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PRINCIPAL COMPONENT ANALYSIS OF MAJOR CONSTRAINTS IN SCHOOL BUILDING CONSTRUCTION PROJECTS IN DHANGADHI SUB-METROPOLITAN CITY, NEPAL

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Abstract

This study investigates the major constraints affecting school building construction projects in Dhangadhi Sub-Metropolitan City, Nepal, with a focus on identifying and analyzing these limitations to propose effective remedial measures. Drawing from the Theory of Constraints (TOC), the research examines various factors such as financial, administrative, resource, technical, environmental, legal, and social constraints prevalent in the construction sector, particularly in developing countries like Nepal. Using a mixed-methods approach, data were collected through questionnaires and interviews from 34 technical personnel involved in 24 selected school building projects (20 completed and 4 ongoing), each with a contract value exceeding NPR 20 lakh. Principal Component Analysis (PCA) via IBM SPSS was employed to reduce 28 identified constraints into seven key components: Financial and administrative challenges, Resource management and coordination, Strategic management of on-site challenges, Project planning, labor issues, and cost estimation, Project scheduling and financial forecasting, Stakeholder engagement, and Budgeting and decision-making issues. These components account for 79.338% of the total variance, highlighting critical areas like delayed payments, coordination issues, and inadequate planning. Similar PCA-based categorization of construction delays has been successfully applied in Nepalese municipal projects (Nepal et al., 2024). The findings underscore the need for improved policy frameworks, better resource allocation, and enhanced stakeholder involvement to mitigate constraints and ensure timely, cost-effective project completion. This research provides valuable insights for project managers, contractors, and policymakers in Nepal's construction industry.

Keywords: School construction, Constraints, Principal Component Analysis, Project management, Stakeholder engagement.

1. Introduction

Constraints are inherent in all work environments. They shape operational boundaries that may be obvious or subtle and are often overlooked in the pursuit of project goals. In Nepal's construction industry, these limitations are particularly complicated due to the collaboration of multiple stakeholders with diverse priorities. Despite significant growth in the sector, fueled by increased demand for materials and equipment after the 2015 earthquake, the COVID-19 pandemic disrupted progress, halting projects in Dhangadhi Sub-Metropolitan City due to unclear policies, supply shortages, and strict lockdown measures (The Impact of COVID-19 Lockdown on Nepal's Construction Sector, 2020). Studies have shown that unrealistic timelines and budgets, lack of qualifications and experience of contract management teams, and improper planning are significant factors affecting effective contract management in Nepalese infrastructure projects (Sah & Bhattarai, 2021).

Constraints, as defined by Rai (2021), are roadblocks that hinder optimal system performance. Goldratt (1990) classified them as physical (e.g., equipment or labor shortages) or non-physical (e.g., policies or mindsets), both of which can impede organizational objectives if not addressed.

In construction, constraints manifest as precedent constraints (dictating task sequences), resource constraints (involving materials or labor allocation), and information constraints (such as delays in design approvals), often disrupting project timelines (Chua & Shen, 2005). The Theory of Constraints (TOC) offers a framework to identify and mitigate these bottlenecks, reducing uncertainties and enhancing project management clarity in competitive landscapes. Multi-party collaborations amplify conflicts and costs, underscoring the need for effective constraint management to minimize waste and achieve high performance. However, limited research on construction-specific constraints highlights the urgency of recognizing these barriers to improve planning and outcomes. This study aims to identify major constraints in school building construction projects in Dhangadhi Sub-Metropolitan City, Nepal.

2. Literature Review

Constraints in construction projects, as defined by Whelton (2004), are conditions, forces, or factors that limit a system's performance within its specific context. These constraints are pervasive in construction environments, often overlooked due to a focus on project objectives, leading to conflicts and disputes that incur significant direct and indirect costs (Yates, 2002). In Nepal's construction industry, unique challenges such as unclear government regulations, lack of standardized contractor pre-qualification criteria, unbalanced bidding documents, a complex tax system, limited equipment availability, and delays in approvals and payments exacerbate these constraints (Nepal Construction Directory & News Portal, 2019). Additional issues include fluctuating material prices, skilled labor shortages due to brain drain, and material scarcity, all of which tie the industry's performance to the country's economic growth. Delayed payments, in particular, have been identified as a major issue in road construction projects in Nepal, leading to cash flow problems, contractual disputes, and delays in project progress (Paudel et al., 2024).

The Theory of Constraints (TOC), developed by Goldratt (1990), provides a structured approach to identify and mitigate bottlenecks that hinder organizational goals. TOC emphasizes continuous improvement through five iterative steps: identifying the constraint, exploiting it, subordinating other activities to it, elevating it, and revisiting the process if constraints shift (Goldratt, 1990).

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Construction constraints are categorized into five types: economic, legal, environmental, technical, and social (Manning, 1995; Schultmann, 2002). Constraints in developing countries, including Nepal, are multifaceted. Rai (2021) and Hwang et al. (2018) highlight economic, legal, environmental, technical, and social constraints as critical barriers. Durdyev and Ismail (2016) identify additional issues such as inadequate skilled labor, high resource costs, poor supervision, and bureaucratic approval processes. Abbasi et al. (2000) note challenges like inadequate knowledge, communication difficulties, and weak interfaces with regulatory bodies. Ascher (1983) and Bryce et al. (2003) point to bureaucratic complexities and rigorous reporting requirements, while Gow et al. (1988) emphasize political, environmental, and personnel constraints. Other studies, such as Iyer et al. (2005) and Kumaraswamy et al. (1998), highlight conflicts between project parties, and Kerzner (2006) notes technological advances and insufficient resources as significant hurdles. These constraints collectively impede project efficiency and require tailored strategies for mitigation.

In the context of Nepalese construction projects, extension of time (EoT) claims have been systematically analyzed using Principal Component Analysis (PCA), revealing three major components: Design and Consultant-Related Issues, Project Management and Execution Challenges, and External and Unforeseen Conditions (Nepal et al., 2024). Similarly, payment delays in road construction projects have been attributed to unavailability of budget, poor financial management, and contractors' failure to understand contract agreements (Paudel et al., 2024). User committees, which are often responsible for implementing small-scale infrastructure in Nepalese municipalities, face challenges such as political interference, lack of technical supervision, and payment discrepancies (Bhattarai et al., 2025; Khadka et al., 2023). These findings provide a strong foundation for analyzing constraints in school building construction.

3. Methodology

The study focuses on identifying constraints in school building construction projects in Dhangadhi Sub-Metropolitan City, Nepal, employing a mixed-methods research design that integrates quantitative and qualitative approaches. Data were collected through structured questionnaires administered to 34 technical personnel (17 client representatives and 17 contractor representatives) from 20 completed and 4 ongoing school construction projects (contract value > NPR 20 lakhs). Questionnaires utilized a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to assess 28 constraints identified from literature review and pilot discussions. The instrument also captured respondents' backgrounds and their perceptions of key issues affecting project outcomes.

Data analysis was conducted using Principal Component Analysis (PCA) with Varimax rotation via IBM SPSS. Reliability was assessed using Cronbach's alpha (threshold > 0.7). The Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity confirmed data suitability for factor analysis. This methodological approach is consistent with previous studies on construction delays and constraints in Nepal, where PCA has been effectively used to reduce large sets of variables into interpretable components (Nepal et al., 2024; Bhattarai et al., 2025). The sample size of 34 exceeds the minimum recommended for PCA (approximately 5–10 cases per variable, though 28 variables would ideally need >140; therefore, results are exploratory and should be interpreted cautiously).

4. Results and Discussion

4.1 Reliability and Suitability of Data

Cronbach's Alpha coefficient was 0.952, indicating high internal consistency (above 0.7 threshold). The KMO measure of sampling adequacy was 0.602, which is acceptable (above 0.6). Bartlett's Test of Sphericity was significant ($\chi^2 = 964.832$, df = 378, $p < 0.001$), confirming that the correlation matrix was not an identity matrix and that factor analysis was appropriate (Shrestha, 2021). Similar KMO values (0.935) have been reported in EoT studies in Nepalese municipalities (Nepal et al., 2024).

4.2 Factor Extraction

PCA identified seven components with eigenvalues greater than 1.0, accounting for 79.338% of total variance. The first component explained 44.719% (eigenvalue 15.327), the second 10.551% (eigenvalue 3.616), and subsequent components contributed progressively less. The scree plot (Figure 1) visually confirmed the seven-component solution.

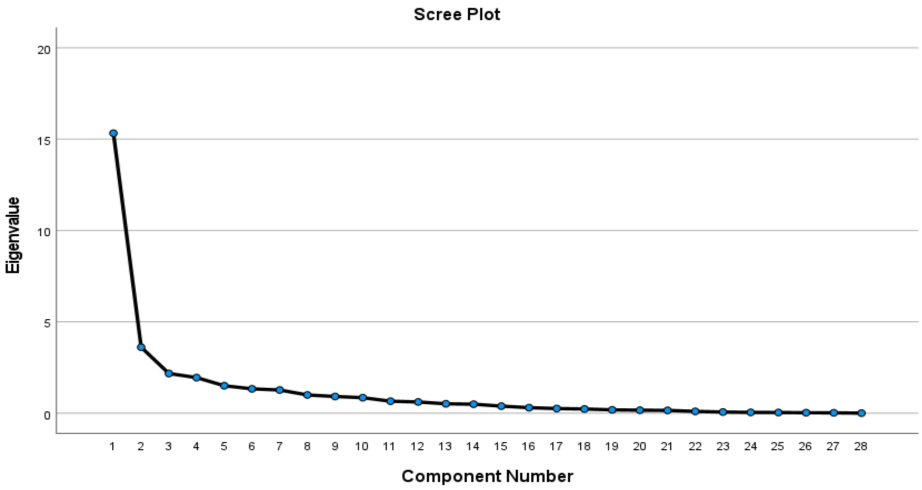

Figure 1: Scree Plot for Constraints in School Building Construction Projects

4.3 Rotated Component Matrix and Themes

Varimax rotation with Kaiser normalization produced a clear factor structure. Based on the rotated matrix, seven thematic components were identified, as shown in Tables 1 and Table 2. The seven components are: Financial and administrative challenges, Resource management and coordination, Strategic management of on-site challenges, Project planning/labor/cost estimation, Project scheduling and financial forecasting, Stakeholder engagement, and Budgeting and decision-making issues.

Table 1: Theme of Rotated Component Matrix

Component	Theme	Number of Factors
1	Financial and administrative challenges	5
2	Resource management and coordination	5
3	Strategic management of on-site challenges	6
4	Project planning, labor issues, and cost estimation	4

5	Project scheduling and financial forecasting	3
6	Stakeholder engagement	3
7	Budgeting and decision-making issues	2

Table 2: Cronbach's Alpha by Component

Component	Theme	Cronbach's Alpha
1	Financial and administrative challenges	0.859
2	Resource management and coordination	0.893
3	Strategic management of on-site challenges	0.896
4	Project planning, labor issues, and cost estimation	0.851
5	Project scheduling and financial forecasting	0.772
6	Stakeholder engagement	0.707
7	Budgeting and decision-making issues	0.673

Component 7 had an alpha of 0.673, below the conventional 0.7 threshold, likely due to the small number of items (two). These results should be interpreted with caution.

4.4 Discussion

The identified constraints highlight critical challenges in school construction projects. Financial and administrative challenges (Component 1), including delayed payments, high material costs, and bureaucratic hurdles, dominate due to their high variance (44.719%). This aligns with prior studies noting cash flow mismanagement and bureaucratic delays as key issues (Hamma-Adama et al., 2021; Onyema & Ikediashi, 2023). In Nepal, payment delays have been shown to create cash flow problems, contractual disputes, and delays in project progress (Paudel et al., 2024). The top-ranked causes of payment delays include unavailability of budget and poor financial management by employers.

Resource management and coordination (Component 2) reflect difficulties in land acquisition, technology gaps, and stakeholder coordination, consistent with Flyvbjerg et al. (2002) and Love et al. (2004). In Nepalese infrastructure projects, coordination issues between client, consultant, and contractor have been identified as a major inefficiency factor (Sah & Bhattarai,

2021). Similarly, user committees managing local projects face significant challenges in resource mobilization and stakeholder coordination (Bhattarai et al., 2025).
Strategic management of on-site challenges (Component 3) – unforeseen site conditions, skilled manpower shortages, and safety compliance – underscores the need for better site investigation and training. These findings mirror the causes of extension of time identified in Kageshwari Manohara Municipality, where inadequate design information, poor project management, and unforeseen ground conditions were significant contributors (Nepal et al., 2024).
Project planning and labor issues (Component 4) point to inadequate design and labor disputes. Scheduling and financial forecasting (Component 5), stakeholder engagement (Component 6), and budgeting/decision-making (Component 7) further highlight areas for improvement. The presence of labor disputes and workforce culture barriers as constraints is consistent with findings from retrofitting projects in Kathmandu Valley, where unavailability of skilled workforce and impractical project schedules were top-ranked delay factors (Bhattarai et al., 2024).

5. Limitations

This study has several limitations. First, the sample size (n = 34) is relatively small for PCA with 28 variables; results should be considered exploratory. Second, the study is limited to Dhangadhi Sub-Metropolitan City and may not be generalizable to other regions of Nepal. Third, data rely on self-reported perceptions, which may introduce bias. Fourth, Component 7 (budgeting and decision-making) had a Cronbach's alpha below 0.7, indicating lower reliability. Future research should use larger samples, include objective performance metrics, and expand to multiple municipalities. Additionally, comparative studies between contractor-led and user-committee-led projects could provide further insights (Bhattarai et al., 2025; Khadka et al., 2023).

6. Conclusion and Recommendations

6.1 Conclusion

This study successfully identified and evaluated the major constraints affecting school building construction projects in Dhangadhi Sub-Metropolitan City, Nepal. Through a comprehensive literature review, application of the Theory of Constraints (TOC), and Principal Component Analysis (PCA), 28 constraints were distilled into seven principal components explaining 79.338% of the variance. These are: Financial and administrative challenges, Resource management and coordination, Strategic management of on-site challenges, Project planning/labor/cost estimation, Project scheduling and financial forecasting, Stakeholder engagement, and Budgeting and decision-making issues. The dominance of financial and administrative challenges (44.719% variance) reflects similar findings in Nepalese road construction, where payment delays and budget unavailability are critical (Paudel et al., 2024). The identification of project planning and labor issues aligns with extension of time studies in Nepalese municipalities (Nepal et al., 2024).

6.2 Recommendations

Based on these findings, the following recommendations are made:

1. **For financial and administrative challenges**: Local governments should ensure timely payments through escrow accounts or dedicated project funds. Bureaucratic

processes should be streamlined with clear deadlines for approvals. This is consistent with recommendations from payment delay studies in Nepal (Paudel et al., 2024).

2. **For resource management and coordination**: Project managers should conduct early land acquisition and stakeholder mapping. Investment in basic construction technology and training is needed. Regular coordination meetings among client, consultant, and contractor should be mandated (Sah & Bhattarai, 2021).
3. **For on-site challenges**: Mandatory geotechnical investigations and safety training programs should be implemented before construction begins. Site supervisors should be given greater authority to resolve unforeseen conditions promptly (Nepal et al., 2024).
4. **For project planning and labor issues**: Design reviews by independent experts and clear labor dispute resolution mechanisms should be established. Project schedules should be realistic and account for potential disruptions (Bhattarai et al., 2024).
5. **For scheduling and forecasting**: Contractors and clients should adopt project management software for cash flow forecasting and schedule tracking. Milestone-based payments should be implemented to improve cash flow (Paudel et al., 2024).
6. **For stakeholder engagement**: Regular community meetings and competency assessments for project managers are recommended. User committees should receive training on project management and financial transparency (Bhattarai et al., 2025).
7. **For budgeting and decision-making**: Participatory budgeting processes and transparent decision-making protocols should be enforced. Bylaws should be developed to clarify financial responsibilities (Khadka et al., 2023).

Policymakers in Nepal's Ministry of Education and local governments should use these findings to revise procurement and contract management guidelines for school construction. Future research should validate these components with larger samples and across different project types (e.g., health posts, roads).

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References

Abbasi, G. U., Al-Khalil, M. I., & Al-Moumen, S. A. (2000). Causes of delays in building construction projects in Saudi Arabia. *Journal of King Saud University – Engineering Sciences*, 12(2), 253–268.

Aapaoja, A., & Haapasalo, H. (2014). The challenges of stakeholder management in construction projects. *International Journal of Project Management*, 32(4), 623–633.

Ascher, W. (1983). New development approaches and the adaptability of international agencies: The case of the World Bank. *International Organization*, 37(3), 415–439.

Bhattarai, S. K., Rayamajhi, L., Lamichhane, S., & Arayal, S. (2024). Navigating Delays: A Comprehensive Study of Public Building Retrofitting Projects in Kathmandu Valley. *Journal of UTEC Engineering Management*, 2(1), 36–52. https://doi.org/10.5281/zenodo.13169684

Bhattarai, S. K., Devkota, P., Joshi, G. K., & Neupane, U. (2025). Assessing User Committees' Effectiveness in Infrastructure Projects: A Case of Palungtar Municipality, Nepal Using Exploratory Factor Analysis. *The OCEM Journal of Management, Technology & Social Sciences*, 4(1), 132–143. https://doi.org/10.3126/ocemjmtss.v4i1.74755

Bryce, J., Kort, R., & Young, S. (2003). Constraints on construction projects in developing countries. *Journal of Construction Engineering and Management*, 129(5), 523–530.

Chua, D. K. H., & Shen, L. J. (2005). Key constraints in construction projects. *Journal of Construction Engineering and Management*, 131(7), 745–753.

Durdyev, S., & Ismail, S. (2016). On-site construction productivity in Malaysian infrastructure projects. *Structural Survey*, 34(4/5), 446–462.

Flyvbjerg, B., Holm, M. S., & Buhl, S. (2002). Underestimating costs in public works projects: Error or lie? *Journal of the American Planning Association*, 68(3), 279–295.

Goldratt, E. M. (1990). *Theory of Constraints*. North River Press.

Gow, D., Morss, E., & Waller, P. (1988). The management of external constraints in development projects. *Public Administration and Development*, 8(2), 141–153.

Hamma-Adama, M., Kouider, T., & Salman, H. (2021). Analysis of financial constraints in Nigerian public building projects. *Journal of Financial Management of Property and Construction*, 26(1), 89–107.

Hwang, B. G., Shan, M., & Supa'at, N. N. B. (2018). Green building project management: Obstacles and solutions for sustainable development. *Sustainable Development*, 26(5), 521–531.

Iyer, K. C., & Jha, K. N. (2005). Factors affecting cost performance: Evidence from Indian construction projects. *International Journal of Project Management*, 23(4), 283–295.

Joshi, S. (2023). Stakeholder engagement in community infrastructure projects in Nepal. *Journal of Rural Development*, 42(1), 55–70.

Kerzner, H. (2006). *Project management: A systems approach to planning, scheduling, and controlling* (9th ed.). Wiley.

Khadka, S., Pahari, B., & Bhattarai, S. K. (2023). Analysis of Project Implementation through Users Committees in Junichande Rural Municipality. *KEC Conference Proceedings 2023*, International Conference on Engineering and Technology, Kathmandu.

Kumaraswamy, M. M., & Chan, D. W. M. (1998). Contributors to construction delays. *Construction Management and Economics*, 16(1), 17–29.

Love, P. E. D., Holt, G. D., & Li, H. (2004). Triangulation in construction management research. *Engineering, Construction and Architectural Management*, 11(1), 15–26.

Manning, R. (1995). *Constraints on construction: A guide for developing countries*. Intermediate Technology Publications.

Nepal Construction Directory & News Portal. (2019). Challenges in Nepal's construction industry.

Nepal, S., Bhattarai, S. K., Sukamani, D., & Nepal, S. (2024). Analysis of Causes for Extension of Time in Construction Projects: A Case Study of Kageshwari Manohara Municipality. *Kathford Journal of Engineering and Management*, 7(1), 1–14.

Onyema, I. C., & Ikediashi, D. I. (2023). Cash flow management and project performance in public building projects. *Journal of Construction in Developing Countries*, 28(1), 45–63.

Paudel, T. N., Bhattarai, S. K., & Neupane, U. (2024). Analysis of Payment Delay in Road Construction Projects: The Case Road Division Surkhet, Nepal. *International Journal on Engineering Technology and Infrastructure Development (InJET-InDev)*, 1(1), 36–51.

Rai, A. K. (2021). Constraints in infrastructure development in Nepal. *Journal of Nepalese Infrastructure*, 4(1), 12–25.

Sah, S. K., & Bhattarai, S. K. (2021). Study of Inefficiencies in Contract Management Practice in Rural Road. *Journal of Advanced Research in Civil and Environmental Engineering*, 8(3&4), 1–8. https://doi.org/10.24321/2393.8307.202105

Schultmann, F. (2002). *Environmental constraints in construction*. Springer.

Shrestha, N. (2021). Factor analysis: A review of KMO and Bartlett's test. *Journal of Statistical Methods*, 12(2), 101–115.

The Impact of COVID-19 Lockdown on Nepal's Construction Sector. (2020). [Online article https://asiafoundation.org/wp-content/uploads/2024/08/The-Impact-of-Covid-19-Lockdown-on-Nepals-Construction-Sector.pdf].

Whelton, M. (2004). *Constraint management in construction*. PhD Thesis, University of Texas.

Yates, J. K. (2002). Construction disputes and their resolution. *Journal of Construction Engineering and Management*, 128(5), 385–392.

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