] identified inflation and bureaucratic bottlenecks as performance barriers, our analysis quantifies the specific economic burden of seismic code compliance, providing essential data for policy development.

Socio-Economic Implications and Equity Considerations

The cost increase findings raise critical questions about seismic safety equity. An 11% construction cost increase may exclude low-income households from code-compliant construction, potentially perpetuating vulnerability among the most earthquake-exposed populations. This creates a policy dilemma: enhanced safety standards that inadvertently increase risk exposure for economically disadvantaged communities.

Our recommendation for differentiated regulatory frameworks addresses this challenge by proposing simplified compliance pathways for residential construction while maintaining stringent requirements for commercial and institutional buildings. This approach balances safety enhancement with socio-economic accessibility.

Training as Implementation Catalyst

The strong training-compliance relationship (90% vs. 50% compliance rates) demonstrates that knowledge gaps, rather than technical impossibility, constitute the primary implementation barrier. This finding suggests that targeted capacity building programs could rapidly enhance implementation effectiveness at relatively modest cost.

The training priority index identifying 48.4% of builders and 58.9% of owners requiring immediate training provides specific targets for intervention programs. These findings support arguments for mandatory training requirements and certification systems for construction professionals working in high-seismic zones.

CONCLUSION AND RECOMMENDATIONS

This study provides empirical evidence that Nepal's revised building codes NBC 105:2020 and NBC 205:2024 face significant implementation barriers despite broad stakeholder support for safety enhancement objectives. The 10.98% cost increase is economically substantial but socially acceptable, while training emerges as the critical implementation catalyst.

Key Findings

Three primary findings emerged:

(1) Widespread technical knowledge gaps constrain implementation despite broad safety enhancement support;
(2) Economic impacts are quantifiable and predictable (approximately 11% cost increase) but may create equity challenges; and
(3) Training quality directly correlates with construction compliance and structural quality outcomes.

Policy Recommendations

Immediate Actions:

- Implement mandatory training and certification programs for construction professionals in high-seismic zones
- Establish differentiated compliance frameworks distinguishing residential and commercial construction requirements
- Develop economic support mechanisms (subsidies, tax incentives, phased compliance) for vulnerable populations

Medium-term Interventions:

- Strengthen municipal enforcement capacity through technical staff training and equipment provision
- Create regional training centers with standardized curricula and certification protocols
- Develop simplified compliance guidelines and technical resources for local builders

Long-term Strategies:

- Integrate seismic construction training into technical education curricula
- Establish performance monitoring systems to track long-term implementation trends

- Conduct post-earthquake assessments of code-compliant buildings to validate safety improvements

Research Implications

This study contributes to the limited literature on building code implementation in developing countries by providing quantitative evidence of implementation barriers and their economic implications. The predictive cost model offers a replicable tool for policy analysis in similar contexts.

Future Research Directions

Future studies should focus on:

1. longitudinal monitoring of implementation trends and safety outcomes;
2. cost-effectiveness analysis of alternative compliance strategies;
3. post-earthquake performance assessment of revised code-compliant buildings; and
4. comparative analysis with other earthquake-prone developing regions to identify transferable implementation strategies.

The successful implementation of seismic building codes requires coordinated action across technical, economic, and institutional dimensions. This study provides evidence-based foundations for such comprehensive approaches while recognizing the complex realities of development-constrained contexts.

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